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Design and evaluation of online and mobile applications for stress management and healthy eating

Kirsikka Kaipainen





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“There must be balance in all things, or else the self will not hold.”

- The Nameless One, Planescape: Torment

“But I have no leisure for them at all; and the reason, my friend, is this: I am not yet able, as the Delphic inscription has it, to know myself; so it seems to me ridiculous, when I do not yet know that, to investigate irrelevant things.”

- Socrates

Design and evaluation of online and mobile applications for stress management and healthy eating

Stressinhallintaan ja terveelliseen syömiseen tarkoitettujen verkko- ja mobiilisovellusten suunnittelu ja arviointi. Kirsikka Kaipainen. Espoo 2014. VTT Publications 55. 95 p. + app. 98 p.

Abstract

Stress management and healthy eating are ongoing struggles for many people in the developed world. The consequences of chronic stress and unhealthy diets are borne at both individual and societal level. Currently, ischemic heart disease is the leading cause of death in the world, and depression is the leading cause of disability. Their early prevention calls for scalable and affordable means to provide support for healthy dietary choices and daily recovery from stress. Modern technology offers potential solutions for daily self-management but few health-promoting applications have reached widespread use despite promising research findings.

The aims of this thesis were to assess the real-world use of health-promoting online and mobile applications, to evaluate their objective and subjective benefits, and to draw design guidelines for preventive applications. Six studies on online and mobile applications for stress management and healthy eating were conducted with diverse settings and target groups. Two of the studies assessed the use of an online and a mobile application for healthy eating and found that less than 10% of the almost 200,000 users they attracted remained active. Two studies evaluated the benefits of technology tools combined with group intervention for stress management and found improved well-being and active use of tools, although human contact was appreciated most. The last two studies analysed stress management applications and suggested new design principles for them.

Based on the findings, freely available applications can reach a large number of users, but the attrition is likely to be very high and it is unclear whether the intended audience is reached. Applications can contribute to improved well-being and provide support for behavioural changes and skills learning as long as they are simple, attractive and easy to integrate into everyday life. The design of applications should support small daily actions that result in immediate benefits, emphasize self-improvement and reflection, and offer guidance while maintaining freedom of choice. The results support the feasibility and applicability of online and mobile applications for health promotion at individual level and highlight the importance of a systematic theory-driven, user-centric and business-oriented approach to intervention development. The societal impact of the applications may remain small unless real-world implementation, maintenance and dissemination are planned from the very beginning of the development process.

Keywords health promotion, stress management, healthy eating, design, evaluation, adherence, behaviour change, online, mobile

Stressinhallintaan ja terveelliseen syömiseen tarkoitettujen verkko- ja mobiilisovellusten suunnittelu ja arviointi

Design and evaluation of online and mobile applications for stress management and healthy eating. **Kirsikka Kaipainen**. Espoo 2014. VTT Science 55. 95 s. + liitt. 98 s.

Tiivistelmä

Stressinhallinta ja terveellinen syöminen ovat alituisen kamppailun aihe monille länsimaisille ihmisille. Niin yksilöt kuin yhteiskuntakin joutuvat vastaamaan pitkäkestoisen stressin ja epäterveellisen ruokavalion seurauksista. Sepelvaltimotauti on tällä hetkellä maailman yleisin kuolinsyy, ja masennus on yleisin työkyvyttömyyden syy. Varhainen puuttuminen ongelmiin edellyttää skaalautuvia ja edullisia keinoja, jotka tukevat terveellisiä syömisvalintoja ja päivittäistä stressistä palautumista. NykYTEknologia tarjoaa monia mahdollisuuksia päivittäiseen hyvinvoinnin hallintaan, mutta lupaavista tutkimustuloksista huolimatta vain harva terveyttä edistävä sovellus on päätenyt laajamittaiseen käyttöön.

Tämän väitöskirjan tavoitteena oli selvittää terveyttä edistävien verkko- ja mobiilisovellusten käyttöä oikeassa maailmassa, arvioida niiden objektiivisia ja subjektiivisia hyötyjä sekä kehittää suunnitteluperiaatteita ennalta ehkäiseville sovelluksille. Stressinhallintaan ja terveelliseen syömiseen tarkoitettuja verkko- ja mobiilisovelluksia tutkittiin kuudessa tutkimuksessa eri asetelmissa ja eri kohderyhmillä. Kahdessa tutkimuksesta selvitettiin terveelliseen syömiseen tarkoitettujen verkko- ja mobiilisovellusten käyttöä ja havaittiin, että sovellusten tavoittamista lähes 200 000 käyttäjästä alle 10 % pysyi aktiivikäyttäjänä. Kaksi tutkimuksesta arvioi teknologiavälineiden hyötyjä yhdistettynä ryhmämuotoiseen stressinhallintaintervention ja havaitsi parannuksia hyvinvoinnissa sekä aktiivista välineiden käyttöä, joskin ihmiskontaktia arvostettiin eniten. Kaksi tutkimuksesta analysoi stressinhallintasovelluksia ja esitti niille uusia suunnitteluperiaatteita.

Löydösten perusteella vapaasti saatavilla olevat sovellukset voivat tavoittaa suuren joukon käyttäjiä, mutta käyttö on todennäköisesti hyvin lyhytaikaista, ja on epävarmaa, saavutetaanko oikea kohdeyleisö. Sovellukset voivat edistää hyvinvointia ja tukea käyttäytymismuutoksia, jos ne ovat yksinkertaisia, kiinnostavia ja sopivia jokapäiväiseen elämään. Sovellussuunnittelun tulisi tukea pieniä päivittäisiä välitöntä hyötyä aikaansaavia tekoja, painottaa itsensä kehittämistä ja pohdintaa sekä opastaa säilyttämään kuitenkin valinnanvapauden. Tulokset puoltavat verkko- ja mobiilisovellusten hyödynnettävyyttä ja soveltuvuutta yksilötason terveyden edistämiseen, mutta niissä korostuu myös suunnitelmallisen teorioihin perustuvan, käyttäjäkeskeisen ja liiketoimintaa painottavan lähestymistavan tärkeys interventioiden kehittämisessä. Sovellusten yhteiskunnalliset vaikutukset voivat jäädä vähäisiksi, mikäli niiden käyttöönottoa, ylläpitoa ja levittämistä oikeassa maailmassa ei oteta heti alusta asti huomioon intervention kehitysprosessissa.

Avainsanat health promotion, stress management, healthy eating, design, evaluation, adherence, behaviour change, online, mobile

Preface

I have always loved a good story. As with any purposeful endeavour undertaken by a human being, there is a story behind this book. It is said that a researcher always influences the research setting by her mere presence. I feel that this works both ways – the researcher is heavily influenced by her research topics and especially by the people she encounters and works with. These interactions form the basis for growth and learning which continue throughout life.

The research presented in this thesis was carried out at VTT Technical Research Centre of Finland during 2009–2013. The original aim stated in my doctoral research plan was to increase knowledge about factors that influence a person's health choices and to develop new preventive online and mobile applications. Looking back, this still sort of describes what I have done. However, the story had several unexpected turns and sub-plots, and the scope has broadened quite a bit. I have many remarkable people to thank for expanding my horizons.

First and foremost, none of this would have happened without my advisor and supervisor, Professor Ilkka Korhonen. He first welcomed me to VTT as my team leader, then supervised my Master's thesis, and subsequently helped me navigate through the murky waters of the PhD work. Ilkka, I am deeply grateful for all the support and advice you have given me and for the friendship I feel we have developed over the years. You have inspired me to challenge myself in more ways than I could ever have imagined.

The friends and co-workers at VTT and in the research projects deserve nothing but praise for their talent, insight and warmth. Special thanks go to Dr. Elina Mattila who has been a wonderful mentor and friend all the way from supporting my first wavering steps into health technology research. Thank you for your intelligence and humour and for sharing so much more than just the office with me. Furthermore, I deeply appreciate the support and leeway my team leaders Dr. Miikka Ermes and Dr. Toni Vanhala have given for pursuing meaningful research directions. Toni, thanks also for sharing the vision in how to change the world. Warm thanks for making the everyday work interesting and enjoyable to Anita Honka, Dr. Juha Pärkkä, Juho Merilahti, Kari Antila, Dr. Pasi Väikkynen, Marja Harjumaa, Docent Mark van Gils, and the rest of the folks in our merry teams. Your social support has been extremely valuable in the process.

I wish to express my appreciation to Research professor Niilo Saranummi for giving me the opportunity to delve into behavioural sciences in the PREVE project and beyond. You saw the big picture and reminded me many times that it really exists. Many thanks also to Anita Honka and Henri Hietala for the serious and not-so-serious reflections about human behaviour and business ecosystems. Even though the PREVE publications did not end up as a part of this thesis, the work carried out in the project set a solid theoretical basis for it.

This research is a result of various collaborative efforts with creative and talented people. I want to thank all of my fabulous co-authors including Dr. Elina Helander, Päivi Lappalainen, Aino Ahtinen, Tero Myllymäki, Dr. Antti Happonen, Dr. Marja-Liisa Kinnunen, Essi Sairanen, Henna Hoffrén, Antti Väättänen, Dr. Heikki Rusko and Dr. Collin R. Payne. Special thanks to Professor Raimo Lappalainen whose experience, expertise and enthusiasm in combining psychology and technology have moved the field considerably forward and shaped my thinking. I also thank the colleagues at TUT including Outi Kenttä, Janne Vainio, Dr. Hannu Nieminen and Harri Honko for fruitful discussions.

I was incredibly fortunate to have the privilege to spend a year at Cornell University in Ithaca, NY, during 2012. I am especially grateful to the two amazing people who spent huge amounts of their time on advising and entertaining me: Dr. Brian Wansink and Adam Brumberg. Brian and Adam, you both helped me strengthen my belief in my capabilities and encouraged me to challenge myself and push forward. I think you are shining examples of leadership and support. I also wish to thank Drew, Sandra, Julia, Margaret and Will for making my cultural adjustment easier and the office life entertaining, and Aner for arranging creative activities during free time as well. Moreover, the friendships I developed in Ithaca with fellow researchers from Europe will hopefully remain life-long. Kris and Simone, you taught me a lot about the fundamentals of experimental research and the reunions like the one we had in Ghent need to continue. Alice and Daniela, I hope to meet you soon again. The other wise people I met in Ithaca, especially Charlie and Marjaneh, spurred my values clarification process by asking profound questions. Ithaca is a special place and I left a piece of my heart there.

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Finally, I am fortunate to have such wonderful family and friends. I inherited my love of books and learning from my parents, who also helped me believe that people can do anything they put their minds to. Hilla, my sister in so many ways, you are a shining light of empathy and goodwill. You have given me more strength and hope than you can imagine (and you have a very creative imagination). Ville, I tried to follow your footsteps before realizing I need to find my own path. Still, it was not a bad way to start. Thank you both for the inspiring growth environment and for the opportunity to get to know your adorable significant others Sampo and Thao. I give a grand salute to all my friends and especially Milla, Heikki, Terjo, Laura, Ari and Mikko for helping me regain my sanity through relaxing activities.

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Tampere, April 2014

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Academic dissertation

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List of original publications

This thesis is based on the following original publications, which are referred to in the text as Studies I–VI. The publications are reproduced with kind permission from the publishers.

- I Kaipainen, K., Payne, C.R. & Wansink, B. (2012). Mindless Eating Challenge: Retention, weight outcomes, and barriers for changes in a public web-based healthy eating and weight loss program. *Journal of Medical Internet Research*, 14(6), e168.
- II Helander, E., Kaipainen, K., Korhonen, I. & Wansink, B. (2014). Factors related to sustained use of a free mobile app for dietary self-monitoring with photography and peer feedback: Retrospective cohort study. *Journal of Medical Internet Research*, 16(4), e109.
- III Lappalainen, P., Kaipainen, K., Lappalainen, R., Hoffrén, H., Myllymäki, T., Kinnunen, M.-L., Mattila, E., Happonen, A.P., Rusko, H. & Korhonen, I. (2013). Feasibility of a personal health technology-based psychological intervention for men with stress and mood problems: Randomized controlled pilot trial. *JMIR Research Protocols*, 2(1), e1.
- IV Kaipainen, K., Mattila, E., Väättä, A., Happonen, A.P., Korhonen, I., Kinnunen, M.-L., Myllymäki, T., Lappalainen, P., Hoffrén, H., Rusko, H. & Lappalainen, R. (2010). Web, mobile and monitoring technologies in self-management of psychophysiological wellbeing: Usage and user experiences. *Proceedings of the IADIS International Conference e-Health 2010, Freiburg, Germany, 29–31 July, 2010*, pp. 167–177.
- V Kaipainen, K., Mattila, E., Kinnunen, M.-L. & Korhonen, I. (2010). Facilitation of goal-setting and follow-up in an Internet intervention for health and wellness. *Proceedings of the 5th International Conference on Persuasive Technology (PERSUASIVE 2010), Copenhagen, Denmark, 7–10 June, 2010*, pp. 238–249.
- VI Ahtinen, A., Mattila, E., Väikkänen, P., Kaipainen, K., Vanhala, T., Ermes, M., Sairanen, E., Myllymäki, T. & Lappalainen, R. (2013). Mobile mental wellness training for stress management: Feasibility and design implications based on a one-month field study. *JMIR mHealth & uHealth*, 1(2), e11.

Author's contributions

The author's contributions to the individual publications of the thesis were as follows:

- I The author had the main responsibility for designing and performing the data analysis and was the primary author of the publication.
- II The author obtained the data for the study from the developers of the application, performed the initial exploratory data analysis, provided several of the main study questions and participated in data analysis and interpretation. The author wrote half of the publication.
- III The author participated in the planning and execution of the randomized controlled trial and had the main responsibility for analysing the impact of technology. The author wrote the technology-related sections of the publication.
- IV The author had the main responsibility for the study of user experiences and she was the primary author of the publication. The author participated in the study design and execution and implemented the portal evaluated in the study.
- V The author had the main responsibility for the analysis of lessons learnt and for the new design. The author also implemented the improved version of the portal. She was the primary author of the publication.
- VI The author played a key role in designing the concept and structure of the application, and she participated in the planning of the study and interpretation of the results. The author wrote most of the related work section of the publication, contributed substantially to writing the discussion and was responsible for half of the revisions.

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Appendices

Appendix 1: User experience survey items in Studies IV and V

Studies I–VI

Study V of this publication is not included in the PDF version.

Abbreviations

ACT	Acceptance and commitment therapy
BCT	Behaviour change technique
BDI	Beck Depression Inventory
BMI	Body mass index
CBT	Cognitive behavioural therapy
eHealth	Use of information and communication technologies for health
HCI	Human-computer interaction
ICT	Information and communication technology
NICE	National Institute for Health and Care Excellence
NMEC	National Mindless Eating Challenge
OECD	Organisation for Economic Co-operation and Development
RCT	Randomized controlled trial
TTM	Transtheoretical model of behavior change
WHO	World Health Organization

1. Introduction

Modern life is complicated. Technological advances were supposed to make our workload lighter, yet it seems that some people have more work than they can handle, and others struggle to get a decent job and to make ends meet. According to the European Working Conditions Survey, 16% of European workers perceived their job as insecure, 18% were dissatisfied with their work-life balance and 20% were at risk of mental health problems in 2010 (Eurofound, 2012). Although the wealth of the nations is on the rise, income inequalities are growing (OECD, 2011).

Growth in wealth is coupled with growth in obesity rates: 22.6% of the population in the OECD countries was obese in 2011 (OECD, 2013). The surplus of energy-rich and nutrient-poor foods, which are usually quite cheap compared with their healthier alternatives, makes it all too easy to fill ourselves for temporary pleasure or to dull our pain. Psychological stress is associated with comfort eating and other detrimental behaviours such as poor dietary choices, physical inactivity, smoking and alcohol consumption (Chandola et al., 2008; Dornelas et al., 2013; Steptoe & Kivimäki, 2013). Furthermore, we are faced with thousands of small decisions every day and we simply cannot deal with all of them consciously with our limited cognitive capacity (Wansink, 2010). Hence, before we even realize what we are doing, we have already grabbed a snack here, a chocolate bar there or eaten the whole pizza without intending to.

The ultimate consequences of hectic lifestyles, chronic stress and job strain, emotional turmoils and an abundance of unhealthy food are visible in the prevalence of mental disorders and chronic diseases. The statistics paint a grim picture of the current state of the world: ischemic heart disease is the leading cause of death (WHO, 2013) and depression is the leading cause of disability in the world (Ferrari et al., 2013). The burden of depression is increased due to its additional contribution to ischemic heart disease and suicides (Ferrari et al., 2013). Although obesity is a risk factor for cardiovascular diseases, obesity in itself is not necessarily a reason for concern if the obese person is otherwise healthy and satisfied with life (Kramer et al., 2013). Thinness does not guarantee good health either. Metabolically unhealthy people, no matter what their weight or body mass index (BMI), appear to be at increased risk of mortality and cardiovascular diseases compared with those who are metabolically healthy (Kramer et al., 2013).

As we can see, the global burden of disease both at societal and personal level is multifaceted and has numerous intertwined underlying causes. Our busy life-

styles are really becoming the greatest culprits in the Western world. In addition to poor diets, a lack of time and energy to engage in physical activities, and constant stress, we are also sleeping too little. A lack of sleep changes metabolism and results in increased appetite, a reduced feeling of satiety and decreased insulin sensitivity (Morselli et al., 2010). This increases the risk of weight gain, diabetes and hypertension (Knutson, 2012). Moreover, negative attitudes displayed towards overweight and obesity contribute to psychological and behavioural problems such as low self-esteem, depression, anxiety and disordered eating (Eisenberg et al., 2012). It is a vicious cycle.

What is the solution to this complex web of problems? How can the global burden of disease be lightened? Clearly, prevention of depression and cardiovascular diseases should be the number one priority. Policies and societal actions are needed to shape the environment in a health-favouring direction, but in the developed part of the world, individual behaviour also seems to be one of the keys. If we could help people manage their stress and eat more healthily, we would be able to drastically reduce healthcare spending caused by chronic diseases and also prevent much needless human suffering. Healthy eating and a reduction in work-related stress can reduce the risk of cardiovascular diseases (Kivimäki et al., 2012; Steptoe & Kivimäki, 2013). Hence, teaching people simple stress management and healthy eating skills could alleviate at least some of the burden.

At individual level, modern technology would appear to provide useful tools that could allow a wider reach and more individualized approaches than public health campaigns (Honka et al., 2011; van Limburg et al., 2011). Computerized interventions have been studied since the late 1980s and found to improve health-related knowledge, attitudes and intentions, as well as health behaviours such as nutrition, smoking and general health maintenance (Portnoy et al., 2008). The strengths of online and mobile applications include affordability, accessibility, anonymity, ability to work through the programs at one's own pace and increased fidelity in intervention delivery (Portnoy et al., 2008; Aronson et al., 2013). The technological advancement of smartphones has opened up new opportunities to support healthy behaviours in everyday life (Riley et al., 2011). Nevertheless, even though many online and mobile interventions have been developed in research, very few have actually been taken into use in the real world or had a significant impact on health outcomes (Christensen et al., 2011; van Gemert-Pijnen et al., 2011; van Limburg et al., 2011). Why is that? What do people need and how can technology serve that need? The research presented in this thesis started out as an exploratory journey to seek answers to these questions and evolved into a mission to develop clear design guidelines for effective and scalable intervention applications for individual use on online and mobile platforms. Stress and eating were chosen as focus domains due to their importance to public health and in order to form a cross-domain understanding of technology-aided health promotion.

The thesis consists of six publications on research of online and mobile applications for stress management and healthy eating carried out during years 2009–2013. Two of the publications focus on healthy eating (National Mindless Eating Challenge and Eatery, Studies I–II) and four on stress management (P4Well inter-

vention tools, GoodLife portal, and Oiva, Studies III–VI). The aim is to shed light on the usage and effects of such applications both in uncontrolled real-world settings and in controlled studies, and to critically examine the design decisions and the usage context of the applications.

The thesis is organized as follows. Chapter 2 outlines what is known about health promotion in general and stress management and healthy eating in particular. Chapter 3 analyses existing design frameworks and guidelines and reviews the literature of technology-aided stress management and healthy eating interventions. Chapter 4 presents the aims and outlines the methods of the studies in the thesis, and Chapter 5 summarizes the studies, addressing each specific research objective. Chapter 6 discusses the findings and their implications, and Chapter 7 draws the final conclusions.

2. Health promotion

The old Latin quotation “*mens sana in corpore sano*”, often translated as “*a sound mind in a healthy body*”, still expresses what is commonly understood as health. The definition proposed by the WHO in 1948 expanded this concept by adding the social dimension, defining health broadly as a “*state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity*” (WHO, 2006). This definition still serves as an aspirational and inspirational goal, although it has received a fair share of criticism. The critics’ greatest concern is that the requirement for “complete health” would mean that most of us are unhealthy most of the time (Huber et al., 2011). A recent suggestion for a more operational definition is “*the ability to adapt and self-manage*” in the social, physical and mental domains (Huber et al., 2011). However, this definition has also been criticized because of its focus on individuals and disregard for environmental, social, political and economic factors, which all influence the possibilities to adapt and self-manage (Shilton et al., 2011).

In this thesis, health is defined as the ultimate goal as stated in the WHO definition. Complete health can perhaps never be reached, but we can strive towards it by supporting people’s abilities to adapt and self-manage, and through policy actions. Health promotion is defined accordingly as “*the process of enabling people to increase control over their health and its determinants, and thereby improve their health*” (WHO, 2005). This encompasses approaches and actions that aim to improve people’s abilities and skills to maintain their well-being despite various challenges. On a broader scale, this also means political, economic and environmental changes that make it easier for people to maintain healthy lifestyles and that keep the environment clean and safe.

The focus in this thesis is on health promotion at individual level and, specifically, stress management and healthy eating interventions. This chapter provides a brief review of the state of the art in health promotion science and interventions in these domains.

2.1 Health promotion at individual level

The aim of individual-focused health promotion actions is to change behaviour. However, individual behaviour is affected by various factors and complex interac-

tions. The ecological systems model is a framework that states that individual behaviour is influenced by multiple environmental levels and that it also influences these levels (McLeroy et al., 1988). This framework was initially used to study child development but has since been adopted into the health promotion context (McLeroy et al., 1988; Bartholomew et al., 2011). Figure 1 illustrates the different levels in this framework. Individual behaviour is mediated not only by the individual's personal abilities and attitudes but also by the interactions between the individual and his or her environment, such as regulations set in place, the availability of fresh produce in the local markets, incentives offered by the workplace, and choices made or wishes expressed by family members.

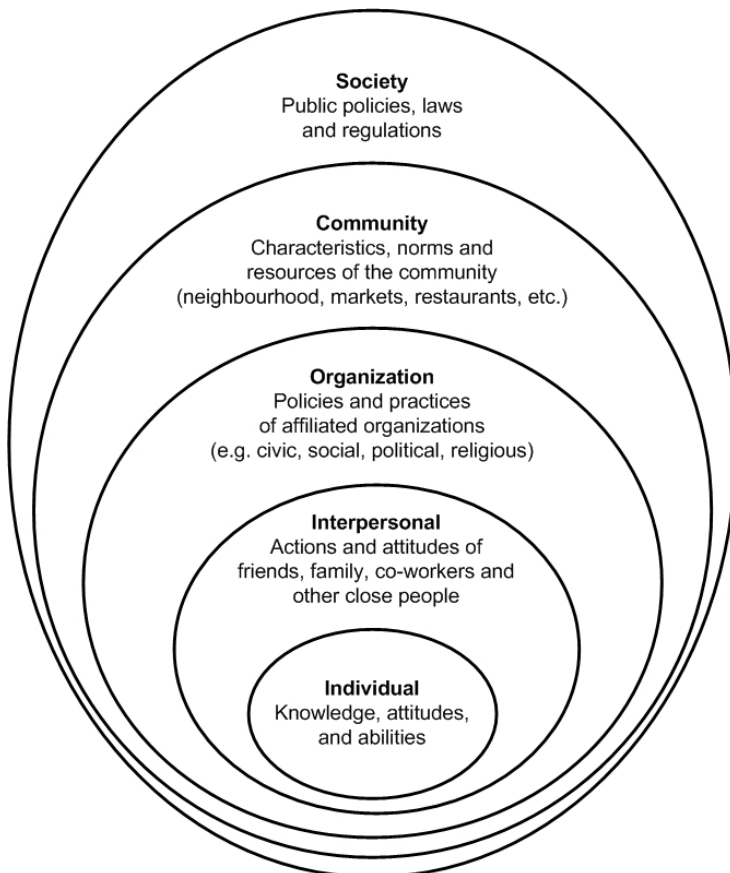


Figure 1. Ecological levels of health promotion (adapted from Bartholomew et al., 2011).

In this thesis, the focus is on health promotion actions that target the individual level. This means improving people's abilities, attitudes and knowledge in a manner that will result in health behaviour change (Bartholomew et al., 2011). It is

nevertheless good to bear in mind that a person's actions are not determined solely by his or her abilities and attitudes, and that multiple other actors have a significant impact. Health promotion issues have been described as complex problems that require intervention at multiple levels and involvement by multiple actors in communities, organizations and societies (Best, 2011). Hence, it is important to provide individuals with direct support, information and incentives to take healthy actions, though complementary actions at higher levels are often needed to achieve sustainable behaviour change on a large scale.

The development of effective interventions requires a solid theoretical basis, a clear understanding of the needs of the target population and consideration of social and environmental factors in addition to individual behaviour (Lippke & Ziegelmann, 2008; van Gemert-Pijnen et al., 2011; NICE, 2014). Various theories and theory-informed strategies for health promotion at different levels have been conceived, some focused on explaining behaviour and others on ways to change it (Glanz & Bishop, 2010; Bartholomew et al., 2011). There is no single theory to suit every problem and context, and, hence, the best way to develop an effective intervention is to choose proper strategies based on several appropriate theories (Lippke & Ziegelmann, 2008; Glanz & Bishop, 2010; Bartholomew et al., 2011). The most important consideration is to have some kind of theory-based rationale and a logic model for the intervention (Craig et al., 2008a; Craig et al., 2008b; Bartholomew et al., 2011). Interventions based on theory and tailored on theoretical constructs appear to be more effective than those that do not have a theoretical basis and are tailored only on behaviour (Noar et al., 2007; Glanz & Bishop, 2010; Webb et al., 2010).

The UK Medical Research Council has published comprehensive guidance on developing and evaluating complex interventions (Craig et al., 2008a; Craig et al., 2008b). The guidelines advocate systematic development that builds from small focused pilot studies to exploratory and definitive evaluations (Craig et al., 2008a; Craig et al., 2008b). Intervention Mapping offers a useful systematic approach to practical intervention development and provides a comprehensive catalogue of different theories, behaviour change techniques and preconditions for their use (Bartholomew et al., 2011). At individual level, techniques to change behaviour always target some of the individual determinants of behaviour such as knowledge, abilities, attitudes, barriers or self-efficacy (Bartholomew et al., 2011).

The comparison of behaviour change techniques used in interventions has been problematic due to the use of different terms for similar techniques in different theoretical frameworks (Michie et al., 2013). To solve this problem, a project to standardize definitions for behaviour change techniques used in interventions is ongoing. Thus far, the project has resulted in a working version of 93 unique techniques divided into 16 categories as presented in Table 1 (Michie et al., 2013). The current limitations of this work are the lack of connections between these 93 techniques and existing theories, and the absence of techniques relevant to community and population-level interventions (Michie et al., 2013).

2. Health promotion

Table 1. Behaviour change techniques used in interventions (Michie et al., 2013).

Category	Examples of behaviour change techniques
Scheduled consequences	Negative reinforcement; Counter-conditioning
Reward and threat	Social reward; Incentive; Self-reward; Threat
Repetition and substitution	Habit formation; Behavioural practice; Behaviour substitution
Antecedents	Restructuring physical/social environment; Changing exposure to cues for the behaviour
Associations	Prompts/cues; Exposure; Classical conditioning
Covert learning	Vicarious reinforcement; Covert sensitization
Natural consequences	Health/social/environmental/emotional consequences; Anticipated regret
Feedback and monitoring	Feedback on behaviour; Self-monitoring behaviour or outcome of behaviour
Goals and planning	Goal setting (outcome/behaviour); Commitment
Social support	Social support (practical/emotional/general)
Comparison of behaviour	Modelling of behaviour; Social comparison
Self-belief	Mental rehearsal; Verbal persuasion; Self-talk
Comparison of outcomes	Pros and cons; Persuasive argument
Identity	Self-affirmation; Identity associated with changed behaviour; Cognitive dissonance
Shaping knowledge	Behavioural experiments; Instructions on how to perform behaviour; Antecedents
Regulation	Regulate negative emotions; Conserve mental resources; Pharmacological support; Paradoxical instructions

Some behaviour change techniques are deemed generally effective. They include *goals and planning*, *feedback and monitoring* and *social support* (NICE, 2014). However, there is no universal set of techniques that would work in every situation. The choice of methods and techniques always depends on the current context, the needs and characteristics of the target population, and the targeted health problem. Pilot studies that test the design of each technique and confirm that the techniques meet users' needs should ideally always be carried out before large-scale evaluations, but, in practice, this often proves challenging due to time or resource constraints (Craig et al., 2008b). Such constraints make it even more important to follow a systematic process that covers all the steps from needs assessment to evaluation and maintenance of the intervention to ensure that all factors are considered in the development process (Bartholomew et al., 2011).

2.2 Stress management

2.2.1 Stress and coping

Stress is a physiological response to an actual or imagined threat (Carver & Connor-Smith, 2010). Nowadays, people who live in the developed world very rarely face life-threatening situations but have plenty of imagined threats that can have real consequences: looming deadlines, fear of losing one's job, financial insecurity, relationship problems, presentations, interviews and so on. Many of these threats have no quick resolution and, thus, the instinctual fight-or-flight response is constantly on. This takes a toll on the body and mind unless healthy coping strategies that allow the person to recover from stress are in place. The need for recovery manifests itself as an urge to take a break from current demands and a reluctance to accept new ones (Demerouti et al., 2009). This urge can be seen as an early phase of growing strain that can lead to prolonged fatigue, mental disorders and cardiovascular diseases (Jansen et al., 2002; Kivimäki et al., 2006; Stansfeld & Candy, 2006; Chandola et al., 2008; Kivimäki et al., 2012; Steptoe & Kivimäki, 2013).

Recovery from stress refers to activities that result in a reduction in fatigue and stress and a restoration in physical and psychological performance ability (Demerouti et al., 2009). During recovery, resources are replenished and energy restored. The four recovery mechanisms identified thus far are psychological detachment (from work), relaxation, mastery experiences, and control during leisure time (Sonnentag & Fritz, 2007). These mechanisms allow a person to rest from demands both psychologically and physically, to gain experiences of success and build new skills, and to engage in activities that he or she finds pleasurable and meaningful. Adequate daily recovery is essential for a person to stay healthy and energetic at work and during leisure time (Demerouti et al., 2009).

Stress is therefore not the problem *per se*, it is rather the person's reaction to stress and inability to recover from it that can have harmful consequences. Some level of stress is good for performance as long as there is sufficient recovery afterwards. Abilities and styles of coping with stress differ between individuals. Approach-oriented coping styles that tend to have a positive effect on recovery include problem-focused coping, which aims to directly address or change the stressor or the situation, and emotion-focused coping, which aims to directly manage cognitions or emotions (Sonntag & Fritz, 2007; Carver & Connor-Smith, 2010). Both are proactive approaches to influencing the source of stress. In contrast, avoidant coping styles that aim to avoid dealing with the stressor or the situation tend to be detrimental in the long term and ineffective in reducing stress (Carver & Connor-Smith, 2010). Avoidance, denial and escape to alcohol or drugs can create social, health-related and financial problems in the long run (Carver & Connor-Smith, 2010). Hence, learning and adopting healthy coping strategies is beneficial both in an occupational and a personal sense.

2.2.2 Stress management interventions

Intervention research on stress management has mostly been carried out in occupational settings and at schools. For the present thesis, the focus is on adult populations in occupational or community settings. In the ideal world, stress management skills would be trained already in early childhood to develop healthy coping strategies that can prevent stress-related problems in later life (Kraag et al., 2006). In real life, this does not usually happen and, hence, adults struggling with stress need supportive interventions. Learning a combination of cognitive strategies for psychological symptoms and relaxation skills for the physiological reduction of stress is likely to result in the best outcomes (Dornelas et al., 2013). In addition, physical activity and exercise help to regulate stress hormones, relieve tension and improve resilience (Dornelas et al., 2013).

Work stress began to attract researchers' and employers' attentions in the 1970s and has gradually become a common concern for organizations (Richardson & Rothstein, 2008). The most common stress management interventions are individual-level programs that utilize different techniques to help the person manage and cope with stress (Giga et al., 2003; Dornelas et al., 2013). A meta-analysis of 36 randomized experimental studies representing 55 occupational stress management interventions showed that cognitive-behavioural programs were more effective than relaxation, organizational, multimodal or alternative interventions (Richardson & Rothstein, 2008). Another meta-analysis of 24 experimental and parallel cohort evaluations of stress management interventions for university students found that cognitive, behavioural and mindfulness interventions significantly reduced stress symptoms (Regehr et al., 2013). One of the cognitive-behavioural approaches to training stress management skills is called Stress Inoculation Training, an empirically supported intervention model that uses cognitive restructuring, relaxation and behavioural skills training techniques and involves three distinct phases of education, coping skills and practising new skills (Meichenbaum, 2007; Regehr et al., 2013).

2.2.3 Acceptance and commitment therapy

Acceptance and commitment therapy (ACT) belongs to the family of so-called third-wave cognitive behavioural therapies, and it has its roots in research on human language and cognition (Hayes et al., 2006). ACT is used in the present thesis as a psychological intervention framework in stress management. The aim of ACT is to learn to resist experiential avoidance, that is the unwillingness to experience negative emotions, feelings and thoughts, and instead to accept them as they are (Hayes et al., 2006). This skill, which allows a person to commit valued actions despite discomfort, is called psychological flexibility (Hayes et al., 2013). The six core processes of ACT can be categorized into acceptance and mindfulness processes (acceptance, defusion, present moment, self), and commitment and behaviour change processes (present moment, self, values, committed action); see Figure 2.

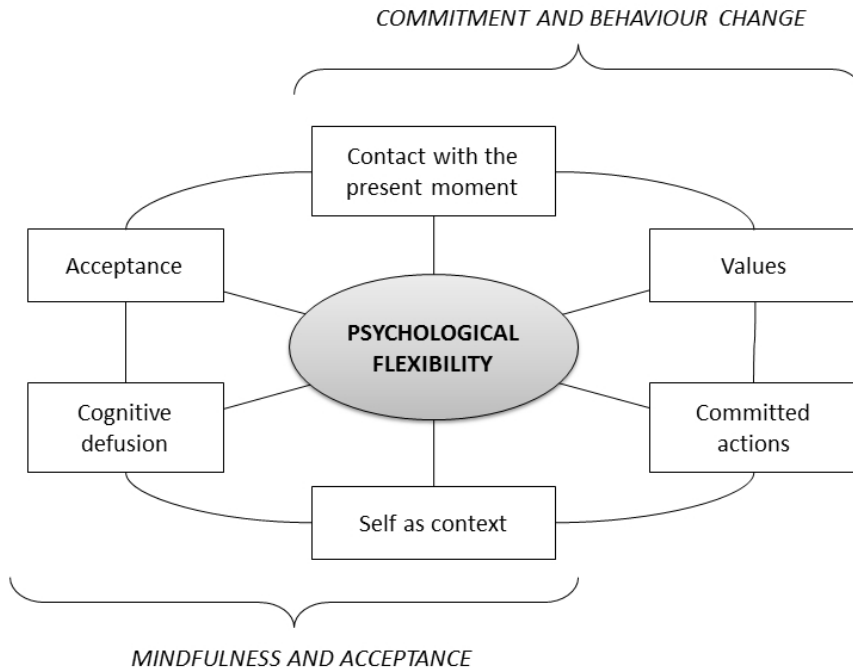


Figure 2. ACT intervention model (after Biglan et al., 2008).

ACT utilizes metaphors and experiential exercises to aid people in gaining distance from their persistent thoughts and emotions and in experiencing awareness of the present moment (Biglan et al., 2008). ACT involves mindfulness exercises but is a broader theoretical and practical framework with a strong emphasis on value clarification and living life according to one's values. The approach has been shown to have positive effects on a wide range of conditions and behaviours, including work stress and weight maintenance (Hayes et al., 2013). Furthermore, psychological flexibility has been found to be associated with good job performance and has even been proposed to be a fundamental aspect of health (Kashdan & Rottenberg, 2010). Studies on work stress interventions utilizing ACT (in the occupational context, "Acceptance and Commitment Training") have resulted in reduced work stress and increased well-being and job performance (Burton et al., 2010; Flaxman & Bond, 2010; Moran, 2011). ACT lends itself well to implementation on online and mobile platforms due to its structured approach and reliance on experiential exercises.

2.3 Healthy eating

2.3.1 Healthy diet and nutrition

Healthy eating and weight loss are sometimes seen as synonymous in people's minds. Nonetheless, as studies suggest, maintaining metabolic health is more important than having a BMI in the normal range (Kramer et al., 2013). The focus is therefore much wider than balancing energy intake and expenditure. The factors that influence metabolic health also include nutrition, physical activity, sleep quality and sleep patterns (Reiter et al., 2012; Gonnissen et al., 2013), eating rhythm, smoking and chronic stress (Chandola et al., 2008; Steptoe & Kivimäki, 2013). Nonetheless, healthy eating in terms of a balanced diet remains one cornerstone of overall health because a human body can use as building blocks only what is put inside it.

Most countries use dietary guidelines in some form to define what constitutes healthy eating, but the approaches to deriving these guidelines differ (Aranceta & Pérez-Rodrigo, 2012; Cuskelly et al., 2012). Despite progress on improving the evidence base of dietary guidelines on health enhancement, they are still not based solely on science or rational analysis (Willett & Ludwig, 2011; Aranceta & Pérez-Rodrigo, 2012; Cuskelly et al., 2012). For the general public, the components and presentation of the guidelines also leave room for improvement (Willett & Ludwig, 2011; Cuskelly et al., 2012). The most readily understandable recommendations focus on food groups to increase or limit, rather than nutrients (Cuskelly et al., 2012). Most guidelines emphasize increased consumption of fruit and vegetables, whole-grain cereals and fish, and control over fat intake and total calorie intake (Aranceta & Pérez-Rodrigo, 2012; Cuskelly et al., 2012). High fruit and vegetable intake has consistently been shown to protect against cardiovascular diseases and cancers, and it is also linked to better health and lower body weight (Guillaumie et al., 2010).

2.3.2 Healthy eating interventions

Healthy eating appears to be largely related to the availability of healthy food in the local neighbourhood (Caspi et al., 2012). When healthy food is available, individual-level factors play a greater role in dietary choices. Fruit and vegetable intake among adults is predicted by habits, motivation and goals (Guillaumie et al., 2010), self-efficacy and knowledge (Shaikh et al., 2008; Guillaumie et al., 2010). Hence, behaviour change techniques that support habit formation, goal-setting, regulation of negative emotions and shaping of knowledge are likely to result in healthier choices and healthier diets. Individual-centred approaches such as motivational interviewing that encourage and engage the person to develop his or her own plans for dietary behaviour change have demonstrated higher success than advice-giving approaches that only deliver facts and nutritional education (Thomson & Foster, 2013).

Recent research suggests that the aim of individual-focused healthy eating interventions should be the gradual establishment of healthy habits through small and concrete changes in daily behaviours and environmental contexts that influence eating choices (Gardner, 2012; Hill, 2009). Small changes in everyday life are likely to be easier to make and maintain than drastic changes in lifestyle, and they can prevent further weight gain or lead to gradual and sustainable weight loss (Hill, 2009). Moreover, a meta-regression of 122 healthy eating and physical activity interventions suggests that the most effective behaviour change techniques for these target behaviours are self-monitoring combined with at least one other self-regulatory technique from control theory, including goal-setting, feedback on behaviour, intention formation, and the review of goals (Michie et al., 2009). Small, measurable and concrete changes with a clear overarching goal valued by the person are likely to increase commitment and perseverance towards behaviour change (Thomson & Foster, 2013). In weight loss trials, dietary self-monitoring either with paper or electronic diaries has been shown to be associated with decreased weight, but there are no definite answers yet to the optimal frequency or duration of self-monitoring (Burke et al., 2011). Daily self-monitoring in the initial change period of 6–12 weeks is still generally recommended in dietary behaviour change (Thomson & Foster, 2013).

According to the WHO's compilation of the evidence on effective interventions for diet and physical activity, the most successful approaches to improve diets are multi-component interventions that are adapted to the local context (WHO, 2009). Involvement of participants in the planning and implementation of the intervention is essential to success (WHO, 2009). Involving family and friends in the behaviour change process is also likely to enhance effectiveness, because social support has been shown to predict healthy eating (Shaikh et al., 2008). Worksite dietary interventions should also aim to make changes at multiple organizational levels instead of focusing only on individual employees (Ni Mhurchu et al., 2010).

2.3.3 Small-changes approach to changing eating habits

It has been estimated that people make over 200 decisions related to food each day (Wansink, 2006). Most of these decisions are made in situations and contexts that recur almost every day, such as preparing breakfast or purchasing lunch at the workplace cafeteria (Thomson & Foster, 2013). Behaviour in such recurring situations becomes habitual, which means that intentions and reflective thinking rarely play a role, and situational cues and past behaviour are much stronger predictors of food-related decisions (Rothman et al., 2009; van't Riet et al., 2011). While the impact of any single decision on health is small, the cumulative impact over months or years can lead to weight gain and health problems (Rothman et al., 2009).

Habits are characterized by automaticity (Gardner, 2012). They are behaviours that are triggered with little or no conscious thought as responses to everyday contexts and learnt through repeated performance in the same context (Verplanken & Wood, 2006). Cues in the environment, specific situations or particular

2. Health promotion

moods can work as triggers for habitual responses (Verplanken & Wood, 2006). Hence, changing the cues in the environment or adopting simple behavioural heuristics for everyday situations are more effective in changing habits than information or education (Wansink, 2010; van't Riet et al., 2011). Environmental changes disrupt habitual mindsets and open possibilities for the formation of new habits (Verplanken & Wood, 2006), and simple behavioural changes form into a habit more quickly than complex ones (Lally et al., 2010). Offering people simple and concrete suggestions to modify their behaviours or environmental cues can make the shift towards healthier eating easy and sustainable.

3. Health promotion with online and mobile applications

This chapter first presents the current best practices for designing and evaluating online and mobile applications for health behaviour change and then summarizes the literature on stress management and healthy eating applications.

3.1 Design of health-promoting applications

Designing an online or mobile application for health promotion is just one step of an extensive development process. In the Intervention Mapping approach, which is widely used in the health promotion field (Bartholomew et al., 2011), choosing and implementing practical applications is preceded by needs assessment and definition of objectives for the intervention in terms of health outcomes and behavioural outcomes. This means that the practical development should not start without first determining the real needs and characteristics of the target population and defining the theoretical basis for the intervention. Furthermore, planning for adoption and maintenance is immensely important to ensure that the intervention will have life beyond the scientific evaluation (Bartholomew et al., 2011).

To increase the impact of technology and avoid ad hoc style intervention development that neglects the needs of the target population and the usage context, several frameworks and models for development of technology-based interventions have been proposed. A recent review identified 16 eHealth frameworks that provide principles and strategies for eHealth development (van Gemert-Pijnen et al., 2011). Almost all of these called for a multidisciplinary development approach, continuous and systematic evaluation during development, and robust methods for evaluation, but none of them was considered to cover all the important aspects, and thus a new framework called CeHRes¹ was proposed (van Gemert-Pijnen et al., 2011). Although the CeHRes framework is healthcare-oriented, it appears to be the most holistic framework for eHealth development containing not only technological but also human and contextual factors (Figure 3). It is intended for developers, re-

¹ CeHRes is an acronym for the Center for eHealth Research and Disease Management.

3. Health promotion with online and mobile applications

searchers and decision-makers, and it can help to build bridges between different stakeholders. It also includes checklists and practical methods for each phase.

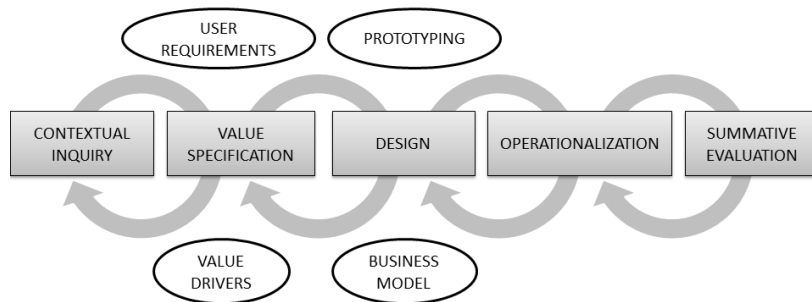


Figure 3. CeHReS roadmap for the development of eHealth (after van Gemert-Pijnen et al., 2011, also available at <http://ehealthwiki.org>).

The CeHRes framework clearly recognizes that eHealth development requires continuous iteration and evaluation, stakeholder participation that spans the entire development process and identification of implementation conditions right from the start (van Gemert-Pijnen et al., 2011). Technology is seen as a tool, not an end goal (Crutzen, 2012). The framework bears similarities to Life-Based Design, which is a recent approach to human-technology interaction design (Leikas et al., 2013). This design paradigm also emphasizes the importance of the wider context of technology usage in psychological and social environments, and stresses that the aim of technology should be to improve quality of life. Both these frameworks can be considered complementary to Intervention Mapping.

3.1.1 Design factors related to adherence and outcomes

Intervention designers always need to consider the specific context and needs of the target population when implementing the practical materials and applications (Bartholomew et al., 2011; van Gemert-Pijnen et al., 2011). Universal design principles are therefore impossible to draw. However, from a purely engineering perspective, it is possible to identify design elements that are associated with positive outcomes or high adherence and engagement. Before outlining them, the definition for adherence must be clarified: *study adherence* refers to the proportion of participants who stay in a study, whereas *intervention adherence* refers to the proportion of participants who use the application as intended (Cugelman et al., 2011). Study adherence and intervention adherence are different constructs, since a person may drop out of the study but continue to adhere to treatment or recommendations (Christensen et al., 2009). In this thesis, *adherence* refers to intervention adherence unless mentioned otherwise.

Research on adherence to online interventions suggests that while participant characteristics partially predict adherence, design factors play an important role (Kelders et al., 2012). Several reviews and meta-analyses have been conducted to

discover such elements in applications that aim to promote mental or physical health (e.g. Barak et al., 2008; Webb et al., 2010; Enwald & Huotari, 2010; Brouwer et al., 2011; Cugelman et al., 2011; Kelders et al., 2012). The findings on elements that have been associated with positive effects or higher adherence are summarized in Table 2. When interpreting the findings, it must be noted that they are merely indicative, and most of the research has been conducted on high-income populations (Kohl et al., 2013). The literature review was carried out using a combination of keyword searches and looking through the reference lists of relevant articles, and it is thus possible that some important reviews were overlooked.

Table 2. Elements that have been associated with positive effects or high adherence in online or mobile interventions.

Element	Description	Reviews	Impact
Use of theory	Grounding the intervention and its components in a firm theoretical framework	Webb et al., 2010	More extensive use of theory associated with larger effect sizes ($P=.049$). Helps to identify theoretical constructs to target and understand how behaviour change techniques work.
Tailoring	Adapting content and methods to user needs and characteristics	Neville et al., 2009 Webb et al., 2010 Cugelman et al., 2011	Associated with larger effect sizes. Helps to select proper behaviour change techniques for participants and increases the relevance of the content.
Frequent updates	New content regularly added to the website	Brouwer et al., 2011 Kelders et al., 2012	Associated with higher adherence (more visits, longer usage period). Maintains user interest and engagement.
Multiple behaviour change techniques	The intervention incorporates several different behaviour change techniques.	Webb et al., 2010 Cugelman et al., 2011	Use of more behaviour change techniques associated with larger effects ($P<.001$). Different techniques target different aspects of the behaviour change process.
Prompts and reminders	Periodic, frequent messages or reminders regarding health behaviour change	Fry & Neff, 2009 Webb et al., 2010 Kelders et al., 2012	Enhanced effectiveness and increased adherence associated with frequent prompts but evidence somewhat inconclusive. Increases interaction with the application.
Social support	Regular contact with peers and/or counsellor	Fry & Neff, 2009 Brouwer et al., 2011 Kelders et al., 2012	Counsellor support is strongly related to greater adherence and associated with better outcomes. Inconclusive evidence of the influence of peer support on adherence.
Shorter duration	Short program (e.g. 4 or 8 weeks), dividing content into short segments	Cugelman et al., 2011 Kelders et al., 2012	Better outcomes and higher adherence in shorter interventions. Engagement tends to fade with lengthier programs.

Even though the use of theory in intervention design is strongly advocated by health promotion experts, a question has also been raised of whether current behavioural theories are suitable in the development of mobile or online interventions (Riley et al., 2011). Arguments have been presented for new or modified theories that would be more appropriate for dynamic and adaptive interventions that are enabled by mobile phones (Riley et al., 2011). Moreover, theoretical constructs and theory-based behaviour change techniques are not easily transferable to concrete design and, hence, this implementation challenge is repeatedly faced with every new technology or application (Hekler et al., 2013).

In addition to the Intervention Mapping approach (Bartholomew et al., 2011) and CeHRes framework (van Gemert-Pijnen et al., 2011), the persuasive systems design model is a design framework intended for technologies that support behaviour change (Oinas-Kukkonen & Harjumaa, 2009; Lehto, 2013). It builds on the work done in the persuasive technology field and introduces four categories of techniques: primary task support, dialogue support, social support and credibility support (Oinas-Kukkonen & Harjumaa, 2009). There are implications that building persuasive features into an application can increase adoption and adherence (Kelders et al., 2012; Lehto, 2013) but, even more importantly, the use of the application has to fit into users' daily routines (Lehto, 2013). Human-computer interaction focuses on user-centred design and thus it can aid behavioural scientists and health promoters to understand how online or mobile applications fit into the users' everyday life and typical ways of interaction (Hekler et al., 2013; Poole, 2013). Intended end-users can be involved in the design process, e.g. using rapid prototyping and interviews (Kelders et al., 2013b). Other general guidelines for designing behaviour change technologies have been proposed by, e.g., Morris (2012) and Consolvo et al. (2009) based on theories and empirical work. Consolvo's eight guidelines are oriented towards designing concrete application features (e.g. aesthetic and positive), whereas Morris' seven guidelines are on a higher level and resemble behaviour change techniques (such as fostering an alliance and applying social influence). One of the challenges of identifying effective elements across intervention is the varying use of terms and concepts. The taxonomy of behaviour change techniques (Michie et al., 2013) should be used to characterize interventions in a standard manner.

3.1.2 Evaluation approaches

Many technologies for health promotion are developed in an engineering-driven ad hoc manner with little user involvement and little regard for the adoption and maintenance of the intervention after the scientific evaluation (van Gemert-Pijnen et al., 2011). Several researchers have been concerned about the difficulty of analysing and comparing behaviour change technologies due to inconsistent and incomplete descriptions of functions, the behaviour change techniques used and the evaluation methods. Common CONSORT-EHEALTH guidelines for reporting eHealth trials have therefore been developed (Eysenbach & CONSORT-EHEALTH Group, 2011). The guidelines also serve as a basis for evaluating the

impact of technology tools and are applicable both to RCT studies and less controlled trials (Eysenbach & CONSORT-EHEALTH Group, 2011).

Randomized controlled trials remain the golden standard of health outcome research, but they are time-consuming and resource-intensive and there is growing concern that the evaluated technology is already outdated by the time the results are published (Hekler et al., 2013; Riley et al., 2013; Thomson & Foster, 2013). Furthermore, RCT designs generally frown on any changes to the intervention under evaluation, which hinders the iterative development of applications and constrains usability improvements or redesign of implemented behaviour change techniques. Other evaluation strategies include mediation/moderation analyses to understand how and for whom the intervention works (Hekler et al., 2013); single case experimental designs in which participants serve as their own controls (Dallery et al., 2013); and theoretically-guided qualitative evaluations (Hekler et al., 2013). Moreover, the smartphone era and mobile application delivery through application markets have made mass participation user trials possible. Hybrid trials that integrate application usage data from thousands of users with qualitative data from a small local controlled trial can yield richer information than either method alone (McMillan, 2012).

Technology evaluations should focus on outcomes that can be linked to specific features (Van Velsen et al., 2013). Log data can be used to analyse usage activity and usage patterns, and this analysis could also be deepened by involving the participants in uncovering reasons for usage (Kelders et al., 2013a). The analysis of usage can be seen as a strategy to enhance intervention fidelity, that is, to ensure the reliability and validity of the intervention so that outcomes can be accredited to the intervention (Bellg et al., 2004). This is done by investigating whether participants use the applications as intended. Process evaluation of online and mobile interventions can utilize tools such as Google Analytics to determine where users come from, how they interact with the application and in what content they engage (Crutzen et al., 2013). A composite measure of adherence consisting of usage time, task completion and interaction could provide the most comprehensive picture of usage (Donkin et al., 2011). The actual public health impact of technology interventions is the ultimate goal, but it is seldom assessed in studies (Kohl et al., 2013). The RE-AIM framework is a model that evaluates five dimensions of an intervention: reach, efficacy, adoption, implementation and maintenance (Glasgow et al., 1999; Kohl et al., 2013). In the eHealth field, the RE-AIM framework has been used to analyse online health promotion programs (Kohl et al., 2013) and mobile physical activity interventions (Blackman et al., 2013). While efficacy has been reported consistently across studies, reporting of other factors is lacking. The use of RE-AIM is recommended to ensure that technological interventions can fulfil their potential and reach wide populations in a cost-effective way.

3.2 Online and mobile applications for stress management and healthy eating

The total number of online and mobile applications available for health promotion is quite challenging to measure, with new mobile applications being published almost every day on application markets. The estimated number of health-related mobile applications on the market in early 2013 was 31,000 (Essany, 2013). The most valiant and successful effort to keep up with the flood of eHealth is called Beacon. Beacon is a website that catalogues eHealth applications and provides reviews and ratings for each application as an information resource to health professionals and the public (Christensen et al., 2010). The website initially focused on mental health websites but has since grown to include mobile applications and Internet support groups as well as domains of physical health. Applications can be included in the Beacon even if there is no scientific evidence available about them, but the rating system clearly shows the level of evidence or the lack thereof (Centre for Mental Health Research, 2014).

There is an extensive body of research available on online interventions (Webb et al., 2010; Kelders et al., 2012; Kohl et al., 2013) but fewer rigorous studies on mobile applications (Fiordelli et al., 2013; Free et al., 2013). Typical online interventions are modular and interactive, consist of 10 sessions spanning over 10 weeks, have weekly updates, facilitate communication with counsellor and peers and result in about 50% adherence to the intervention (Kelders et al., 2012). The level of adherence varies widely from below 10% to over 90%, and adherence rates are significantly higher in RCT studies than in freely available applications or open access websites (Kelders et al., 2012). Interventions for lifestyle tend to have different set-ups than mental health interventions, which have a stricter structure and shorter duration (Kelders et al., 2012).

Online interventions to promote health behaviour, healthy eating, physical activity, alcohol consumption and smoking have showed relatively small but statistically significant effect sizes ($d = 0.16$, 95% CI 0.09 to 0.23) (Webb et al., 2010). Determinants of effectiveness are still unclear (Kohl et al., 2013). As for mobile applications, the focus has mostly been on chronic conditions, and few intervention studies have been conducted utilizing smartphones (Fiordelli et al., 2013). Nevertheless, mobile phones hold great promise as an intervention delivery channel because they can enable deeper integration into users' everyday lives (Klasnja & Pratt, 2012).

3.2.1 Stress management applications

There appear to be few studies that focus solely on preventive stress management applications (Rose et al., 2013). RCT studies on online and mobile applications have been conducted mostly in the physical health or mental disorder domains and less in preventive mental well-being (Harrison et al., 2011). The Beacon website lists sixteen online (including one support group) and four mobile applications for stress management. Like their traditional counterparts, technology-aided stress management programs are often based on CBT and aimed at teaching healthy coping and stress management skills. Outside complete programs, audio-based relaxation ap-

lications are common. As no reviews or meta-analyses focusing on stress management applications could be found, Table 3 summarizes the reviews of applications for mental well-being published during 2009–2013. The summary was compiled using keyword searches and examinations of reference lists of relevant articles. The table also covers reviews of interventions for mental disorders such as depression and anxiety, since they are often consequences of chronic stress, and they are all usually treated with cognitive-behavioural techniques.

Table 3. Findings from reviews of online and mobile mental well-being applications and intervention studies.

Review	Studies/Applications	Findings
Review of adherence measures in RCT studies of online interventions for depression and anxiety compared with open access websites (Christensen et al., 2009)	23 trials: 8 on depression; 1 on depression, anxiety and stress; 1 on generalized anxiety disorder; 5 on panic; 4 on social phobia; 4 on post-traumatic stress disorder	Dropout rates from RCT studies ranged from 1% to 50%, which was low relative to open access websites, which can have as high as 99% dropout rate.
Meta-analysis of RCT studies on computerized interventions for depression and anxiety disorders (Andrews et al., 2010)	22 trials: 6 on depression, 6 on panic, 8 on social phobia, 2 on generalized anxiety disorder	Effects comparable to face-to-face treatments. Good user acceptance.
Review of RCT studies on preventive and online interventions for depression and anxiety (Griffiths et al., 2010)	29 papers describing 26 trials: 8 on depression, 16 on anxiety disorders, 2 on both depression and anxiety	CBT was used in all interventions. Effect sizes comparable to face-to-face treatments. Three programs freely available in English.
Overview of the mobile mental health field (Harrison et al., 2011)	6 mobile applications ranging from stress to depression, pilot studies	Good acceptance and improvements in well-being were found but results are inconclusive results due to small sample sizes and lack of control groups.
Review and meta-analysis of computer-based psychological treatments for depression (Richards & Richardson, 2012)	45 papers describing 40 studies (19 RCTs) and 18 different interventions, 14 online	Efficacy and effectiveness have been demonstrated in diverse settings and populations. Professionally supported interventions have better outcomes and higher retention.
Analysis of persuasive features in commercial mobile applications related to mental well-being (Chang et al., 2012)	12 mobile applications (9 iPhone, 3 Android) ranging from mood tracking to positive psychology	User acceptance was moderately good or very good, but behaviour change techniques and persuasive features were scarcely used.
Meta-analysis of online depression interventions (Cowpertwait & Clarke, 2013)	18 different RCT studies with a total of 2,946 subjects, mean age 43 years and average proportion of females 67%	Reduction in depression and increase in well-being. Attrition comparable to face-to-face treatments. Outcomes were improved by reminders and human support.

Even though stress management has been the focus of relatively few studies, it serves as a behaviour change technique for other health behaviours (Michie et al., 2013). Interestingly, a meta-analysis of online interventions for health behaviours such as healthy eating or physical activity found that interventions that utilized stress management strategies had the largest effects (Webb et al., 2010). This supports the notion that healthy coping with stress is a prerequisite for other healthy behaviours (Carver & Connor-Smith, 2010). Some online interventions studied in the workplace and RCT settings have used stress management as a gateway module to other problem areas such as depression or alcohol abuse (Billings et al., 2008; van Straten et al., 2008). It should be noted that stress management studies may find only small impacts on psychological outcomes due to the floor effect in a stressed but otherwise healthy sample (e.g. Rose et al., 2013).

Design strategies focusing specifically on mental health technologies have been proposed by Doherty et al. (2012). Although these guidelines are crafted for the treatment of depressive symptoms, which creates a different user mindset to a focus on preventative stress management, the strategies are general enough to be useful also in the development of mental well-being interventions. The proposed strategies to improve engagement in applications are interactive experience, tailored and personal experience, professional support as guided self-help and social support from a peer community (Doherty et al., 2012). These strategies appear quite similar to what has been found to increase effectiveness of online interventions in general.

3.2.2 Healthy eating applications

Table 4 summarizes reviews and meta-analyses published during 2009–2013 on healthy eating applications. The summary was composed using keyword searches and going through reference lists of relevant articles. In addition, the Beacon website lists three online programs for nutrition, and ten online and two mobile applications for weight/obesity, as well as twelve programs and two support groups for eating disorders or distress. In general, the effects of healthy eating applications have been found to be positive but small. The transtheoretical model of the stages of change (TTM) appears to have been the most commonly used theory. Commercial mobile applications seem to incorporate only a small number of behaviour change techniques.

Table 4. Findings from reviews of online and mobile healthy eating applications and intervention studies.

Review	Studies/Applications	Findings
Review of tailored behaviour change interventions for nutrition, physical activity or weight management (Enwald & Huotari, 2010)	23 studies (21 RCTs): 10 on nutrition, 2 on nutrition and physical activity, 7 on physical activity, 4 on weight management	Tailoring was more effective in nutrition than physical activity interventions. TTM was the most commonly used theory in nutrition interventions.
Review of computer-tailored interventions for dietary behaviour change (Neville et al., 2009)	13 articles describing evaluation of 12 interventions (5 online)	Seven studies found significant positive effects. Unclear whether effects were sustainable in the long term. Retention rates ranged from 63% to 90%.
Review and analysis of tailoring in online interventions (Lustria et al., 2009)	30 studies: 10 on nutrition/diet, 7 on physical activity, 3 on alcohol, 7 on smoking	Behaviours and the stage of the change were the most common tailoring criteria. Health outcomes were not analysed.
Review of reviews on online health behaviour change interventions with the RE-AIM framework (Kohl et al., 2013)	41 papers (27 reviews, 16 meta-analyses): 3 on dietary behaviour	Primary focus on younger populations. Small effects that were not maintained. eHealth devices may not be cost-effective.
Analysis of behavioural strategies in commercial weight loss applications on iPhone/Android (Pagoto et al., 2013)	29 self-monitoring weight loss mobile applications: 16 iPhone, 13 Android	On average, 18.8% of 20 strategies were present in the applications. Stress reduction, motivation improvement and problem solving were missing from most applications.
Analysis of theory-based features of diet/nutrition or weight management applications in App Store (Azar et al., 2013)	10 selected applications: 2 on diet tracking, 2 on grocery decision making, 2 on restaurant decision making, 2 on healthy cooking, 2 on weight tracking	All applications were low on the use of theory or theory-based behaviour change techniques. Applications that had more theory-based or persuasive features were not among the most popular applications in the App Store.

Recent developments include mobile phone games to support healthy eating using short breaks in everyday activities to increase users' knowledge and behavioural skills (Klasnja & Pratt, 2012). Innovative approaches using social learning in a local community to improve diets have also been piloted (Klasnja & Pratt, 2012). Self-monitoring is still one of the strategies generally considered effective, but one of the challenges in self-monitoring dietary intake with mobile or online applications is the recognition of the amount and content of food consumed. Although advances have been made in the automated capture of dietary intake, an automated analysis of nutritional content and portion size is still difficult from photographs (Stumbo, 2013). Crowdsourcing could provide a partial solution to this

3. Health promotion with online and mobile applications

(Stumbo, 2013). Another option that does not require computational resources is to use photographs as reflective prompts. Photographs may also be preferable in populations with lower literacy (Maitland et al., 2009).

4. Aims and methods of the research

The overall objective of this thesis is to present design guidelines for health-promoting applications in order to increase their usage and improve their effects on a large scale. This main aim is pursued from multiple perspectives through the following specific research questions:

- 1) How are online and mobile applications promoting healthy eating used on a large scale with no professional contact? (**adherence**, Studies I–II)
- 2) What are the psychological effects and subjective benefits of online and mobile applications used to support a psychological intervention for stress management? (**outcomes**, Studies III–IV).
- 3) What general design guidelines can be drawn for health-promoting online and mobile applications? (**design**, Studies V–VI).

Forming a coherent picture of the field of health-promoting applications is an enormous task. The three distinct focus areas were chosen due to their relevance to application design. For an application to have an impact on behaviour and fulfil its function it needs to be used (*adherence*); for it to be used, it needs to be *designed* properly; and to discover the design elements that lead to positive *outcomes*, the changes in users' behaviour and health need to be determined and their causes identified. Figure 4 illustrates this three-dimensional framework that works as a basis for the research presented in the following chapters. Each individual study concentrates on one of the research questions and provides insights into the other two.

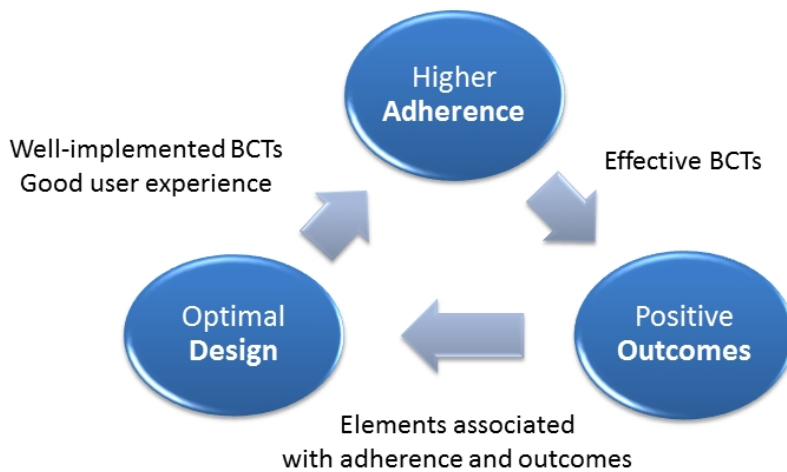


Figure 4. Conceptual framework for the design of health-promoting applications.

The rest of this chapter positions the research at the intersection between health promotion and computer science fields, describes the research methods employed in the studies and summarizes the ethical aspects of the studies.

4.1 Research environment

This exploratory research journey into technology-aided health promotion began in 2009. Back then, a solid body of research already existed on online interventions for mental disorders such as depression and anxiety (e.g. Barak et al., 2008), but the prevention of such disorders with technology support had received less attention. However, the harmful psychological and physiological consequences of stress and insufficient recovery were quite well known (e.g. Chandola et al., 2008), and a lack of resources in healthcare made prevention of utmost importance. The potential of technology tools in the self-management of stress seemed considerable due to its cost-effectiveness and scalability. It was also evident that the development of effective interventions required interdisciplinary collaboration. The series of six studies resulted from the author's attempts to bridge the gaps between computer science, psychology and health promotion.

The studies have been carried out in two research projects, both of which aimed at developing novel technology-aided services for health promotion. The first of the two projects was called P4Well: "Pervasive and Personal Psychophysiological wellbeing and recovery management concept based on stress, sleep and exercise". Studies III–V stem from this two-year project (2008–2009) in which a technology toolkit was developed to support a brief group intervention for stress management. The second project, Salwe "Elixirs of Mind and Body" (2011–2013), yielded Studies I–II and VI. This project had a broader focus, which provided an

opportunity to seek cross-domain understanding of similarities and differences between applications for stress management and healthy eating.

The timeline of the application development and data collection periods for the studies is illustrated in Figure 5. The advancement of technology can be observed from the timeline: earlier studies evaluate online programs, whereas latter studies focus on mobile applications. At the time of writing this thesis, “online” (web) and mobile are coming closer together as smartphones and mobile web are becoming ubiquitous. The role of the technology platform may still be important in terms of the applications’ usage context.

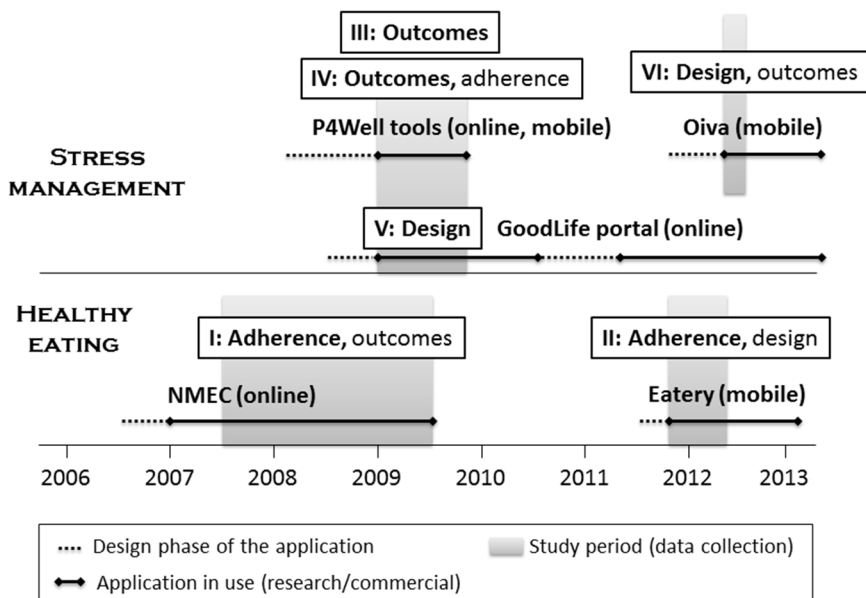


Figure 5. Time frame of the development and evaluation of the applications under study. The main focus of each study is presented after the Roman numerals.

4.2 Research methodology

4.2.1 Overall approach

The studies in this thesis include large-scale observational studies (Studies I and II), a pilot RCT (Study III) and small-scale field trials (Studies IV–VI). Both quantitative and qualitative methods are employed to seek answers to research questions that focus on real-life implications. This approach is characterized as mixed method research, and its primary philosophy is pragmatism (Johnson et al., 2007). Mixed methods are most suitable when research problems are examined from multiple perspectives, for example, in explaining quantitative outcomes by qualitative data, or in gathering insights from qualitative studies to inform the design of quantitative

4. Aims and methods of the research

evaluations (Creswell et al., 2011). Moreover, mixed method approaches in the evaluation of complex interventions are valuable, especially when the results are counterintuitive (Craig et al., 2008b). In eHealth research, they aid in understanding “*what works for whom under what conditions*” (Glasgow et al., in press). The research questions addressed in this thesis certainly involve multiple perspectives: application design potentially influences the user’s adherence, health behaviours and ultimately health.

The aim and context of each individual study can be illustrated by mapping each one at the different stages of the development-evaluation process of complex interventions (Craig et al., 2008b). Figure 6 shows the approximate positioning of each study. In the healthy eating studies, retrospective analyses of freely available applications were carried out. The focus of Study I was on evaluating adherence, outcomes and change processes, whereas Study II mainly examined large-scale usage. In the stress management studies, Study III was a pilot RCT to test the preliminary efficacy of the intervention, and Study IV looked into its feasibility, whereas Studies V–VI concentrated on design aspects and early feasibility. Process-wise, the findings of Studies III–IV fuelled Study V and later Study VI (see also Figure 5). This is common and advisable in the development process, as the intervention and study protocol are shaped based on the findings from feasibility trials before moving on to larger evaluations (Craig et al., 2008a; Bowen et al., 2009).

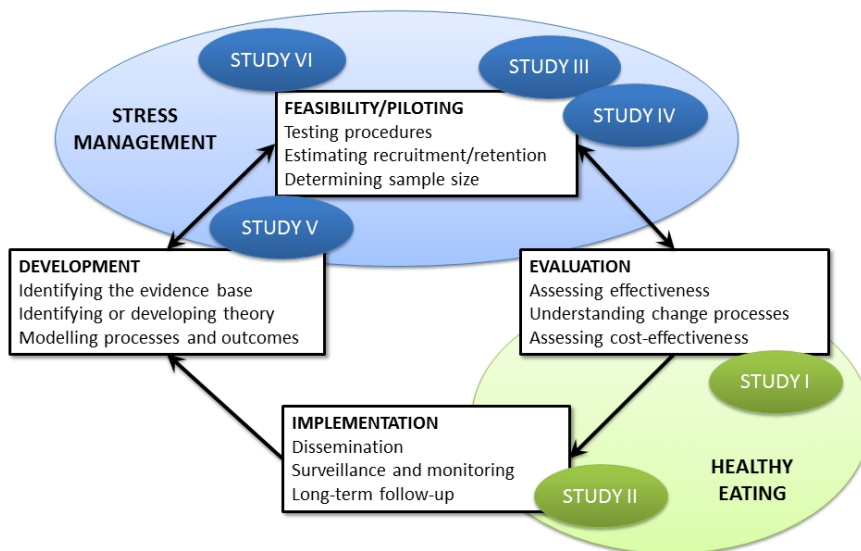


Figure 6. Positioning the studies at different stages of the intervention development and evaluation process, presented in the MRC guidance for complex interventions (after Craig et al., 2008b).

4.2.2 Study settings and participant recruitment

Study I was first initiated in 2007 at Cornell University in the United States as a large-scale uncontrolled evaluation/implementation study of an online application. The study was preceded by smaller pilots of the system (Wansink, 2010). The study had no active recruitment, but prospective participants could find the application online through search engines or links and register for free. Study II can be characterized as a retrospective mass participation user trial (McMillan, 2012) in which the study hypotheses were not formed until after collecting the data. These retrospective analyses were motivated by the missing piece of the picture in the field of health-promoting applications, that is, how well the intervention applications work in practical settings and wide-scale dissemination (Glasgow et al., in press).

Studies III–V used somewhat different sets of data from the same research project (P4Well) in which three trials were carried out during 2009. The first trial was a pilot RCT (reported in Study III) that recruited male participants through an advertisement in a local newspaper in the Jyväskylä region in Finland. The second trial was an uncontrolled feasibility trial that recruited participants in the Helsinki region through an email invitation to a wellness program from an insurance company to its entrepreneur customers. The feasibility trial was carried out to test the fit of the intervention in a real-world setting (Bowen et al., 2009). These two trials ran in parallel during spring 2009 (combined data used in Study IV). The control group of the pilot RCT was placed on a waiting list and treated during the follow-up phase of the trial. Finally, the third trial was another small-scale RCT conducted in autumn 2009 that recruited female participants through a newspaper advertisement in the Jyväskylä region. The preliminary findings from the first pilot RCT were used in summer 2009 to improve the study design and fix usability issues in the technology tools.

All three trials in Studies III–V involved group meetings as part of the intervention: three meetings in the RCTs (led by psychologists in the research group) and four meetings in the feasibility trial (led by a psychologist from a partner company in the research project). The intervention period was 9–10 weeks in the pilot RCT, 14 weeks in the feasibility trial and 8–9 weeks in the second RCT. The combined user experience data from the three trials were analysed in Study V after the intervention period of the second RCT had ended. Power calculations were not formally performed for the RCTs prior to recruitment. However, other researchers have recommended drawing sample sizes for pilot RCTs by using the rules of “minimum 10 per group” or “at least 20 in total”, and a more recent method offers an estimate of “9% of the sample size of the main planned trial” (Cocks & Torgerson, 2013).

Study VI recruited a convenience sample through an email to the staff of a local university in Tampere, Finland. Convenience samples are deemed proper for limited efficacy testing when no generalizable results are yet sought and the findings are intended to suggest improvements and provide justification for comprehensive evaluations (Bowen et al., 2009).

4.2.3 Data collection and measures

All the studies used somewhat different quantitative measures for outcomes and adherence due to the different study settings, target behaviours and intervention components. Validated instruments to measure various psychological outcomes were employed in Study III. Study VI used only a small set of validated instruments for psychological variables in short form to minimize the participant burden because the main focus of the study was on feasibility and qualitative analysis of design factors. User experiences and subjective benefits were also quantified using surveys in Studies III–V. This can be considered a process evaluation focusing on studying user experiences to determine which factors contribute to adherence (Donkin et al., 2011; Kohl et al., 2013). The user experience survey items used in Studies IV and V are listed in Appendix 1. They were partially based on the Technology Acceptance Model for Mobile Services (Kaasinen, 2005), which emphasizes ease of use, trust, ease of adoption and perceived value of technology services.

Adherence and usage activity were defined in each study as a composite of usage time, task completion and interaction with the system, as suggested by Donkin et al. (2011). Application log data were collected in all the studies. In Studies III–V, the application usage activity was also inquired about in the user experience surveys, and Study I measured task completion in the monthly surveys. Studies I and II composed the adherence measure from interactions with the system and task completions. In Studies III and IV, interaction with the system was calculated for each individual application, since the aim was to link outcomes to specific intervention components as suggested by Van Velsen et al. (2013). Study V examined the usage patterns in a qualitative manner. In Study VI, adherence was measured based on interactions with the system and the total usage time.

Qualitative data were collected in Studies I and III–VI to uncover reasons for usage or non-usage (Kelders et al., 2013a). Studies I and III–V employed open-ended questions in user experience surveys to complement close-ended questions. Semi-structured interviews were conducted in Study VI to collect in-depth data about user experiences and usage patterns of the Oiva application. In-depth interviews are said to provide an excellent view of individual perceptions and beliefs (Curry et al., 2009). Each interviewee was asked the same questions, while allowing for spontaneous or unexpected lines of thinking that could yield new ideas (Wilkinson et al., 2004). The interviews were recorded and transcribed.

4.2.4 Data analysis

Studies I and II were inductive in nature, starting with exploratory analysis of the data and developing hypotheses from them (Curry et al., 2009). Study III utilized repeated-measures ANOVA to assess the intervention effects between treatment and control groups. The analyses in Studies IV and V were mainly descriptive due to the small sample sizes. The general approach to handling log data in different studies was first to explore the data to understand how they were stored, then to

ensure that the timestamps were correct and finally to calculate the usage sessions and their durations based on timestamps and other log information.

Thematic coding was employed in Studies I, V and VI to identify recurring themes in participants' open-ended responses (I and V) and interviews (VI). The coding was only descriptive in Studies V and VI due to small sample sizes that would have made it meaningless to calculate frequencies (Joffe & Yardley, 2004). In Study I, the frequencies of appearances of themes in the responses were also calculated. Only one person performed the coding in each study and, thus, inter-rater reliability could not be calculated. In Study V, behavioural theories and persuasive design principles were reviewed and used to guide interpretation of the findings. Using theory to guide the analysis of qualitative data has been said to fit the development of design guidelines in the field of behaviour change technologies (Hekler et al., 2013).

4.3 Ethical aspects

All the studies involved human participants who voluntarily took part in the research. Explicit informed consent was obtained from the participants in all the studies except Study II, in which the terms and conditions of the application stated that users' depersonalized data could be used for analysis and other purposes. The users implicitly approved these terms by using the application. All personal information was removed from the data before further analysis to ensure privacy and confidentiality.

The procedures of Study I were originally approved by the Institutional Review Board of Cornell University. The Research Ethics Committee of the University of Jyväskylä gave its approval for Study III. Other studies did not seek approval from ethics committee because they were deemed to involve minimal risk and their focus was on usage and user experiences rather than clinical outcomes.

5. Summary of the studies

The applications evaluated in this thesis are summarized in Table 5. The descriptions of the applications partially follow the reporting guidelines for technology-aided behaviour change interventions (Eysenbach & CONSORT-EHEALTH Group, 2011).

Table 5. Summary of the applications presented in Studies I–VI.

	Study I	Study II	Studies III-IV	Study V	Study VI
Application	NMEC	Eatery	P4Well tools	GoodLife portal	Oiva
Target behaviours	Healthy eating, weight loss	Healthy eating	Stress management, sleep, exercise	Stress management	Stress management
Technology platform	Online	Mobile	Mobile, online, personal devices	Online	Mobile
Theoretical basis	Habit formation	Control theory (assumed)	CBT, ACT	CBT, ACT	ACT
Study design	Retrospective cohort study	Retrospective cohort study	Pilot RCT/feasibility trial	Qualitative evaluation	Feasibility trial
Intervention provided in addition	None	None	ACT-based intervention with 3–4 group meetings	ACT-based intervention with 3–4 group meetings	Initial ACT-based training session
Sample size	2,053	189,770	24 / 35	55	15
Participant characteristics	81% from the United States, 90% female. Mean BMI 28.	iPhone users. 68% from United States time zones, 12% from European time zones.	Finnish middle-aged adults with stress. 100% male (Study III) / 66% male (Study IV).	Finnish middle-aged adults with stress or sleep problems. 58% female.	Finnish adults with stress. 60% female.
Intervention duration and intensity	Minimum 1 month. Daily actions advised. Monthly interaction with application.	Duration not specified. Daily self-monitoring implicitly advised.	3 months. 3 group meetings, applications used in the meantime.	3 months. 3 group meetings, portal used in the meantime.	1 month. Daily usage of application recommended.
Study period	07/2007–07/2009	10/2011–04/2012	01/2009–11/2009	01/2009–12/2009	05/2012–06/2012

5.1 Behaviour change techniques identified in the applications

The reporting guidelines for interventions recommend consistent and comprehensive description of the different components of the intervention to ensure comparability and replicability of the findings (Eysenbach & CONSORT-EHEALTH Group, 2011). For this reason, a post-hoc analysis of the behaviour change techniques employed in the applications was conducted for this thesis. While the development of standardized definitions for the behaviour change techniques used in the interventions is still under way, the most recent version of a consensually agreed taxonomy for specifying intervention content was published in March 2013 (Michie et al., 2013). The BCTs identified in the applications are listed and briefly described in Table 6 using the terminology from this taxonomy. It must be noted that the coding of BCTs should normally be done by two independent, trained observers. In this case, the author of the thesis was the sole coder with no formal training for the task. The contents of the table should therefore be interpreted as suggestive descriptions of elements found in the applications.

Table 6. Summary of the behaviour change techniques and practical strategies identified in the applications presented in Studies I–VI.

	NMEC	Eatery	P4Well tools	GoodLife portal	Oiva	N of applications using the technique
Goals and planning						
Goal-setting (behaviour)	Three habit changes, estimated adherence to them	-	Goal-setting in mobile apps (and in group meetings)	Step-wise goal setting	One exercise for goal-setting	4
Problem solving	Prompt the user to analyse barriers and strategies for suggested changes	-	Problem solving exercise in the portal	Barrier analysis exercise	Exercises on barriers for healthy eating and physical activity	4
Goal-setting (outcome)	Choosing an eating goal	-	Goal-setting in mobile apps (and in group meetings)	Step-wise goal-setting	One exercise for goal-setting	4
Action planning	Suggestions with detailed actions	-	-	Step-wise goal setting and action planning	-	2
Discrepancy between current behaviour and goal	-	-	Value analysis exercise in the portal	Value analysis exercise	Values section: exercises about values and actions	3
Review outcome goal(s)	-	-	-	Goal evaluation on user-set target date	-	1

Feedback and monitoring						
Feedback on behaviour	-	Healthiness rating for the food pictures, healthiness compared with those of past weeks	Heart rate variability measurement with professional feedback	-	-	2
Self-monitoring of behaviour	Report adherence to habit changes	Record eating behaviour with photographs	Mobile wellness diary, mobile fitness coach, pedometer, heart rate monitor	General self-monitoring form	-	4
Self-monitoring of outcome of behaviour	Report weight each month	-	Mobile wellness diary	General self-monitoring form	-	3
Biofeedback	-	-	Heart rate variability measurement with professional feedback	-	-	1
Social support						
Social support (general)	-	Commenting and liking others' food pictures	Discussion forum in the portal	Discussion forum	-	3
Shaping knowledge						
Instruction on how to perform a behaviour	-	-	Relaxation application	-	Experiential mindfulness and relaxation exercises	2

Natural consequences						
Information about health consequences	-	-	Information about stress, sleep, exercise and mood in the portal	Information about stress, sleep, exercise and mood	Introductions explaining the benefits of exercises	3
Monitoring of emotional consequences	-	-	-	-	Reflection screens after exercises, diary	1
Anticipated regret	-	-	-	-	Values clarification exercises	1
Comparison of behaviour						
Social comparison	-	Comparison with other users' average healthiness scores	-	-	-	1
Information about others' approval	-	Food healthiness rated by other users	-	-	-	1
Associations						
Prompts/cues	Opt-in weekly or monthly email reminders	-	Mobile wellness diary reminders	Opt-in email/SMS reminders of goals	-	3
Repetition and substitution						
Behaviour substitution	Suggestions to change behaviours to new ones	-	-	-	-	1
Habit formation	Suggestions for daily habit changes in similar context	-	-	-	-	1

Comparison of outcomes						
Credible source	Messages signed by Dr Brian Wansink	-	-	-	Videos with professor Raimo Lappalainen	2
Regulation						
Reduce negative emotions	-	-	Mindfulness exercises in the portal, mobile relaxation application	Mindfulness and relaxation exercises in the portal	Exercises for cognitive defusion, acceptance, relaxation and mindfulness	3
Antecedents						
Restructuring the physical environment	Suggestions to put healthy food in a visible place and unhealthy food out of sight	-	-	-	-	1
Avoiding/reducing exposure to cues for the behaviour	Suggestions to change physical cues to eating	-	-	-	-	1
Identity						
Framing/reframing	-	-	Values clarification tool in the portal	Values clarification tool	Exercises on values clarification, committed actions	3
Valued self-identity	-	-	Values clarification tool in the portal	Values clarification tool	Values clarification exercises	3
N of techniques used in the application	12	5	15	13	12	

5.2 Large-scale use of online and mobile applications

5.2.1 Usage of a free online healthy eating and weight loss program with a small-changes approach (Study I)

Study I evaluated usage patterns, weight outcomes and self-reported barriers for behavioural changes in the National Mindless Eating Challenge (NMEC). The aim was to determine the overall reach of the online program during the two years it was available to the public and assess the association between adherence and outcomes. Implications for designing online interventions using a small-changes approach were also drawn.

NMEC was a free online program for healthy eating and weight loss. The program was designed to support users in making small daily changes to their eating habits or environment that would result in significant changes in eating behaviour and/or weight in the long term. The changes suggested by the program were mostly based on research on mindless eating behaviour (Wansink, 2006; Wansink et al., 2009; Wansink, 2010). The program was developed following the publication of the *Mindless Eating* book (Wansink, 2006) as an additional resource for the public interested in the approach.

NMEC was launched in December 2006 and offered as a free service until July 2009. The sign-up process for the program consisted of a survey that collected background information and asked participants their initial eating goals, and the assignment of three random suggestions for habit changes relevant to the chosen goal. The participants were able to redraw the suggestions until they were satisfied with them. After this, they were encouraged to follow the suggestions on a daily basis and to return for a follow-up survey at the end of the month. In the follow-up survey, participants reported their adherence to the suggestions and new suggestions were given for the following month. No recommendations were provided on how long to stay in the program.

The data set analysed in Study I was collected between July 2007 and July 2009. During that time, 2,053 participants signed up for the program. Most of them were white, educated females from the United States (Table 7). Their mean BMI was 28.1 and most had weight loss as their initial goal (83%). The participants who were not from the United States were mostly from Canada (11%), but altogether the program attracted participants from 38 countries.

Table 7. Demographics of participants who registered for the NMEC program.

Number of participants	2,053
Gender: Female	1,829 (89%)
Age (SD)	39.8 (12.80)
White/Caucasian	1,840 (90%)
College degree or higher	1,641 (80%)
From the United States	1,672 (81%)

Attrition from the program was high, with only 25% (N=504) of the participants who started the program returning for a follow-up. Figure 7 shows the usage trends observed among the participants in terms of calendar months in the program and follow-up for survey completion. Many participants skipped one or several months before returning to the next follow-up, which can be seen in the lower follow-up survey completion rates. Only 38% of the 504 returning participants (9.2% of all registered participants) stayed in the program for more than two months and completed at least two follow-up surveys. These participants lost on average 1.0% of their initial weight over the course of the program ($t=2.62$, $P=.009$), whereas the weight change of less active participants was not statistically significant. High adherence to habit change suggestions was associated with higher weight loss. Furthermore, adherence to a suggestion was correlated with its perceived ease ($r=.622$, $P<.001$), which indicates that people are fairly good at estimating how well they will be able to comply with suggestions.

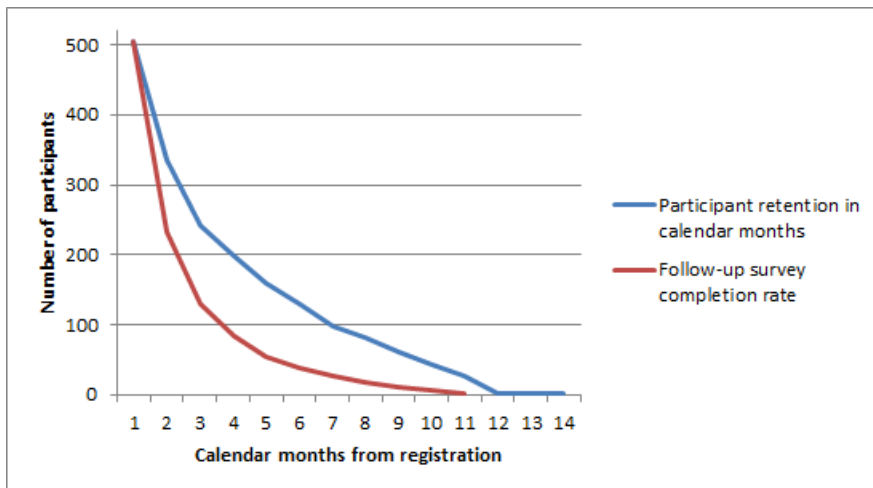


Figure 7. Usage trends in the NMEC program (Kaipainen et al., 2012).

The most commonly reported barriers to habit changes were forgetfulness, busy period in life or unusual situations, and irrelevance or unsuitability of the suggestion. Loss of motivation and emotional eating were also often mentioned. Easy suggestions were appreciated, and several participants stated that heightened awareness of eating habits and previously mindless behaviours was more important than any specific changes. Reminders and goal-setting were also mentioned as helpful.

This study shows that high attrition is a challenge in a freely available online program. Even though the participants were self-selected and probably had higher motivation than the average population, only 9% remained in the program long enough to achieve weight loss. However, the majority of the participants were not

obese but overweight, and hence it may have been more important for them to become aware of their mindless habits than to lose a large amount of weight. The design of the online program could have benefited from further tailoring to address the different needs of the participants, such as emotional eating, and to ensure that suggestions were at appropriate challenge levels for each person.

5.2.2 Usage of a free mobile application for monitoring eating behaviour with photography and peer feedback (Study II)

Study II examined the usage trends in the Eatery, a freely available iPhone application for healthy eating. The aim was to identify factors related to sustained use of a mobile application that utilized food photography and crowdsourced healthiness ratings for self-monitoring and feedback. This was done by analysing data that were collected through the application between October 2011 and April 2012.

The Eatery targeted people who wanted healthy eating to be easy and fun. The main functions of the application were food recording by taking a picture with the mobile phone, self-evaluation of the food's healthiness on a simple "fat" to "fit" scale, and peer evaluation of others' pictures using the same scale. Each photo taken by a user received peer feedback as an average healthiness score based on other users' ratings.

The application usage data were acquired by the author in June 2012 by request to the developers (Massive Health) who had extended an open offer to provide data for research purposes. Information on user background, adherence, healthiness scores and picture characteristics was extracted from the data and analysed. Adherence was defined based on the total usage time and the total number of pictures. "Active" users were defined as having taken at least ten pictures and having used the application for at least seven days.

The Eatery had 189,770 registered users during the 5.5 months, but attrition was also very high. Only 3% (N=4,895) of all registered users ended up as active users of the application, and most of the registered users (69%) took no pictures of food. It is likely that the application was often installed and tried out for fun without any serious intention to start dietary self-monitoring. Nonetheless, the average usage time of active users was 47 days, and they took an average of 59 pictures. This indicates that at least some users monitored their eating fairly regularly. Users with strict diets (low fat, low/no carbs, or vegan/vegetarian) were more likely to become active users, and they were also most active in rating other users' pictures. This may imply that the application attracted users who were already interested in their diets and/or who were already healthy eaters.

The initial time of using the application was also associated with adherence. Users who registered on weekdays and in the morning or daytime were slightly more likely to become active users than those who registered at the weekend or in the evening. This is an intriguing finding considering how people's mentality changes over the course of the day and week: people who start using the application in the middle of the week before lunchtime probably have more serious intentions.

5.3 Psychological and behavioural effects of applications for stress management (Studies III and IV)

Study III evaluated the psychological effects of the P4Well intervention, which combined an ACT-based group intervention with various technology tools for stress management. The effects of the intervention were studied in a randomized controlled trial among stressed male participants with symptoms of mild depression (“Mild Depression group”). Study IV presented results on usage activity and perceived benefits of the online and mobile applications as well as the other components utilized in the P4Well intervention. This study focused on user experiences and included data from a less controlled setting among stressed entrepreneurs (“Stress group”) in addition to the RCT study.

Participant demographics and depressive symptoms are presented in Table 8 based on the data used in Study IV. The RCT reported in Study III was a small-scale study with a waiting list control group. Psychological measures were collected at baseline, after the intervention period (3 months) and at a 6-month follow-up. A total of 24 participants were recruited to the RCT study, 12 randomized into the intervention group and 12 into the control group. One participant from the intervention group was lost in the follow-up. Study IV did not use data from the follow-up and thus it included all 12 participants in the analysis of user experiences. In the Stress group that served as a feasibility trial in a more real-world setting resembling occupational health, 23 started the study but only 11 completed the post-intervention measurements.

Table 8. Demographics of participants in the P4Well user experience study (Study IV).

	Mild Depression group	Stress group
Number of participants	12	23
Gender (female/male)	0/12	12/11
Age (range)	48 (32–59)	54 (37–62)
BDI score (range)	14.6 (6–30)	6.3 (0–14)

The aim of the P4Well intervention was to empower the person in the daily self-management of his or her mental and physical well-being, primarily focusing on stress management (Happonen et al., 2009). The intervention was a combination of three or four CBT- and ACT-based group meetings spread over 9–14 weeks and a collection of technology tools that the participants could use between the meetings for daily self-management. Figure 8 illustrates the intervention process for both groups. The control group of the randomized controlled trial (N=12) completed the same baseline questionnaires and conducted heart rate variability measurements but were not given any technology tools or group meetings during the study period.

5. Summary of the studies

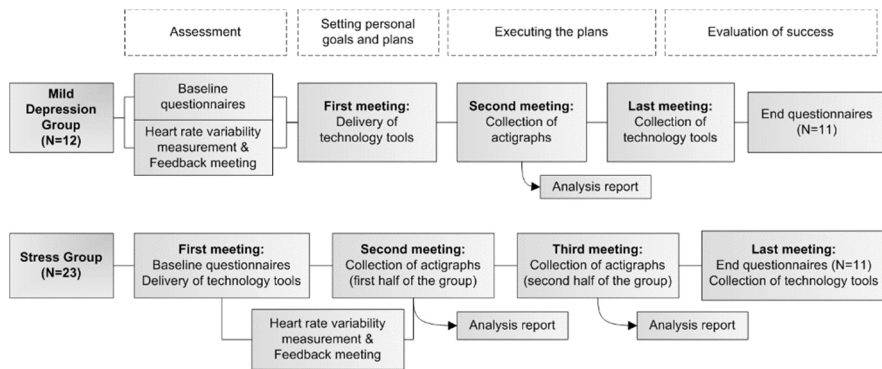


Figure 8. The P4Well intervention process (Kaipainen et al., 2010).

Technology tools were delivered to the participants during the first group meeting. The toolkit consisted of a mobile phone with three preinstalled applications: a pedometer, a heart rate monitor and credentials to a web portal called GoodLife (“Hyväksi” in Finnish). The web portal was designed and developed specifically for the P4Well intervention, whereas the other tools were commercial solutions. The three mobile applications were a wellness diary (Mattila, 2010), an adaptive fitness coaching application and an audio-based relaxation application. In addition to the tools that were at the participants’ disposal throughout the study, actigraphs were used for approximately one month for monitoring sleep quality and quantity. Due to the small sample size and short duration of the intervention, the heart rate variability measurements and actigraphy were used only as intervention components instead of outcome measures.

The results of the RCT showed that the intervention had positive effects on several psychological measures, including self-rated health, psychological symptoms and self-rated working ability. Depressive symptoms decreased more in the intervention group than in the control group (marginally significant group by time interaction for BDI, $P=.072$). Positive impact was also observed in process measures of burnout and job strain such as cynicism and over-commitment. All the participants in the Mild Depression group reported that their well-being had improved because of the intervention. The most common improvements were increased motivation, decreased stress and increased exercise. Almost all participants took at least one of the offered technology tools into active use. The total professional time used per person during the intervention period was 44 minutes, meaning that the intervention was also cost-effective.

Different needs and interests were apparent between the Mild Depression group and the Stress group, which probably influenced their adherence to the study and their technology preferences. A comparison of the two groups shows that the dropout rate in the Stress group was much higher than in the Mild Depression group: 12/23 participants dropped out of the Stress group before post-intervention measurement, vs 1/12 from the Mild Depression group. In addition to

different needs, it is possible that the participants in the Stress group were simply extremely busy because they were entrepreneurs. Among those who remained in the study, the pedometer and the mobile wellness diary were the most favoured tools in the Stress group, whereas participants in the Mild Depression group favoured the relaxation application.

The web portal was used less actively than the mobile applications, and it suffered from usability issues so its full potential was not tapped. Several respondents also stated that they were reluctant to spend time in front of a computer outside of work. The portal was mostly used in the beginning of the study period, whereas the mobile applications were used throughout the intervention. This was in fact quite in line with their intended usage, since the portal served mainly as an information source and the mobile applications as tools for daily self-management.

The P4Well intervention appeared to provide flexible solutions for different needs, but the way it was implemented also placed a high cognitive burden on already stressed participants. Many said they lacked time to familiarize themselves with all the technology tools. The results suggest that a more gradual introduction to technology tools and emphasis on simple and attractive applications could increase the value of technology in supporting stress management skills. Nevertheless, human contact and professional feedback were the most appreciated components of the intervention, indicating that personal interaction had the most impact despite all the technologies.

5.4 Designing for behaviour change

5.4.1 Iterative design of an online stress management program (Study V)

The online GoodLife portal (“Hyväksi” in Finnish) was originally developed to serve as a central information resource of the P4Well technology toolkit (see Studies III–IV) and to provide CBT- and ACT-based exercises the user could perform to improve stress management skills (Happonen et al., 2009). The aim of Study V was to identify areas of improvement in order to make the portal better suited to independent use. The study delineates design principles and lessons learnt for other designers of health-promoting applications so that they can avoid potential pitfalls.

Study V utilized the user experience and usage data for the portal gathered in Studies III and IV. In addition, a small RCT with 20 women in the intervention group yielded data for the purposes of this study. The RCT lasted from autumn 2009 to spring 2010 and its primary outcome results are still unpublished. However, its study design was similar to Study III and thus the user experience data were included in this qualitative analysis of design factors, yielding a total sample size of 55.

The qualitative content analysis focused on the open feedback provided by the participants in the user experience surveys. Recurring themes were identified in the responses and categorized using a thematic coding approach. Usage activity was calculated from log entries to summarize the total number of interactions with the portal and its specific sections. Log entries of portal usage were explored

5. Summary of the studies

manually for selected participants with different activity levels to assess general usage patterns.

Based on the combined user experience findings and usage patterns, areas of improvement were identified. Behavioural theories, persuasive design principles and design guidelines for health-promoting applications were reviewed, and the suggestions for concrete improvements were formed. The main findings and the solutions addressing the underlying issues are presented in Table 9. These solutions were implemented in the portal, which underwent a major overhaul in terms of information structure and user interface. The most significant change was the redesign of the front page into a dynamic page that displayed content based on the user's activity in the portal and the approximate stage of the behaviour change.

Table 9. The main identified weaknesses and their solutions.

Finding	Underlying issue	Suggested solutions
It was hard to find personally relevant material	Lack of guidance	Clearer and guided structure Better tunnelling and tailoring Emphasis on personal motivation in goal-setting and planning
The importance of goal-setting was not emphasized	Inadequate goal-setting and follow-up functions	Goal-setting as a central function Reminders of goals Prompted follow-up Rewarding of achieved goals
Users got lost on the website	Redundancy of content in different modules Lack of guidance	One main tunnel with tailored content to cover all themes Clearer and guided structure
Users were reluctant to spend time using a computer	Intervention lacked engaging and motivating features	Reduce text, add graphics Lighten structure Reminders of goals

5.4.2 Design guidelines for mobile stress management applications (Study VI)

The aims of the one-month field study reported in Study VI were twofold. First, the study assessed the feasibility of the mobile Oiva application for training stress management skills. This served as a pilot study before the mobile intervention was evaluated in a randomized controlled trial. Second, the design decisions made in Oiva were scrutinized based on individual interviews with the aim of proposing tentative design guidelines for mobile stress management interventions.

Oiva is an ACT-based mobile application for training stress management skills (Ahtinen et al., 2012). It consists of 46 small experiential exercises that target the different ACT processes of being present, self as context, cognitive defusion, acceptance, values and committed actions. The exercises are divided into four modules.

The field study was carried out in May–June 2012 and the participants were recruited via email to university staff. Fifteen voluntary participants (Table 10) interested in stress management were provided with mobile phones with a preinstalled Oiva application and encouraged to use the application every day. Their well-being was assessed at baseline and after one month with psychological measures. After one month, usage logs were collected from the mobile phones and interviews were carried out. The content of the interviews was categorized with thematic coding. Log files were available from 14 participants.

Table 10. Demographics of participants in the Oiva field study.

Number of participants	15
Gender (female/male)	9/6
Age	5 were <30 years 5 were 31–40 years 5 were >40 years
Stress (scale 1–5) ¹	3.1 (0.2)
Satisfaction with life (scale 5–35) ¹	23.1 (1.3)
Psychological inflexibility (scale 7–49) ¹	17.2 (1.5)

¹ Standard error of mean in parentheses

The results validated the acceptability of the Oiva application and confirmed its feasibility for stress management among stressed office workers. According to the log files, the participants used the application actively on average every third day, with a total average usage time of 3 hours and 12 minutes (range 56–339 minutes) during 34 days (range 26–46 days). Their stress decreased ($z=3.00$, $P=.003$) and life satisfaction increased ($z=2.32$, $P=.02$) during the study period. Most of the participants (11/15) felt that one month was too short a period to go through all the exercises and establish fundamental lifestyle changes. Contrary to expectations, the participants rarely used the application in mobile situations, with the exception of simple relaxation and mindfulness exercises. These short and simple exercises were considered the easiest to perform in their busy everyday lives. They also provided immediate benefits by allowing participants to take relaxing and invigorating breaks in the midst of their daily hassles.

Table 11 summarizes the tentative design guidelines that were derived based on the study findings. The guidelines could have implications in terms of the way behaviour change techniques (Michie et al., 2013; see also Table 1) are implemented in the intervention, and potentially relevant BCTs are thus also mentioned in the table. Albeit the sample was small and thus the findings may not be generalizable, these guidelines can serve as a starting point for further studies on mobile applications for stress management and mental well-being. From the ACT point of view, learning the skill of being present (i.e. mindfulness) appeared to be well transferable to a mobile intervention, but supporting the more challenging psychological processes of acceptance may require a different approach.

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Table 11. Tentative design guidelines for mobile stress management applications derived from the findings of the field study. Potentially relevant behaviour change techniques (Michie et al., 2013) are also listed for each guideline.

Guideline	Description	Relevant BCTs
Provide exercises for everyday life	Short and simple exercises that can be performed amidst daily hassles and do not require much thought or preparation. These exercises provide immediate benefits such as calming down quickly.	<i>Instruction on how to perform a behaviour:</i> Brief, simple, and interactive. <i>Demonstration of the behaviour:</i> Short audio clips can work well. <i>Conserving mental resources:</i> Exercises that can be done almost anywhere.
Find proper time and place for challenging content	Exercises for challenging stress management skills such as values or acceptance require concentration and effort and are thus not suitable for every situation. This could be solved by providing the users with an option to filter and choose exercises based on their needs and situation or using context-awareness to detect suitable moments.	<i>Behavioural practice/rehearsal:</i> Challenging exercises could be targeted in a peaceful context or time, when the skill is not needed at that moment. <i>Graded tasks:</i> Stress management exercises could be graded based on their challenge level.
Focus on self-improvement and learning instead of external rewards	Emphasis on intrinsic motivation in learning stress management skills and experiencing the benefits in real life. Engagement with the content rather than the application.	<i>Information about emotional consequences:</i> Express the benefits of exercises to mental well-being. <i>Pros and cons:</i> Personal values as rationale for behavioural changes.
Guide gently but do not restrict choice	Recommend the next steps while still allowing autonomy and freedom of choice.	<i>Feedback on behaviour:</i> Unobtrusively show the recommended next steps based on prior activity.
Provide an easy and flexible tool for self-reflection	Reflection after exercises is essential to learning. Structured tool for reflection could work better than a free-form diary.	<i>Monitoring of emotional consequences:</i> Prompt assessment of feelings and changes in them. <i>Comparative imagining of future outcomes:</i> Give a guided structure for reflection. <i>Valued self-identity:</i> Connect reflection to personal values.

5.5 Summary of the contributions of the studies

Before moving on to discuss the findings and their implications, Table 12 briefly summarizes the main contributions of the studies to the literature.

Table 12. Summary of the contributions of the studies.

Study	What was known?	What was asked?	What were the findings?
I	Small-changes approach to dietary behaviours shows promise at population level. Online weight loss programs can be efficacious.	1) Can an online application engage people to carry out small changes? 2) Does it lead to healthier eating or weight loss?	1) Low adherence: 9% of 2,053 users could be classified as active users. 2) Small but significant weight loss among those whose adherence was high.
II	Adherence rates to free online and mobile applications can be as low as 1%, and adherence is usually lower outside RCT settings.	1) Can a mobile application engage people to dietary self-monitoring without outside intervention? 2) What are the characteristics of active users?	1) High reach but low adherence: 3% of 189,770 users used the application for more than a week and took more than 10 pictures. 2) Initiating use during work-days and daytime was associated with higher adherence.
<p><i>Summary of Studies I and II: Attrition from the two freely available applications was very high, which is in line with the findings of prior studies. The mobile application reached many more users than the online program but its impact appears lower, which may be related to the more extensive use of behaviour change techniques in the online than the mobile application.</i></p>			
III	Scalable and cost-effective interventions are needed to prevent stress-related problems. Online treatments have proven effective in mental health.	Is an intervention that uses technology tools to support a group-based treatment for stress management feasible and acceptable?	The intervention had a positive impact on well-being and working ability. All tools had active users. Human contact and professional feedback were highly valued.
IV	Technology tools such as online and mobile applications can help people in the daily management of their well-being.	1) Do technology tools help participants to improve their well-being? 2) Which factors aid or hinder the usage of tools?	1) Participants were able to find relevant tools for their personal needs. They reported reduced stress and improved understanding of their own health. 2) Simple and easy-to-use tools were used and valued most.
<p><i>Summary of Studies III and IV: Brief group intervention that was supported with technology tools had a positive impact on well-being among middle-aged stressed participants. The most useful intervention components included simple and easy-to-use tools as well as personal feedback from a professional. Human contact may be necessary for commitment to behavioural changes, but technology tools could be used to optimize the use of professionals' time. Freedom to choose personally relevant tools may enhance user acceptance but increase the cognitive burden if no personalized guidance is given.</i></p>			

5. Summary of the studies

V	Technology tools used to support a group intervention can be useful, but independent use may set different requirements for the tools.	<p>1) Which improvement needs are found in an online stress management application for adults?</p> <p>2) How should online stress management applications be designed?</p>	<p>1) Adherence was low due to lack of guidance, lack of interaction and lack of emphasis on personal goals.</p> <p>2) Goal-setting and a review of goals are generally effective techniques. Interactivity and guided structure could increase user engagement.</p>
VI	ACT interventions are effective in stress management. Mobile applications could integrate training of stress management skills into everyday life.	<p>1) Is an ACT-based mobile application feasible in training stress management skills?</p> <p>2) What are the design implications for mobile stress management applications?</p>	<p>1) The application was used actively. Users' well-being and mindfulness skills improved.</p> <p>2) Provide simple exercises for immediate benefits; target challenging exercises for specific context; focus on intrinsic motivation; guide but preserve freedom of choice; facilitate self-reflection.</p>
<p><i>Summary of Studies V and VI: Breaking the application down into easily digestible pieces and concrete, interactive exercises can enhance user acceptance and engagement among stressed adults. A clear structure and guidance while maintaining freedom of choice may work best in stress management. Simple exercises are suitable for mobile situations while challenging content requires quiet moments.</i></p>			

6. Discussion

The objective of this thesis was to gain new knowledge on: 1) large-scale usage, 2) objective and subjective benefits and 3) design principles of online and mobile applications for stress management and healthy eating. To achieve this objective, quantitative and qualitative evaluation methods were employed both on commercially available and self-designed applications with diverse settings and populations. This combination of interdisciplinary studies provides unique insights into preventive applications that can benefit both research and practice. The following synthesises the findings from the studies and discusses their implications in relation to the existing body of knowledge.

6.1 Main findings

6.1.1 Large-scale use

Studies I and II assessed the large-scale use of two healthy eating applications in an attempt to understand how online and mobile applications are used in uncontrolled real-world settings. Attrition from the two freely available applications was very high: only 9% of the registered participants in NMEC (Study I) and 3% in the Eatery (Study II) could be classified as active users. These low levels of adherence are typical of free online or mobile applications. Prior observational studies have found adherence rates as low as 1%, and adherence appears to be generally lower outside RCT settings (Kelders et al., 2012). In fact, high attrition may be a natural occurrence in self-help applications (Eysenbach, 2005). It should be noted that prior studies of online interventions have used varying definitions of adherence: some have measured adherence as the completion of all program modules and others as a function of logins (Christensen et al., 2009; Kelders et al., 2012).

Studies I and II used different definitions of adherence due to their different behaviour change techniques, but both measures were composites of the total usage period and task completions (Donkin et al., 2011). The mobile Eatery application was intended for daily use for dietary self-monitoring, whereas the interactions with NMEC were scheduled to take place on a monthly basis. “Active use” in Study I meant a minimum usage period of more than two months, whereas the

definition was much more lenient in Study II at ten days or more. From this perspective, NMEC was more successful in engaging users in the program.

Different adherence rates may be explained by the different behaviour change techniques used in the applications (Kelders et al., 2012). NMEC relied on small concrete changes to guide habit formation and changing environmental cues, whereas the Eatery focused on self-monitoring and peer feedback. NMEC provided information on the small-changes approach and used goal-setting as a technique, whereas the Eatery did not ask the user to set any explicit goals. Hence, the Eatery users who had no external instruction about the application might have been unclear about its purpose and intended usage and quit the application after one or two tries. The ambiguous “fat-fit” scale for rating food healthiness may also have reduced the application’s perceived credibility, which appears to predict usage intention (Lehto & Oinas-Kukkonen, 2014). In contrast, the NMEC users knew they were expected to carry out the changes for one month and then return to report their success. Adherence in the Eatery could have been higher if the rest of the techniques from the control theory (goal-setting, intention formation and review of goals), which appear to be effective in healthy eating interventions (Michie et al., 2009), had been used. Furthermore, NMEC users could opt to receive weekly or monthly reminders, which usually tend to increase adherence (Christensen et al., 2009).

The small-changes approach has been studied relatively little prior to NMEC in online or mobile applications for healthy eating. Daily Challenge is an online well-being program in which participants receive daily suggestions of small actions related to well-being (Poirier & Cobb, 2012). The concept is fairly similar to NMEC but the actions have a broader focus and a new action is given each day. The recent evaluation of Daily Challenge showed that having social ties in the program was associated with improved well-being (Cobb & Poirier, 2014). Social support has also been found to predict adherence in online interventions (Brouwer et al., 2011; Cugelman et al., 2011). In the Eatery, the number of comments and likes, i.e. additional feedback from peers, had an association with adherence, although it could be argued that users who used the application for a longer time also had more time to form social ties, and this would hence be an effect rather than a cause. Qualitative studies about application usage could shed more light on this.

Despite the higher user engagement, the total user base was surprisingly small in NMEC, little more than 2,000 users in two years. In comparison, the Eatery attracted almost 190,000 users in six months. This drastic difference in the number of users could reflect the evolution in healthy eating applications over the past years. A more likely explanation is the effect of the delivery channel and promotion (Bartholomew et al., 2011). NMEC was offered online during 2007–2009 with very little promotion (mainly the *Mindless Eating* book and its accompanying website), whereas the Eatery was published in the App Store in 2011 and featured in press and social media (Massive Health, 2011). Thus, the Eatery received more visibility and was easy to download and try out, whereas the participants interested in NMEC probably had to purposely seek it out after learning about the book. The registration process was also lengthier in NMEC, which may have screened out

participants who had merely a fleeting interest in the program, since low intention to use may change into no intention if it takes time to take the application into use (Kaasinen, 2005). Furthermore, it must be noted that the data set analysed in Study I did not contain the first six months that NMEC was available in 2007. This initial period was used to calibrate the program and to run experiments with a restricted sample of participants (Wansink, 2010), after which the program was opened to public use. It is possible that the public's interest in the program had waned during these six months. Nevertheless, the present advantage of mobile over online applications may be their established delivery channels through trusted application markets.

Neither of the applications required payment and they were thus likely to attract many people who were merely curious with no serious intention or need to start making changes to their eating habits. Obviously, this remains speculative without any qualitative research on user mindsets. Nonetheless, an interesting observation is that the users who first tried out the Eatery in the evening or at the weekend were less likely to continue using it. This could merit further research on the best timing to start the behaviour change process. In the persuasive technology field, the concept of opportune moments suggests that proper timing for the initiation of behaviour change is essential (Lehto et al., 2013). Findings from other studies in this thesis do not offer direct insights into this matter, but the general barriers of "being busy" and "forgetting" emerged in them as explanations for not using the applications or making changes (Studies I and VI). It is possible that dietary self-monitoring by taking a photograph prior to eating is so dependent on conscious effort that it can rarely be kept up for a long time.

To sum up, the two free applications both aimed to make healthy eating easy. Attrition from the applications was high but comparable to other observational studies of freely available applications. The awareness-raising influence of trying out small changes or sporadic self-monitoring could have an impact on the population level, but it is uncertain whether these applications reach those who would need them the most.

6.1.2 Psychological and behavioural effects

All the studies except Study V examined intervention outcomes in some depth. Studies III and IV conducted the most comprehensive evaluation and found an overall positive impact on well-being and benefits connected to application usage. Despite the positive impact, the effects were relatively small and the implementation of the intervention was suboptimal. Technology tools were given to participants with no personalized instructions or tailoring to individual needs or preferences, and while participants were still able to find personally relevant tools, they felt burdened by the sheer number of different tools. In terms of process evaluation, the impact of individual components of the intervention on objective or subjective outcomes was difficult to assess due to the large number of components and the small number of participants. Moreover, the theoretical model behind the

functions of different components had not been thoroughly thought out. The more recent Study VI suggests that the usage of a single application can have an impact on well-being, but the trade-off is that its focus is narrower.

Despite the benefits of technology tools, professional support appeared to be the most important intervention component in Studies III and IV. Participants ranked group meetings and personal feedback from a professional as the most useful elements. Peer support was also seen as useful by some, but it was not exploited fully. The discussion forum in the portal was visited frequently in the beginning even though there was very little discussion. Other researchers have also recognized the challenge of designing peer communities that come to life (Doherty et al., 2012; Kelders et al., 2012). In Studies III and IV, the number of users was definitely too small to achieve the critical mass of discussion forum participants for active discussions. The number of users also influences perceived anonymity and trust (Doherty et al., 2012). People may not want to disclose sensitive issues if the user base is too small or if they do not trust that they will stay anonymous.

It remains an open question whether the technology tools used in Studies III and IV could provide benefits without a group intervention. The feasibility trial in Study IV had relatively high attrition, possibly because the participants were entrepreneurs and thus quite busy, and they also had little contact with researchers. This higher attrition outside an RCT setting is, again, in line with the findings of prior studies (Kelders et al., 2012). Professional support is generally associated with higher adherence and outcomes (Kelders et al., 2012), but scalable applications are forced to keep it to a minimum. Nonetheless, busy people may be the ones in most need of an intervention and may respond best to simple solutions that provide immediate benefits, as the findings of Studies III and IV imply. Furthermore, the findings of Study VI indicate that one initial group meeting could be enough to motivate the use of the application, especially if reminders to enhance adherence are incorporated (Webb et al., 2010; Kelders et al., 2012). In addition, the weight loss outcomes among participants with high adherence in Study I indicate that small but significant changes in health outcomes can be achieved through an online application even with no contact with professionals or peers. In Study II, the impact on eating behaviour could not be reliably estimated, and there were some indications that the most active users may already have been healthy eaters or at least paid attention to their eating choices.

The findings of Studies III and IV bear similarities to an RCT study conducted in an employee health promotion setting. The one-year trial utilized a similar set of technology tools combined with five group meetings based on TTM and ACT, after which participants were encouraged to use the offered tools for daily self-management (Mattila et al., 2013). The study found that 30% of participants used the technology tools actively throughout the year, adherence was associated with better weight-related outcomes, and simple tools were appreciated most (Mattila et al., 2013). Smooth integration into daily life appears to be more important to long-term adherence and outcomes than multitude of options (Ahtinen et al., 2009; Mattila et al., 2013).

To sum up, technology tools appear to provide additional benefits to well-being when used to support a group intervention or when users are participants of a research trial. The real-world impact of the use of stand-alone applications studied in this thesis remains unclear.

6.1.3 Design principles

Studies V and VI focused on qualitative evaluation of design factors in stress management applications. Both studies suggest that breaking the intervention application down into short sections and concrete exercises results in better user experience and involvement regardless of the technology platform. Other studies have also found that people who struggle with mental issues lack the capacity and desire to read long passages (Doherty et al., 2012). Study VI formed five distinct design guideline propositions that bear some similarities to earlier guidelines (Doherty et al., 2012; Morris, 2012) but are more concrete and specific to stress management or mild mental health problems. Given the small samples and the limited amount of empirical data, these design implications or design hypotheses need to be tested further (Hekler et al., 2013).

The series of Studies III–VI illustrate how the development process of complex interventions (Craig et al., 2008a) often needs to backtrack from feasibility and pilot trials and return to the design stage. The GoodLife portal was originally designed for the P4Well intervention (Studies III and IV) and found not to be well suited to independent use. Its design was revamped, resulting in a simplified and guided structure with the focus on goal-setting (Study V). As technology developed, smartphones became a feasible delivery channel for stress management interventions and, thus, Oiva (Study VI) was designed as the spiritual successor of the GoodLife portal using similar design principles and rooting the theoretical basis more firmly in ACT. Both applications maintained the principle of freedom of choice, which was appreciated by participants of Studies III–IV. Having the freedom to choose personally relevant content and tools may lead to better adherence and outcomes than being forced through a linear program, especially in preventive programs that target mild symptoms (Doherty et al., 2012).

The main barriers to the use of technology tools in Studies III and IV were their complexity, usability issues and low personal relevance. The barriers may be partially similar to those in healthy eating applications. In Study I, participants also preferred habit changes that were easy and simple, and common reasons for low adherence included irrelevance or inapplicability of habit change suggestions. Although the application in Study I used tailoring, it was done on a relatively superficial level and did not account for the personal situation or psychological needs. Theory-based tailoring of interventions could have improved adherence and effects in all the studies (Webb et al., 2010; Cugelman et al., 2011).

One of the elements generally associated with effectiveness is the use of multiple behaviour change techniques in the intervention (Webb et al., 2010; Cugelman et al., 2011). A comparison of the behaviour change techniques employed in the

applications in Studies I–VI (Table 6) shows that the number was lowest in the Eatery (Study II), in which only five techniques could be identified. The number of techniques ranged between 12 and 15 in the other applications. Furthermore, all of the other five applications used goal-setting and problem solving techniques. Although the influence of the techniques cannot be directly compared between studies, the inclusion of additional techniques from control theory could have increased adherence to the Eatery, as argued earlier in Section 6.1.1. Goal-setting, in particular, is advocated as a generally effective technique (NICE, 2014). Another effective element, social support (NICE, 2014), was present in Studies II–IV but its utilization in practice was quite low.

To sum up, the lessons learnt here can be used by designers to avoid potential pitfalls. Design principles should be drawn from psychological theories and their implementation adapted to the technological delivery channel. Real effort should be put into participatory user-centred development. NICE guidance for individual behaviour change lists effective techniques and gives recommendations that help focus attention on the context in which the application will be used (NICE, 2014). In addition to the design implications drawn in Studies V and VI, the elements generally associated with effectiveness in online and mobile interventions (see Table 2) should be considered when designing new applications. Process evaluations to identify specific influential elements are also advisable.

6.2 Implications for research

Several suggestions for further research emerge from the studies. First of all, there is a gap to bridge between research and the real world in terms of what is available and used, and what is being studied. Even though application markets are full of health and fitness applications, few evaluations of them exist in scientific literature, and very few applications developed by researchers have been released to the general public. Studies conducted in RCT settings often have poor external validity and generalizability and the real-world applicability of the interventions is thus uncertain (Neville et al., 2009). Hence, to determine the real societal impact of the applications, more work should focus on **how to reach the real target populations** and not merely volunteers of RCT studies or convenience samples. To achieve this, quick translation of innovations into research and practice through collaboration between researchers and commercial designers may be the best route (Pagoto & Bennett, 2013). In this “team science” approach, researchers ensure that behaviour change techniques are properly implemented to produce meaningful health outcomes, whereas commercial designers ensure that applications are usable, engaging and appealing. Intervention development supported by CeHRes framework and/or Intervention Mapping also puts a stronger focus on adoption and maintenance (van Gemert-Pijnen et al., 2011).

The reasons for the low adherence outside RCT settings are not yet well understood, and the efficacy of freely available applications is difficult to assess. The high attrition rates of NMEC and the Eatery are in line with prior research that

suggests that adherence is lower in community settings (Christensen et al., 2009; Kelders et al., 2012). Qualitative studies on user mentalities could help explain why adherence is so low in freely available applications. Participants in RCT settings are usually volunteers, undergo screening procedures and have contact with research personnel, so it is understandable that they are more likely to stay in the study. However, community users who happen to find an online or mobile application that fits their needs may not have been ready for treatment otherwise, and it is possible that even short engagement with the application provides benefits (Christensen & Mackinnon, 2006). One approach to combine real-world use and efficacy studies could be **hybrid trials** that conduct mass trials to gather quantitative usage data and small-scale controlled studies to assess the efficacy and gather qualitative explanatory data (McMillan, 2012).

For a meaningful comparison of the adherence outcomes between studies, **adherence and attrition should be defined in a more consistent manner** (Kelders et al., 2012). A composite measure based on usage time, task completion and interaction with the system may work best (Donkin et al., 2011). Nevertheless, it should be noted that the intended usage patterns and expected engagement with the application may vary greatly, as can be seen when comparing NMEC, the Eatery, the GoodLife portal and Oiva. The Eatery and Oiva may have required almost daily use in the initial phase in order to achieve their purpose, whereas NMEC and the GoodLife portal were intended for more sporadic use. These differences in intended use need to be accounted for when comparing adherence rates. Furthermore, iterative development and testing of applications make it possible to detect how changes that are made to the application influence adherence and behaviour. Process evaluation and measuring of different adherence components have become easier with online and mobile analytics tools (Crutzen et al., 2013).

The studies in this thesis presented different approaches to health behaviour change in different settings and domains but with the common aim of making it easy for a person to change his or her behaviour. The NMEC study provides suggestive evidence that the small-changes approach can help in weight management, but more studies with more rigorous methods are warranted. In stress management, P4Well and Oiva also base themselves on the philosophy of daily actions to change lifestyles in the long term. This seems to be feasible. These studies have served as an inspiration for “Mindless Change”, a mobile application that combines small daily changes with a learning theory framework (Vainio et al., 2014). The small-changes approach fits well with the constructive learning approach in the education field. Expanding understanding of health behaviour change to **educational technology frameworks** merits further study because health behaviour change is, in essence, a learning and skills training process (Aronson et al., 2013). Social support is a related area in need of more research. Although this area was barely touched in this thesis, the social support needs for healthy eating may be different from those for sensitive stress-related issues.

The adequacy of existing behavioural theories for the development of **dynamic interventions** that use technology has been questioned by some researchers

(Riley et al., 2011). Existing theoretical constructs and models of behaviour change were mostly developed before the era of smartphones. New methods of data collection and intervention delivery enabled by mobility can benefit the development of behavioural theories (Hekler et al., 2013). Closer interaction between behavioural science and HCI fields can provide valuable insights into people's behavioural patterns and mentalities in their everyday life through analysis of their mobile or online behaviour (Poole, 2013). The temporal context of the initiation of application usage could merit further study, as observed in Study II. Moreover, the "idle time" in phone usage could be leveraged by stress management or healthy eating applications (Poole, 2013).

Multicomponent interventions using several technology tools and behaviour change techniques are challenging to develop. Sometimes the problem is not the inadequacy of theories but the improper or incomplete use of theory in application design (Hekler et al., 2013). Prior research has found that multicomponent theoretical frameworks may be more difficult to translate into practice, and the studies utilizing such an approach have often been "theory-inspired" rather than "theory-based" (Michie & Abraham, 2004; Guillaumie et al., 2010). Key components of a theory are sometimes omitted or misrepresented (Lippke & Ziegelmann, 2008). This was also the case with the P4Well intervention, which was based on TTM and ACT but only used the theoretical constructs superficially in the complex intervention development. Thus, it lacked theoretical fidelity, which could have helped to explain which components of the intervention did or did not work (Michie & Prestwich, 2010). The use of theory and theory-based behaviour change techniques is generally associated with better outcomes across behaviours, but it is worth keeping in mind that applying single techniques without a coherent intervention model seldom works (Greaves et al., 2011). Thus, using **systematic approaches** such as UK MRC guidance for complex interventions and Intervention Mapping in intervention development and evaluation is highly recommended and even required to enable evidence synthesis (Craig et al., 2008a; Bartholomew et al., 2011; Greaves et al., 2011). For application design, systematic approaches have also been developed, and one of the most prominent in the behaviour change field is the Persuasive Systems Design model (Oinas-Kukkonen & Harjuma, 2009; Lehto, 2013).

Considering how eating, stress and general well-being are intertwined, the integration of **multiple behaviour changes** into one intervention is worth studying further. From the ACT perspective, healthy behaviours can be considered meaningful actions that are in line with personal values. This is the approach taken in a recently finished RCT study targeting stressed and overweight adults with Oiva as one intervention arm of the study (Lappalainen et al., in press). Although the results of the RCT have not been published yet, the ACT approach has shown promise in weight management in prior studies (Lillis et al., 2009; Lillis et al., 2011).

Finally, research on health-promoting technologies needs to speed up to ensure findings are still relevant at the time of their publication. For example, NMEC was launched at the end of 2006 and the results were published in 2012. This means that the online program was already outdated by the time the results were

public. With the Eatery, the progress was faster, but the delay between publishing the application and the findings was still more than two and half years. The **agile science approach** with iterative development and publishing of results as well as alternative designs for RCTs is needed to keep up with technology advancement (Riley et al., 2013). Mixed methods research often provides the most comprehensive findings but is challenging to conduct, which is why best practices for mixed methods research have been developed and should be followed (Creswell et al., 2011).

6.3 Implications for practice

Are the applications analysed in this thesis effective, acceptable and feasible for use in health promotion in the real world? The findings suggest that technology tools can have an impact on stress management skills and eating behaviours, but they may not be sufficient on their own. It is likely that the people in the greatest need of an intervention will not find the applications on their own. Hence, practitioners and health promotion professionals need guidance on which online and mobile applications are effective and can be recommended to people (Pagoto & Bennett, 2013). Even though people ultimately have the main responsibility for their own health, the person struggling with stress or healthy eating is not solely responsible for identifying solutions. The following discusses how the applications and approaches evaluated in this thesis can be used in practical settings.

Small, realistic and incremental changes in eating behaviours such as those pursued in NMEC could be feasible especially among low-income populations that may not be able to afford major changes in dietary intake or be willing to make them (Siek & Maitland, 2010). However, the presentation and approach should be adapted to the target population (Siek & Maitland, 2010). NMEC attracted mostly female, white, well-educated participants, possibly due to its academic look, and people who found NMEC probably started looking for it because of the *Mindless Eating* book (Wansink, 2006). While NMEC is no longer available, the mobile “Mindless Change” application, which uses the small-changes approach combined with learning theories, is currently in development and the aim is to make the application publicly available (Vainio et al., 2014). As for dietary self-monitoring, the Eatery was taken off the App Store in spring 2013 when its developer company was acquired by another company. Since then, other applications that use photography for self-monitoring of dietary intake and crowdsourcing to infer healthiness ratings for food pictures have been developed (Stumbo, 2013). The photography method for dietary self-monitoring can also be used without a specific application by simply taking pictures of foods with a mobile phone camera.

The stress management applications have been taken into use in the real world. A Finnish insurance company launched the improved version of the Good-Life portal in 2011 as a free service to its clients and the service is still available as of April 2014. Oiva was published in Google Play and the App Store in October 2013 as a free application, and data on its usage are accumulating. Its web-based

version has been developed in cooperation with the Finnish Association for Mental Health and it was launched in February 2014. Oiva is being studied in two RCTs and also in real-world contexts (e.g. workplace, high school). The reach of the application is currently limited to Finnish-speaking populations but it would be relatively easy to translate it into other languages. The P4Well intervention concept can be adapted to other settings in a relatively straightforward manner, although care should be taken that the personnel who hold the group meetings also have a good understanding of the technology tools used to support the intervention. Analysis of the behaviour change techniques used in the tools and connecting them to the needs and preferences of target users is also warranted.

The high attrition rates observed in the freely available applications are a reason for concern, but they are not necessarily a sign of a lack of impact. No-cost applications are likely to attract many people who try out the application out of curiosity but have no real need for it, and those who stay in the program may be the ones who benefit most from it. For instance, one study examined community users of an online intervention for depressive symptoms and found higher adherence among users whose depression or anxiety symptoms were more severe (Batterham et al., 2008). The lower dropout rates from RCTs than from freely available applications (Christensen et al., 2009; Wanner et al., 2010; Kelders et al., 2012) are understandable considering that participants in RCT studies are usually pre-screened volunteers who are motivated to take part in scientific research (Kelders et al., 2012). However, community users who happen to find the online or mobile application may not be ready for treatment otherwise, and it is possible that even short engagement with the application provides benefits (Christensen & Mackinnon, 2006). Moreover, face-to-face health services also have high attrition rates and online/mobile interventions should be compared with them to be fair (Christensen et al., 2009). Increasing commitment by requiring payment to the service does not seem to guarantee success either. An analysis of commercial weight loss program participants who paid for their subscription found that non-usage attrition was still fairly high, only 30–35% of users were active at the end of their subscription period of 12 or 52 weeks (Neve et al., 2010).

When interpreting the findings from RCT studies, it is worth keeping in mind that real-life usage may differ from the RCT setting. The comparison of adherence between RCT participants and community users in the P4Well study supports this notion, since attrition was higher among community users. Other studies have also found differences between participant behaviours inside and outside RCT settings. For example, one study comparing community users and RCT participants of a physical activity website found that reminder emails did not increase adherence among community users although they were effective for trial participants (Wanner et al., 2010). Furthermore, in contrast to findings by Batterham et al. (2008), a review of RCT studies on depression and anxiety websites associated adherence with lower depressive symptoms (Christensen et al., 2009). This may indicate that people with severe symptoms may lack the capacity to participate in a research trial but be willing to try out an application on their own. In any case, applications should be simple, immediately useful and easy to integrate into everyday routines.

People have many things going on in their lives in addition to using health-promoting applications, and their interest is likely to fade despite all the efforts to design for engagement. This begs the question: is it even necessary to use the applications for a long time? Perhaps it depends on the behaviour change techniques used in the application and the processes it intends to support. Some participants of NMEC said that increased awareness of eating habits was more important than the exact changes. Then again, one month was not enough to go through all the content for several of the participants in the Oiva study. It could be argued that the behaviour change principles in NMEC and the Eatery could be learnt relatively quickly and that there may thus not have been any need to continue using them for a long time, whereas Oiva contained sections such as values clarification that required a great deal of thought and reflection. Nonetheless, it might have been possible to transfer some of the skills learnt with the application to daily habits even after discontinued application use.

In the end, the societal impact of research-based applications remains small unless their uptake, usage patterns and scalability are tested in the real world. The RE-AIM framework would be useful in assessing reach, effectiveness, adoption, implementation and maintenance of applications (Glasgow et al., 1999; Kohl et al., 2013). Furthermore, greater practitioner and end-user involvement in the design process would help avoid a mismatch between technology and the designated context of use (Van Velsen et al., 2013). Stakeholders who are to use and promote the applications in their daily practice need to be engaged already in the planning phase (Bartholomew et al., 2011; van Gemert-Pijnen et al., 2011), as merely opening a website or publishing a mobile app in application markets does not guarantee that the intended target audience will ever find it. Health promotion practitioners are therefore encouraged to take an active stance in eHealth development in order to have more effective and acceptable tools at their disposal. This can result in new, innovative tools that better meet people's expectations and needs (Barak et al., 2008) and are as attractive and engaging as competing activities (Glanz & Bishop, 2010).

6.4 Limitations of the studies

The thesis firmly advocates using design frameworks and systematic approaches such as Intervention Mapping in the development of online and mobile interventions, but such approaches were not consciously used in any of the studies. This is perhaps the most striking limitation and, at the same time, the greatest lesson learnt. Had the studies been designed in a more systematic manner, stronger conclusions could have been drawn from the findings. For example, the specific change objectives or behavioural determinants that the intervention techniques aimed to change were not specified. The relatively opportunistic approach in choosing the applications to evaluate in Studies I and II also weakens the coherence of the work as a whole. Nevertheless, the advantage of this opportunistic and exploratory approach is the formation of a broader picture of the field of health-promoting applications.

The measures used in different studies varied in terms of their validity and scope. Studies I and II only had self-reported data about participant background and health behaviours. Thus, the weight loss results in Study I (NMEC) may not correspond to objectively measured data. Moreover, the “fat-fit” scale in Study II to measure healthiness of eating behaviour was quite ambiguous and prone to subjective interpretation. Gender bias was evident in Study I and typical of most studies of online prevention interventions, which mostly reach female, well-educated, white participants (Kohl et al., 2013). This nevertheless means that the results may not be generalizable to other audiences (Kelders et al., 2013b). Furthermore, in Study II, practically no background information was available on the users, and there is no way of knowing how biased the sample was. Study III used validated instruments to measure psychological outcomes, but the user experience surveys (also used in Studies IV and V) were only loosely based on existing instruments to measure user experience. Grounding the items in the surveys more firmly on the change objectives of the intervention, while at the same time using conventional user experience metrics to improve usability (e.g. Tullis & Albert, 2013), could have made it possible to better understand which intervention components worked as intended and for whom they were suitable. Finally, the adherence measures in terms of application usage lacked granularity in Study I because the timestamps for user visits did not contain the exact date, only the month.

Studies III–VI on stress management applications (P4Well, GoodLife, Oiva) had relatively small samples with volunteer participants, and Study VI was a pilot study with a convenience sample. In study III, gender bias was avoided through recruitment strategies that especially invited men to participate, but unfortunately this resulted in a smaller sample size than expected. Moreover, the power calculations to determine a sufficient sample size for a pilot RCT (Cocks & Torgerson, 2013) were not formally performed. Due to the voluntary nature and small sample sizes of the studies, caution must be taken in generalizing the results. In Study III, randomization was not successful in terms of age and BMI, which could perhaps have been expected given the small sample. In hindsight, the feasibility trial, which was conducted in parallel with the pilot RCT and described in Study IV, could have preceded the pilot RCT in order to test the procedures and weed out usability issues in the applications. Due to time constraints the trials were squeezed together, which is typical but unfortunate in complex intervention research (Craig et al., 2008b). Study VI was a feasibility trial with focus on design factors and as such its results should be considered implications for further studies rather than generalizable findings.

In contrast to Studies III–VI in which the small sample size limits the generalizability, the findings from Study II need to be interpreted with caution for the opposite reason: a sample size of about 190,000 almost invariably yields statistically significant results, even if their practical significance remains small. For example, the association between users’ registration time and their adherence was in practice quite small: 29% of people who used the application for dietary self-monitoring at least a few times registered during daytime, which is not that much higher than

the 23% of those who did not start dietary self-monitoring. Hence, these findings provide an interesting basis for further studies but are not very strong *per se*.

The participants in Studies III–IV and VI were not using their own mobile phones but instead were given separate mobile phones with pre-installed applications. This does not represent the natural setting of mobile use and having a separate device for the applications had an effect on the context and intention of use, as evidenced by the results (participants sometimes forgot to take the phone with them or left it intentionally at home). This is a challenge in feasibility studies of mobile interventions: the researchers have to choose between using extra resources on developing the application for all common mobile platforms or on providing separate phones to participants who do not have a suitable phone model. The third option, which is becoming more feasible, is to develop a responsive web application that can be used on mobiles, but in this scenario the user experience may suffer. It should be noted, however, that in Study II the participants downloaded the Eatery application to their personal phones, but the attrition was still very high.

Finally, it may not be feasible to compare the findings between the stress management and healthy eating domains because the applications under study were at different stages of the development-evaluation process of complex interventions (see Figure 6). The thesis does not include studies that focus on small-scale qualitative trials or RCTs of healthy eating applications or evaluations of large-scale use of stress management applications. Another important aspect to consider is that the healthy eating applications were trialled among an English-speaking audience, and stress management among Finnish people. Attitudes towards food and stress may differ between cultures and thus the findings may not be directly transferrable to other settings.

6.5 Future directions

Where do we go from here? Relatively solid evidence now exists that online and mobile applications, either alone or used to support an intervention, can successfully improve stress management and eating behaviours and perhaps even save healthcare resources if implemented properly. Design factors clearly influence adherence and outcomes, but intervention design encompasses much more than just application features. The next step from application design is to implement, adapt and maintain the technology tools in real-world settings so that they fulfil their promise and truly address the societal problems of chronic diseases and mental ill-being. This thesis has referred to several key publications that provide concrete and actionable recommendations on how to perform “rapid, responsive, and relevant research” (Riley et al., 2013). The interested reader would benefit greatly from seeking out these original publications on research methodology (Hekler et al., 2013; Riley et al., 2013; Glasgow et al., in press) and intervention development frameworks (Craig et al., 2008a; Bartholomew et al., 2011; van Gemert-Pijnen et al., 2011).

The first step is to move from technology design to intervention design and to seriously consider the business context (van Gemert-Pijnen et al., 2011; Crutzen, 2012). Developing interventions and intervention applications that are not based on theory and evidence is a waste of resources (McNaughton, 2012). Nonetheless, a fledgling researcher or designer may feel overwhelmed by the number of different frameworks, each of which uses slightly different terminologies. Perhaps the most important lesson is to define at least some kind of logic behind the design choices. Intervention Mapping (Bartholomew et al., 2011), the CeHReS framework (van Gemert-Pijnen et al., 2011) and the MRC guidance (Craig et al., 2008a) provide good starting points and help to keep the overall picture in mind. The applications presented in this thesis can be characterized as theory-inspired rather than theory-based, and they would have benefited greatly from a systematic approach starting from needs assessment and connecting intervention objectives with theory-based behaviour change techniques. In this sense, Oiva is the most mature of the evaluated applications because it is most firmly rooted in theory.

Researchers need to bravely build bridges between disciplines because intervention research cannot otherwise keep up with the rapid evolution of technology and proliferation of commercial applications (Fiordelli et al., 2013; Riley et al., 2013). This calls for a team science approach in which researchers collaborate with commercial designers (Pagoto & Bennett, 2013) and single case experimental designs to test the feasibility and effects of the applications among different target groups and settings (Dallery et al., 2013). Application development should be done through rapid iterative testing of minimum viable products with the target audience (van Gemert-Pijnen et al., 2011; Hekler et al., 2013; Riley et al., 2013; Glasgow et al., in press).

The focus also needs to be broadened from individual level. Stress management and healthy eating are complex and multifaceted issues, and a systems thinking approach is warranted with problems that require intervention at multiple levels (Best, 2011). A self-organizing and constantly changing world has little use for static interventions that lack feedback loops that enable them to adapt to a person's behaviour. This notion is supported by findings that interventions that use dynamic tailoring to update their output seem to produce more lasting effects than static ones (Krebs et al., 2010). Thus, integrated and multidisciplinary approaches with the focus on action and rapid learning are needed. The next steps of studying the effects and uptake of applications for health promotion could be organizational interventions that require a broader and eclectic evaluation framework (see, e.g., Cox et al., 2007) and mass experiments using application markets as a delivery channel (McMillan, 2012). Online social networks and the social web open up new opportunities for disruptive innovation by individuals themselves (Oinas-Kukkonen & Oinas-Kukkonen, 2013). The challenge is to carry out rapid but rigorous research on efficacy because demonstrating efficacy is the only route to policy impact (Pagoto & Bennett, 2013).

Finally, there is far too little action on the social determinants of health even though knowledge is sufficient. As Maitland et al. (2009) put it: the true challenge of technological intervention tools in the future may be highlighting social inequali-

ties and persuading changes of policies. Designers of individual-focused applications should not be blind to the reality of the everyday challenges of the target population. Online and mobile applications are tools that can address people's needs in innovative and scalable ways, but the first step is to determine the true needs. First and foremost, get to know your audience, and remember that technology is a good servant but a bad master.

7. Conclusions

This thesis has presented six distinct studies on large-scale usage, objective and subjective benefits, and design principles of online and mobile applications for stress management and healthy eating. The studies provide an overview of the field of preventive individual-focused applications for self-management of health and well-being. The main findings are summarized as follows:

- Freely available applications can potentially reach large populations, but their usage is likely to be short-lived unless they are complemented with additional methods such as peer or professional support. It is also unclear whether they reach their intended target audience.
- Technology tools can support daily self-management and contribute to positive well-being outcomes. People appreciate simple and attractive solutions most and applications need to be relevant to people's personal needs and circumstances.
- Preventive applications should be designed to guide without restricting choice and to put the focus on self-improvement and self-reflection. Easy integration into everyday life is essential for sustained use.
- The development and evaluation of technology-aided interventions is interdisciplinary and challenging. Close attention should be paid to proper use of theory and implementation of behaviour change techniques to move the field forward from "theory-inspired" to "theory-based".

These findings give further support to the feasibility and potential impact of applications on stress management and healthy eating. Furthermore, they point out the importance of a systematic approach to intervention development and focus on intervention design rather than technology design. The designers of health-promoting applications need to understand the psychological processes they are targeting and, most importantly, the actual person who is the intended user of the technology. The societal impact of the applications is likely to remain small if target users and other stakeholders are not engaged throughout the development process.

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Appendix 1: User experience survey items in Studies IV and V

The texts in *[square brackets in italics]* describe the organization of the survey.

Usage activity

1. Which of the following devices and applications have you used and how frequently have you used them?

[Answer options for all devices and applications]

- I haven't tried it at all
- I have tried it, but I don't use it regularly
- Once a day or more often
- A couple of times per week
- Once a week
- Less often

[Question about Wellness Diary (with optional open-ended feedback)]

Which of the following sections of the Wellness Diary do you use actively?

- Weight
- Exercise
- Eating; Steps
- Stress
- Smoking
- Alcohol use
- Other

[Question about the GoodLife portal (with optional open-ended feedback)]

Which of the following sections of the portal have you used?

- Good life
- Mood
- Sleep and recovery
- Exercise
- Relationships

[Question about the GoodLife portal (with optional open-ended feedback)]

Which tools have you used?

- Information content
- Questionnaires (e.g. life quality, health, exercise)
- Analysis tools (behaviour, values, barriers, changes)
- Social atom

- Form tools (problem solving, problem analysis)
- Printable self-observation form or exercise diary
- Relaxation or mindfulness exercises

User experiences

[Asked about all devices and applications (with open-ended feedback)]

2. How do you feel about the following statements on a scale of 1-5 (1=Totally agree, 5=Totally disagree)?

- Motivates me to maintain or improve my well-being
- Helps me reach my goals
- Is easy to use
- Has functions that are suitable for me
- Does not give good enough feedback
- I intend to use it also in the future
- Using it causes me stress
- It is useful
- I would recommend it to others as well

3. Choose the three most important devices or applications that are also the most suitable for monitoring well-being: *[Three items checked from a list of devices and applications]*

4. Choose the three devices or applications that are least suitable for monitoring well-being: *[Three items checked from a list of devices and applications]*

5. Which of the following statements describe the features and usage of the portal? How do you feel about the following statements on a scale of 1-5 (1=Totally agree, 5=Totally disagree)?

- Information provided by the portal *[With open-ended feedback]*
 - Information was easy to get
 - Content was useful
 - Information source is necessary
- Questionnaires and analyses *[With open-ended feedback]*
 - Instructions were sufficient
 - Questionnaires and analyses were easy to complete
 - Questionnaires and analyses were useful
 - Feedback was sufficient
 - They contained enough background information
 - They helped to recognize and understand personal problems
 - They helped me to plan lifestyle changes
- Heart rate measurement and Lifestyle assessment & Actigraph *[With open-ended feedback]*
 - Feedback from Lifestyle assessment was useful

- Feedback from a professional was important in understanding the results of the Lifestyle assessment
- Actigraph disturbed my sleep
- I monitored the feedback on actigraph screen
- Feedback report from actigraph was useful
- Messages to professional [*With open-ended feedback*]
 - Messages to professional were easy to send
 - Messages with professional are useful
 - I intend to use them actively
 - Using it causes me stress
 - I would recommend it to others as well

6. What kinds of benefits have you gained from using the well-being services, applications and devices in this pilot?

- Increased amount of exercise
- Weight loss
- Reduced stress
- I have achieved a better state of health
- I have a clearer understanding of my health
- I have a clearer understanding of my fitness
- I have received more information about health issues
- My willingness to improve my health has increased
- Something else?

7. What has been useful in the P4Well study and treatment process? (1=Useful, 5=Useless)?

- Intervention meetings (group meetings led by a psychologist)
- Measurement and feedback (heart rate measurement, actigraph)
- The portal
- Mobile tools
- Personal devices
- Group support

8. Something else? You can present your thoughts freely about the devices and services being used and about how you think or hope that they influence your well-being. [*Open-ended feedback*]

STUDY I

Mindless Eating Challenge
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for changes in a public web-based healthy
eating and weight loss program

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Original Paper

Mindless Eating Challenge: Retention, Weight Outcomes, and Barriers for Changes in a Public Web-Based Healthy Eating and Weight Loss Program

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Abstract

Background: Most dietary programs fail to produce lasting outcomes because participants soon return to their old habits. Small behavioral and environmental changes based on simple heuristics may have the best chance to lead to sustainable habit changes over time.

Objective: To evaluate participant retention, weight outcomes, and barriers for changes in a publicly available web-based healthy eating and weight loss program.

Methods: The National Mindless Eating Challenge (NMEC) was a publicly available, online healthy eating and weight loss program with ongoing recruitment of participants. This volunteer sample consisted of 2053 participants (mean age 39.8 years, 89% female, 90% white/Caucasian, BMI mean 28.14). Participants completed an initial profiling survey and were assigned three targeted habit change suggestions (tips). After each month, participants were asked to complete a follow-up survey and then receive new suggestions for the subsequent month.

Results: In terms of overall attrition, 75% (1549/2053) of participants who completed the intake survey never returned to follow up. Overall mean weight loss among returning participants was 0.4% of initial weight ($P=.019$). Participants who stayed in the program at least three calendar months and completed at least two follow-up surveys (38%, 189/504) lost on average 1.8 lbs (1.0%) of their initial weight over the course of the program ($P=.009$). Furthermore, participants who reported consistent adherence (25+ days/month) to the suggested changes reported an average monthly weight loss of 2.0 lbs ($P<.001$). Weight loss was less for those who discontinued after 1-2 months or who did not adhere to the suggested changes. Participants who reported having lost weight reported higher monthly adherence to suggestions (mean 14.9 days, SD 7.92) than participants who maintained (mean 12.4 days, SD 7.63) or gained weight (mean 12.0 days, SD 7.50; $F=14.17$, $P<.001$). Common reported barriers for changes included personally unsuitable or inapplicable suggestions, forgetting or being too busy to implement changes, unusual circumstances, and emotional eating.

Conclusions: Because the bulk of the free and commercially available online diet and nutritional tools conduct no evaluation research, it is difficult to determine which aspects of a program are successful and what are reasonable expectations of results. The results of this study suggest that online interventions based on small changes have the potential to gradually lead to clinically significant weight loss, but high attrition from publically available or “free” programs still remains a challenge. Adherence to and effectiveness of small habit changes may be improved through further tailoring to individual circumstances and psychological needs.

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KEYWORDS

Adherence; Barriers; Habits; Internet; Self report; Small changes; Weight loss programs

Introduction

Effective healthy eating interventions are needed to reverse the global obesity trend [1]. Most current weight loss programs and diets have failed to produce sustainable changes, partially due to the difficulty of maintaining healthy eating behaviors in an environment that constantly urges people to consume unhealthy food in excess [2]. Furthermore, programs that focus on education about calories and nutritional guidelines may place such high demands on participants' cognitive abilities that long-term adherence will be difficult [3].

Recent research suggests that small and concrete habit changes that gradually lead towards larger lifestyle changes may be the best way to achieve sustainable results [1]. Habit is starting to be considered as one of the most powerful predictors of eating behavior, and habits are mainly cued by situational factors [4]. Simple heuristics that are applicable in a wide variety of situations can help people to modify their automatic responses to food triggers in their environment to form new healthier habits [5]. In this way, healthful choices become activated by cues in the environment without effortful deliberation, intentions, or willpower [6].

The small-changes approach has been successfully embraced by various individuals and policy makers [1], but the challenge for interventions is to provide easy and effective habit change suggestions for each individual. Tailoring interventions to match individual characteristics and needs can lead to significant improvements in their effectiveness and relevance to recipients [7-9]. Dietary counselors can do tailoring in person-to-person interactions, but the resources for individual counseling are limited. The reach of habit change interventions can be best widened to the general population through partially or wholly automated web-based programs. Web-based weight loss and maintenance programs have demonstrated moderate efficacy in behavioral change [9-11], and randomized controlled trials have shown varying outcomes ranging from no weight loss to an average loss of 16.8 lbs (7.6 kg) [12]. Individualized counseling and feedback appear to improve outcomes [13].

The small-changes approach is still a relatively new concept in web-based intervention programs. To our knowledge, only one online intervention thus far has utilized the approach to support participants in making small sustained changes in dietary or physical activity behaviors [14]. The results of a randomized controlled trial showed that this intervention had positive effects on eating habits and the amount of physical activity, but it was no more effective than generic information [14]. Another online intervention, Daily Challenge, sends participants daily suggestions of small actions to improve well-being [15]. Its impact on well-being has not yet been evaluated.

The aim of this research was to evaluate the retention and weight outcomes of an online, tailored healthy eating and weight loss program, National Mindless Eating Challenge (NMEC), and recognize barriers for small habit changes. The NMEC program provides participants a tailored set of habit change suggestions

for each month and offers them a checklist for self-monitoring and accountability [5]. The suggestions are based on findings from laboratory research about eating behavior [16]. Prior pilot trials of the NMEC program indicate that it can result in a slow and steady weight loss through small lifestyle changes that have the potential to become permanent [5].

Methods**Intervention**

The National Mindless Eating Challenge (NMEC) was a publicly available, Internet-based dietary intervention program designed to aid participants in making small, effective eating-related changes in their daily lives [5]. [Multimedia Appendix 1](#) shows the main page of the program. The program was offered passively from December 2006 until July 2009 as a resource to the public who found the program via search engines or hyperlinks or were directed to the program by a member of the research group as a response to their inquiry for assistance in weight management. The move to a new platform in June 2007 offered a more complete capture of data. This study was conducted with participants who were involved with the program for any period of time between July 2007 and July 2009. Participants who signed up in the freely available program completed an initial survey consisting of self-report measures of demographics, physical characteristics, and psychological characteristics. After completing the survey, they selected their initial eating goals (lose or maintain weight, eat healthier, eat more, or help their family eat better) and subobjectives. They were then randomly assigned three different environmental, behavioral, or cognitive suggestions that were relevant to the eating goal and subobjective they had chosen.

The habit change suggestions were selected from a pool of 232 different research-based suggestions, such as using smaller plates at meals, never eating directly from a package, or drinking water with every meal and snack [16]. The suggestions were phrased in an active form (such as "Put down your utensils between bites"). Some suggestions provided a brief explanation on why the change would work (such as "This will allow you to slow down the pace of your eating"). Additionally, the program contained references to the *Mindless Eating* book [17], which details the underlying research and contains similar suggestions for changing one's habits and environment.

After receiving the suggestions, participants were asked to estimate their adherence to the changes and how easy it would be to accomplish each change. To help them with adherence, they were asked to write down potential barriers that could prevent them from accomplishing each change. For each barrier, they were then asked to write down a strategy that would help them overcome this barrier. Participants were encouraged to adhere to the suggestions every day during the following month. To make this easier, they received a printable checklist to check off their adherence to changes on a daily basis. They also had an option to define their own small change they wanted to make

in addition to the three suggestions and could choose to receive weekly reminders.

At the beginning of the following month, participants were sent an email inviting them back to the website, where they completed additional questions and were assigned new suggestions or tips for the subsequent month. The process repeated itself every month. Study procedures were approved by the Institutional Review Board.

Participants

Participants were voluntary individuals who registered on the National Mindless Eating Challenge website between July 2007

and June 2009 and gave their consent for researchers to use their data for the purposes of the study (n=2053). The characteristics of all registered participants and returning participants (those who completed at least one follow-up survey) are presented in Table 1. The proportion of returning participants was 25% (504/2053). The returning participants were slightly older, more educated, and weighed slightly less than nonreturning participants (those who never returned for follow-up surveys after registration). Nonreturning participants were excluded from outcome analyses.

Table 1. Baseline characteristics of participants.

Characteristics	All participants (n=2053)	Returning participants (n=504)	F test, returning & nonreturning (P value)
Age (years) ^a	39.8 (12.80)	42.6 (12.08)	32.737 (< 0.001)
Female ^b	1829 (89)	458 (91)	1.215 (0.270)
White/Caucasian ^b	1840 (90)	463 (92)	3.608 (0.058)
United States ^b	1672 (81)	410 (81)	0.004 (0.951)
College degree ^b	1641 (80)	423 (84)	6.667 (0.010)
Household income < \$50,000 ^b	558 (27)	114 (23)	3.673 (0.055)
Weight (lbs) ^a	172.2 (42.28)	168.9 (37.80)	4.119 (0.043)
Body mass index ^a	28.1 (6.51)	27.9 (6.24)	1.030 (0.310)
Initial eating goal ^b			
Lose weight	1709 (83)	455 (88)	0.601 (0.438)
Maintain weight	106 (5)	24 (5)	0.219 (0.639)
Eat healthier	197 (10)	30 (6)	10.262 (0.001)
Help family eat better	37 (2)	5 (1)	2.478 (0.116)

^a Values are expressed as mean (SD).

^b Values are expressed as n (%).

In addition to the United States, participants were from Canada (11%), the United Kingdom (2%), Australia (0.5%), Germany (0.5%), France (0.5%), and 32 other countries. Most participants (83%) had weight loss as their initial eating goal. Ten percent wanted to eat healthier, 5% wanted to maintain their weight, and 2% aimed to help their family eat better. Four participants did not specify whether they wanted to lose or maintain weight. Eating healthier was slightly more common as an initial eating goal among nonreturning than returning participants.

Measures

Participant retention was measured by the number of monthly surveys participants completed in the program between July 2007 and July 2009 and by the number of calendar months participants stayed in the program (months that passed from the registration to the last completed follow-up survey).

All measures about participant characteristics were self-reported during registration or during follow-up surveys. Demographics

(age, gender, race, education level, annual household income, and country) were asked in the registration survey. Weight and height were asked in the registration survey and in each follow-up survey.

Weight loss outcomes were calculated as the difference between the weight reported at the last follow-up survey a participant completed and the weight reported in the registration survey. Hence, the length of the follow-up varied between participants.

Adherence to habit change suggestions was measured as the number of days (0-31) participants reported having followed the suggestions they had been given. Perceived effectiveness of changes was measured on a 1-9 scale (Not Very Effective – Very Effective). The total amount of effective changes for each month was calculated as the number of changes that were rated as 6 or above in effectiveness. Participants' experiences with changes were collected through free-form entries in follow-up surveys.

Analyses

Descriptive statistics were used to characterize participant retention. Student *t* tests were performed to assess the overall significance of weight changes over time. Analyses of variance were used to compare the adherence to changes and the perceived effectiveness of changes between participants who lost, maintained, or gained weight between subsequent surveys. The suggestions with high adherence were examined by taking a subset of cases where at least 20 participants had reported adherence of at least 20 days. Student *t* tests were used to examine the significance of weight changes associated with suggestions with high adherence. The suggestions that participants considered as the most and the least effective were derived based on the mean effectiveness ratings of suggestions that had been received by at least 25 participants (approximately 5% of the sample). Demographic differences in tip perceptions were assessed with analyses of variance.

Reported experiences with changes were analyzed with qualitative content analysis methods. The experiences were categorized into main themes of barriers and facilitators, under

which findings were further categorized under emerging subthemes. The total occurrences of themes were counted to identify recurring themes.

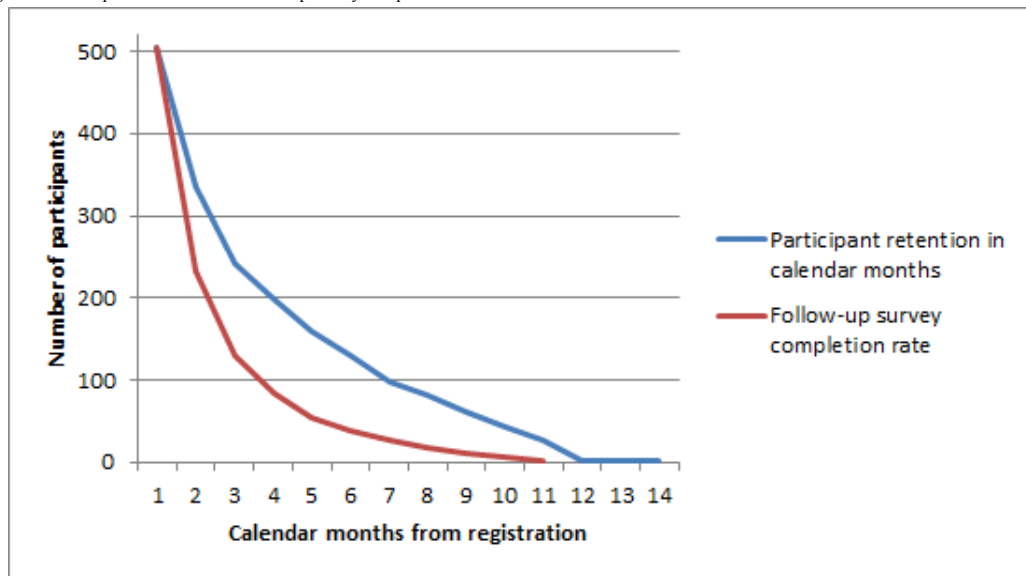
All quantitative analyses were done using SPSS version 19.0. *P* values less than .05 were considered statistically significant.

Results

Participant Retention

Figure 1 shows the adherence to the program over the course of the 14 months after signing up. Participant attrition was 75% after the initial registration: 1549/2053 participants never completed the intake survey or never returned for a follow-up survey. The participants who returned for at least one follow-up stayed in the program on average 3.7 calendar months (SD 3.10) and completed on average 2.2 follow-up surveys (SD 1.93). Most of them (88%, 445/504) had weight loss as their initial eating goal. Out of the returning participants, 38% (189/504) stayed in the program for more than two months and completed at least two follow-up surveys.

Figure 1. Participant retention and follow-up survey completion rate.



Weight Changes

Over the course of the program, 42% of returning participants (213/504) lost weight (mean 3.24% of initial weight, SD 2.94), 29% (145/504) gained weight (mean 3.35%, SD 3.68), and 27% (136/504) maintained their weight over the course of the program. Weight change data were missing from 2% (10/504) of the participants. Overall mean weight loss was 0.41% (0.75 lbs) of the initial weight ($t=-2.346$, $P=.019$). Participants who had weight loss as their initial goal lost on average 0.48% (0.9 lbs) of their initial weight ($t=-2.534$, $P=.012$). Clinically

significant weight loss, 5% or more of initial body weight, was achieved by 7% of the participants (36/504).

Table 2 presents the weight and BMI changes of participants with different levels of engagement in the program. The participants who stayed in the program for at least three months and completed at least two follow-up surveys (38% of the returning participants) lost on average 1.0% (1.8 lbs) of their initial weight ($t=-2.622$, $P=.009$). The mean time these participants stayed in the program was 6.4 months (SD 2.77), and they completed on average 4.0 follow-up surveys (SD 2.20).

Table 2. Weight and BMI changes among returning participants.

	Level of engagement		
	One-time visitors ^a	Two-month participants ^b	Three+ month participants ^c
Number of participants	271	44	189
% of returning participants	54	9	38
Mean weight change, lbs (SD)	-0.06 (5.746) <i>P</i> =.868	-0.69 (3.982) <i>P</i> =.263	-1.77 (8.574) <i>P</i> =.006
Mean weight change, % (SD)	-0.04 (3.156) <i>P</i> =.853	-0.38 (2.306) <i>P</i> =.285	-0.97 (5.012) <i>P</i> =.009
Mean BMI change (SD)	-0.09 (1.892) <i>P</i> =.471	-0.01 (0.664) <i>P</i> =.900	-0.26 (1.511) <i>P</i> =.023

^a Completed only 1 follow-up survey.

^b Completed 1-2 follow-up surveys and stayed in the program for 2 months.

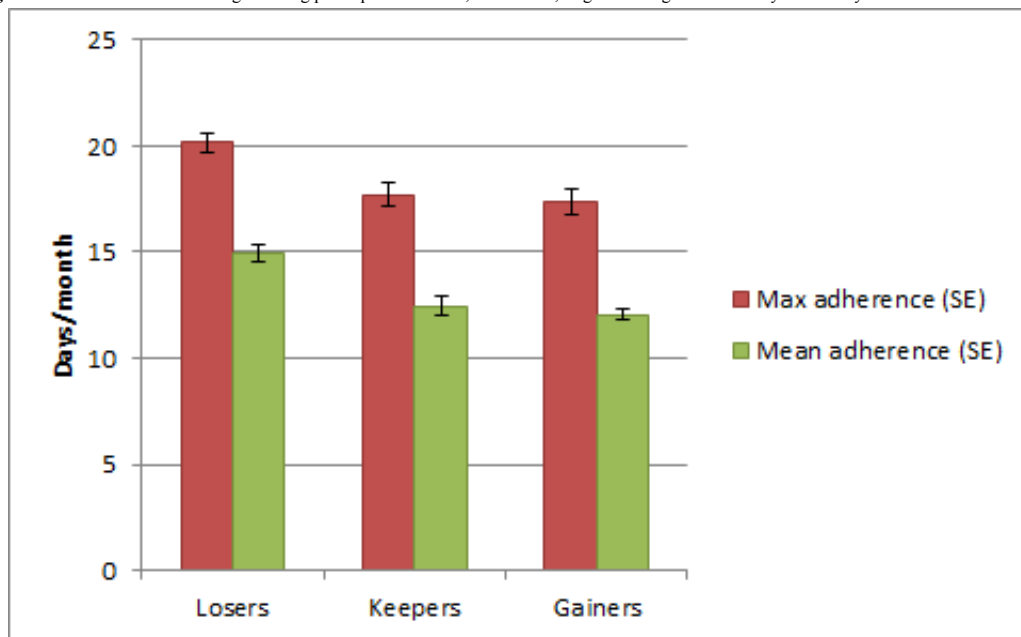
^c Completed at least 2 follow-up surveys and stayed in the program for at least 3 months.

Adherence to Changes

Adherence to changes was reported in 88% (979/1107) of all follow-up surveys. The days the participants reported having adhered to the habit change suggestions were on average 13.3 days (SD 9.77) over 1 month. Participants who had lost weight

between subsequent surveys reported higher monthly adherence to suggestions (mean 14.9 days, SD 7.92) than participants who had maintained their weight (mean 12.4 days, SD 7.63) or who had gained weight (mean 12.0 days, SD 7.50; *F*=14.17, *P*<.001); see Figure 2. Similarly, maximum adherence was highest among weight losers.

Figure 2. Adherence to three changes among participants who lost, maintained, or gained weight between any two surveys.



Adherence and Weight Outcomes

Participants who reported consistent adherence (at least 25 days in a month) to the suggested changes reported an average monthly weight loss of 2.0 lbs (*P*<.001). Figure 3 displays the percentage weight loss for different levels of mean adherence to suggestions. Participants whose mean adherence was 25 days

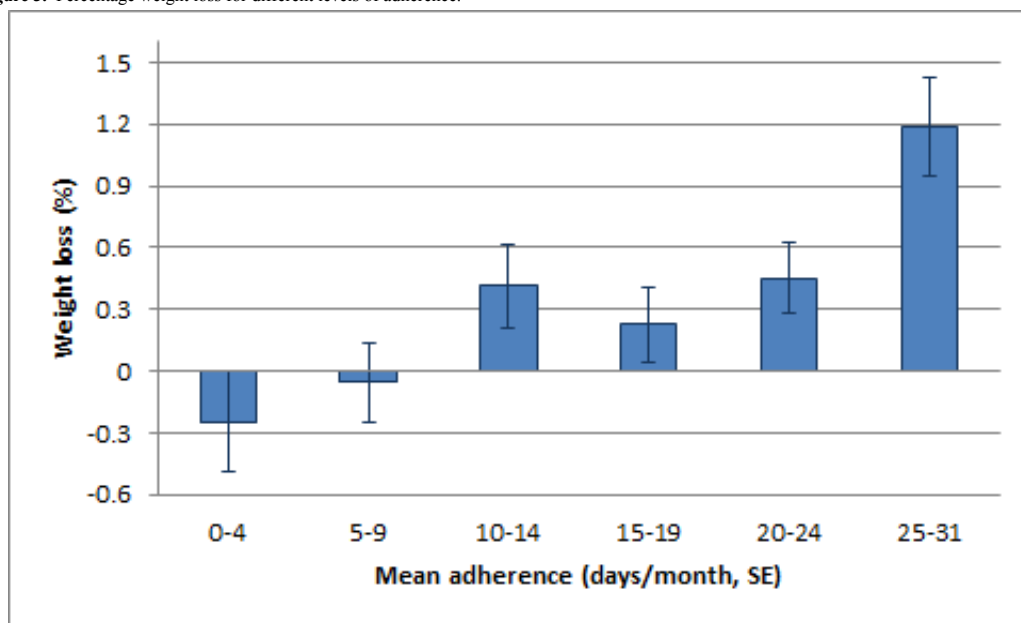
or more had a mean weight loss of 1.2%, a significantly higher number than participants who adhered only 0-4 days (*F*=3.991, *P*=.001) or 5-9 days (*P*=.014). Mean adherence to suggestions was positively correlated with weight loss percentage (*r*=.166, *P*<.001). Moreover, adherence to a suggestion was correlated with perceived ease (*r*=.622, *P*<.001).

Table 3 presents the mean weight outcomes of a subset of cases in which suggestions had adherence reports of at least 20 days from at least 20 participants. Two suggestions in this subset of 14 suggestions were associated with significant weight loss and one on borderline significance.

Table 3. Weight outcomes of suggestions with high adherence.

Tip	n of cases	Mean weight change, lbs (SD)	t test (P value)	Mean adherence (SD)	Mean effectiveness (SD)	Mean ease (SD)
Put down your utensils between bites. (This will allow you to slow down the pace of your eating.)	23	-2.48 (3.85)	-3.089 (.005)	24.96 (4.14)	7.70 (1.64)	6.48 (2.09)
Allow yourself an afternoon snack only if you've first eaten a piece of fruit.	24	-1.88 (4.46)	-2.062 (.051)	24.42 (4.02)	7.00 (1.96)	6.86 (1.93)
Any time you think you might eat when you're not hungry, go ahead and do so, but only if you first say (out loud): "I'm not hungry, but I'm going to eat this anyway".	20	-1.58 (2.94)	-2.400 (.027)	22.90 (2.90)	6.05 (2.09)	6.00 (2.08)
Drink 8 cups of water a day (that's only two full 32-oz glasses).	39	-1.29 (5.33)	-1.509 (.140)	24.32 (3.74)	6.20 (2.39)	7.10 (1.93)
Have a glass of water with every meal and snack.	30	-1.23 (5.75)	-1.173 (.250)	25.47 (4.13)	7.57 (1.83)	7.52 (1.68)
Use the Half-plate Rule: at dinner, load up the right side of your plate with salad, fruit, or vegetables. The other side can be starches and meat.	20	-1.05 (3.46)	-1.359 (.190)	24.05 (3.68)	7.20 (1.51)	7.10 (1.37)
Restrict your eating to the kitchen or dining room. (Doing this will make it more inconvenient to mindlessly eat between meals.)	24	-0.91 (4.02)	-1.107 (.280)	24.33 (3.97)	6.21 (2.59)	6.50 (2.23)
Eat something hot for breakfast at home within the first hour of waking up.	25	-0.79 (3.03)	-1.306 (.204)	26.16 (3.34)	6.92 (2.58)	7.42 (2.15)
Avoid going more than 3-4 hours without have something small to eat. (That way, you will be less likely to overdo it at meals.)	43	-0.75 (6.87)	-0.711 (.481)	25.51 (4.01)	6.69 (2.02)	6.93 (2.00)
Avoid eating anything directly from its bag, container, etc.	27	-0.66 (4.34)	-0.790 (.437)	24.67 (4.19)	6.89 (2.17)	6.30 (2.30)
Use smaller plates on meals.	21	-0.35 (2.98)	-0.542 (.594)	24.41 (3.91)	7.73 (1.16)	7.36 (1.99)
Never eat directly from a package – always portion food out into a dish so you need to face exactly what you will eat.	21	0.27 (4.81)	0.257 (.800)	23.71 (3.64)	7.19 (1.81)	6.86 (2.33)
Pack a baggie of precut veggies and fruit for at least one snack per day.	22	0.46 (3.69)	0.590 (.561)	23.87 (3.76)	7.17 (1.95)	7.17 (1.72)
Keep counters clear of all foods but the healthy ones.	21	0.86 (5.17)	0.760 (.456)	27.00 (3.46)	6.86 (2.24)	8.29 (1.49)

Figure 3. Percentage weight loss for different levels of adherence.



Perceived Effectiveness of Changes

The average amount of suggestions that the returning participants perceived as effective was 1.46 (SD 1.06). The average perceived effectiveness of all suggestions was 5.12 (SD 2.73) on a 1-9 scale. Table 4 presents the five most effective and five least effective suggested changes. The table also displays the total numbers of participants who received the suggestion as well as the mean values for ratings of effectiveness and ease, reported adherence, and weight changes from the time the suggestion was received by a participant to the time of the follow-up.

Participants who lost weight between subsequent surveys reported a higher amount of effective suggestions (mean 1.66, SD 1.03) than participants who maintained weight (mean 1.38, SD 1.03) or gained weight (mean 1.24, SD 1.07; $F=15.256$, $P<.001$). Effectiveness was strongly correlated with adherence ($r=.610$, $P<.001$) and ease ($r=.691$, $P<.001$).

Some demographic differences were found in participants’ perceptions of suggestions. The mean effectiveness ratings for suggestions were higher among participants who were white/Caucasian (5.2 vs. 4.7, $F=5.162$, $P=.023$) or had at least a college degree (5.2 vs. 4.8, $F=6.336$, $P=.012$). Moreover, the mean ease ratings were higher among participants who were white/Caucasian (4.9 vs. 4.4, $F=4.573$, $P=.033$) or who were from the United States (4.9 vs. 4.6, $F=4.070$, $P=.044$).

Barriers and Facilitators for Changes

Experiences of changes were reported in 745 follow-up surveys. Common barriers and facilitators for changes that emerged from

the reported experiences are summarized in Tables 5 and 6. The identified barriers were roughly divided into change-related, personal, and external barriers. The most common change-related barrier was that the suggestion was in some ways unsuitable for the participant: for example, too specific to certain situations, actually making the problem worse, or inconvenient to do. In addition, several participants stated that some changes were not applicable to their lifestyles at all or that they were just difficult to implement in most situations. Within personal barriers, simply forgetting to make the changes and being too busy to pay attention to changes were the most common ones. Emotional eating (due to negative emotions, tiredness, or stress) and losing track or motivation (“I did not even try”) also came up often. The most commonly mentioned external barrier was unusual circumstances when eating behavior was less under one’s own control (such as vacations or staying with someone else).

Facilitators for lifestyle changes were divided into program-related and personal facilitators. The most prevalent statement was that changes were “easy”. This statement was not usually elaborated further. Other program-related facilitators were reminders (calendar checklist, email reminders, or concrete environmental cues) and goal-setting. Personal facilitators were mostly related to gradual changes in awareness or behaviors and the feelings these changes evoked. Many participants commented that specific changes were less important than becoming aware of eating habits and paying attention to behaviors that had been mindless. Positive feelings as well as noticing results (such as enjoying food more and having energy) were other common themes.

Table 4. Most and least effective suggestions.

Suggestions	n of cases	Mean effectiveness (SD)	Mean ease (SD)	Mean adherence (SD)	Mean weight change, lbs (SD)
Most effective					
1. Keep counters clear of all foods but the healthy ones.	31	6.8 (2.01)	7.6 (1.80)	23.8 (7.22)	0.3 (4.69)
2. Never eat directly from a package – always portion food out onto a dish so you need to face exactly what you will eat.	52	6.7 (2.13)	5.9 (2.62)	16.1 (7.93)	-0.2 (3.70)
3. Eat something hot for breakfast at home within the first hour of waking up.	42	6.3 (2.82)	6.6 (2.89)	20.0 (9.83)	-0.2 (3.56)
4. Avoid going more than 3–4 hours without have something small to eat. (That way, you will be less likely to overdo it at meals.)	90	6.2 (2.35)	6.2 (2.49)	18.1 (9.04)	-0.8 (5.57)
5. Put down your utensils between bites. (This will allow you to slow down the pace of your eating.)	72	6.1 (2.64)	4.7 (2.58)	13.5 (9.62)	-1.7 (5.29)
Least effective					
1. Cinch your belt up 1 notch tighter than usual before you start to eat.	33	3.1 (2.79)	3.2 (2.86)	7.5 (9.65)	-0.9 (2.48)
2. Brush your teeth when you feel like snacking (10:30 and 3:45 are the most tempting times).	48	3.4 (2.68)	3.6 (2.67)	6.3 (7.61)	0.2 (2.64)
3. Use the 3 Bite Rule: eat whatever you want, but limit it to 3 small/medium-sized bites.	55	3.6 (2.32)	3.1 (2.27)	7.9 (7.53)	-0.8 (3.02)
4. Exercise at a time when you usually snack. (This way you are not only removing calories that you would have normally eaten, you are also burning calories.)	26	3.8 (2.27)	3.6 (2.40)	7.2 (6.07)	-1.3 (2.46)
5. After dinner, brush and floss your teeth to prevent evening snacking.	47	3.9 (2.71)	3.7 (2.76)	8.6 (7.95)	-0.5 (3.21)

Table 5. Common barriers to changes based on participants' experiences.

Barrier	Prevalence	Common explanations
Change-related barriers		
Unsuitable changes	87	Too specific (9), dislike (9), problematic to fit in the schedule (8), made problem worse (6), changes were incompatible (5), already a habit (5), wasting food felt difficult (5), irrelevant (4), inconvenient (3)
Inapplicable changes	37	Situation not encountered (21), did not fit the schedule (4)
Difficult changes	34	Difficult to do outside home (12), too much effort (7), difficult month (4), hard to plan ahead (4), hard to be consistent (2)
Personal barriers		
Forgetting	83	Distractions (9), simply forgetting about changes
Being busy	49	Lack of time (11), stress (11), busy schedule (5), major deadline (2)
Not even trying	31	Lack of motivation (10), not feeling committed (5)
Losing track	31	Losing motivation (11), no regular tracking (11), losing focus (8)
Need to eat	30	Hunger (10), cravings (8), danger times (7), availability of food (6), overeating (5)
Emotional eating	17	Stress eating (5), compulsive eating (2)
Ingrained habits	14	Falling back into old patterns
External barriers		
Unusual circumstances	57	Vacation (18), lack of control over food choices (14), traveling (12), holiday season (11)
Health issues	18	Own (12), sickness (5), family (1)
Social pressure	13	Partner's/family's habits, social gatherings
Unavailability of food	11	Healthy food not at hand (5), no access to healthy food (3), fruit not in season (2)

Table 6. Common facilitators of changes based on participants' experiences.

Facilitator	Prevalence	Common explanations
Program-related facilitators		
Easy	75	Creating habits that can last (8), small change to existing habits, simple changes
Reminders	21	Checklist and other concrete reminders (12), email reminders (5), environmental cues (4), accountability (4)
Having goals	17	Thinking about goals (5), determination (3), strategies (3), regular tracking (3)
Personal facilitators		
Increased awareness of eating habits	41	What, how, and when one eats, recognizing mindless eating habits
Positive feelings	28	Not feeling deprived (6), not feeling hungry (6), enjoyment of food (3), feeling better (3)
Modifying or expanding the changes	19	Continuing with earlier changes (6), making additional changes (3)
Changes in eating habits	19	Eating more slowly (8), portion control (7), mindful eating (2)
External support	15	Mindless Eating book (5), other health program (4), availability of healthy food (3), social support (2)
Seeing results	13	Improvement from small changes (5)
Planning ahead	11	Learning to plan and prepare
Already a habit	9	Easy to increase frequency
Psychological changes	9	Overcoming food-related issues (3), sense of control (2)

Discussion

In this study, we evaluated weight outcomes and participant retention in a publicly available web-based healthy eating and weight loss program based on a small-changes approach. The results of the study showed significant but modest weight loss outcomes, with larger effects among participants who were more engaged in the program, stayed in it for a longer time, and completed more follow-up surveys. That is, those who completed at least three months of the program or adhered at least 25 days per month to the suggested changes reported a significantly higher average monthly weight loss than those who dropped out early or who did not adhere to the suggested changes. The small-changes approach shows promise, but encouraging adherence and finding suitable changes for each person still remain a challenge.

Participant Retention

One fourth of the participants who registered and received the first set of habit change suggestions returned for follow-up. Loss of participants over time was fairly quick, with only half of those who returned for follow-ups staying in the program for more than two months. This kind of high attrition is typical for voluntary online programs, in which the intervention is neither mandatory nor critical to participants [18-21] and that do not provide additional incentives other than positive feedback and benefits to health and well-being. Attrition rates in weight loss interventions vary considerably even in face-to-face settings, with reported rates ranging from 10% to more than 80% [22]. In the case of NMEC, we can only speculate the reasons for participant attrition. We could propose three main reasons why participants stopped returning for follow-up: 1) they were satisfied with the results, 2) they decided that the program was not worth their time anymore, or 3) they just forgot about it while going on with their busy lives. It is likely that the main contributor is a decrease in motivation after the initial interest [10]. In addition, email reminders were the only method of communication with participants, and there was no real human contact that could have resulted in higher engagement to the program [21].

Nevertheless, rapidly decreasing retention is not necessarily an indication of the program failing to reach its aims. It has been suggested that the main role for web-based programs in prevention and treatment of obesity may be to deliver short positive messages and reminders that can lead to increased awareness and seeking of assistance from other sources [23]. The participants of the NMEC program may have needed the initial boost to get started with concrete habit changes, but after the initial month or two, some voluntarily reported that they had already gained enough awareness and skills to start making up their own changes that would best suit their individual circumstances. The strength of the small-changes approach is that the principle is simple and quick to learn [1,5]. Additionally, it is possible that some participants decided to acquire the book that was referred to in the program and felt no need to return to the online program after reading it. The book and the online program could be viewed as complementary self-help resources. In fact, it might be beneficial for participants if intervention

programs contained references to external resources based on their needs as an alternative to combining treatment strategies for comorbidities into the same intervention [24]. For example, if there is a reason to suspect that a participant suffers from depression or anxiety, a weight loss program could guide them to interventions that handle such issues.

Weight Outcomes and Effectiveness of Changes

Nearly half of participants lost weight over the course of the program, and the average amount they lost was 3.2% of their initial weight. Although the other half of participants either maintained or gained weight and the overall mean weight loss was modest, the results suggest that small-changes approach is promising in weight loss and maintenance, considering that effect sizes in online healthy eating and weight loss interventions have been generally small [9,25]. Moreover, most participants were overweight, not obese, and the focus of the program was not primarily losing weight but rather healthier and more mindful eating. Small weight losses or even maintenance of current weight are valuable achievements and useful in preventing weight gain [12]. High adherence was associated with larger outcomes: for those whose adherence to changes was 25 or more days per month, weight loss averaged 2.0 lbs in a month.

Half of the suggestions in the program were generally perceived as effective, and participants who lost weight rated a higher amount of suggestions as effective. Some tips that were reported as effective were associated with small (although not statistically significant) weight gain. This may have been due to other factors, but it may also indicate that people perceive effectiveness in different ways. Tips that were associated with weight gain or weight maintenance were likely to either increase the amount of healthy food consumed (“keep counters clear of all foods but the healthy ones”) or give a good start to each day (“eat something hot for breakfast”). Therefore, effectiveness could have meant that participants succeeded in changing the habit, ate healthier, and felt better about themselves even if they did not lose weight. This notion was supported by several participants’ comments.

Effectiveness, ease, and adherence were all strongly correlated. Hence, finding relevant and easy habit changes for each individual would be essential. Tailoring interventions to individuals generally increases effectiveness [7,8]; the NMEC program tailored suggestions simply based on participants’ eating goals. Further tailoring to individual circumstances and psychological characteristics would likely improve outcomes and adherence, and participants’ own predictions about ease and effectiveness of habit changes should be used to screen out changes that have a very low probability to succeed. Moreover, suggestions in the NMEC program were considered somewhat more effective and easy by white/Caucasian participants, more effective by those with higher education level, and easier by Americans. Because suggestions were developed based on research done in the United States, suggestions and the program itself may have been more suitable or attractive for an audience with similarities to the developers. Cultural tailoring in terms of language, graphics, and consideration of common eating habits and environments could increase participant adherence

and satisfaction [26], although the most basic suggestions are likely to be widely applicable even without tailoring.

Adherence to Changes

Not surprisingly, participants who lost weight adhered more to suggested changes than participants who maintained or gained weight. Even though the difference was small (a couple of days more per suggestion), it may be enough to tip the scale to the side of weight loss. Adherence was also strongly correlated with perceived effectiveness and ease, which suggests that no matter what the changes were, participants benefited from them if they committed to making them and found them easy to do. These findings are in line with earlier research that has associated higher intervention adherence with better behavioral outcomes [20,25]. If adherence to actual changes is low, the intervention does not have a lot of chance to impact behavior, except in the rare cases in which the impact results from keeping the goals in mind.

Considering that high adherence was associated with higher weight loss, identifying the best suggestions for weight loss could be possible by analysis of suggestions that received high adherence ratings. Among the 14 suggestions that were adhered to for at least 20 days by at least 20 participants, 2 were associated with significant weight loss. Both of them required some willpower but did not restrict the amount of eating or food choice; rather, they drew attention to eating pace or eating choices. Indeed, several participants commented that these kinds of suggestions helped to increase awareness of eating habits. Even though data about prior history of dieting were not collected in the program, several female middle-aged participants may have had earlier unsuccessful dieting experiences [3]. Many diets are characterized by restrictive rules that may lead to feelings of deprivation [17,27], binge eating [28], or eating bouts [29]. A small-changes approach could result in healthier attitudes towards food and eating in response to hunger and satiety signals since it does not restrict eating but makes people more conscious of their eating habits, if they are able to adhere to changes.

Adherence is likely to be mediated by the strength of the existing habits that need to be changed: if a new habit is supposed to replace an existing strong habit, the change is likely to be more difficult than if the habit to be replaced is weak or nonexistent [6,30]. This came up in several participants' comments about deeply ingrained habits. Difficulty of a habit change influences how much time it will take to form a new habit. Lally and colleagues did a study with 96 participants and found that habit formation took on average 66 days, but there was a large variation from 18 days to 254 days depending on the complexity of the habit [31]. In the NMEC program, some participants said that they would have wanted to continue with the changes from the prior month rather than receive new suggestions. This may indicate that they were still struggling with habit formation or that they had been in unusual circumstances where changes were not applicable. Ideally, suggested changes should be generic and flexible enough so that they are doable every day. As some participants mentioned, this will provide a sense of accomplishment, improve self-efficacy, and encourage them to continue with further changes [32].

Barriers and Facilitators for Changes

Analysis of participants' experiences with changes indicates that habit change suggestions were perceived as more effective and easy to adhere to if they matched participants' personal situation, lifestyle, and psychological needs. Unsuitable, inapplicable, or difficult changes were soon discarded as requiring too much effort or being irrelevant. Furthermore, unusual circumstances such as vacations and busy schedules with deadlines made it difficult to adhere to suggestions that concerned environmental changes and food choices, especially if the suggestions were situation-specific. To accommodate people's changing circumstances such as travels and holiday seasons that disrupt existing habits [30], it may be most beneficial to provide flexible heuristics that are applicable to any situation. Another possibility is to attempt to profile participants' needs frequently and adapt the advice for changing situations [33,34].

Losing track of changes or forgetting them completely was relatively common among participants. Email reminders and a calendar checklist helped several to monitor their behaviors and stay on track, but not everyone benefited from periodic prompts and reminders, which is in line with earlier studies [35]. Concrete cues and reminders in the environment, such as having the checklist in the kitchen, appeared to be helpful for several participants. Participants' adherence to daily changes might be improved by encouraging and advising them to set concrete but unobtrusive triggers and cues in places where they can frequently see them [6,36]. The simple small-changes intervention could also lend itself ideally to mobile phones, which are carried around most of the day and accessed frequently.

Having easy changes to make, having goals in mind, and learning to plan ahead were helpful for participants [32], and suggestions that increased their awareness about their eating habits appeared to be especially useful. Such suggestions typically involved either modifying their eating environment or learning to focus and slow down. These kinds of suggestions could be used to overcome emotional eating, which was a fairly common stumbling block. A lot of needless eating in today's society is caused by emotional needs that cannot be fulfilled, and some people use food instead to fill the emotional void or to fight their tiredness or stress [37]. Indeed, depression and obesity have been shown to have a reciprocal link [38]. Addressing the problematic relationship with food may require additional strategies that focus on improving self-esteem, self-control, and constructive coping [38].

Limitations

The voluntary setting with no active recruitment or promotion of the program is both a limitation and strength of this study. That is, the program involved no human contact, and participants reported their own weight and their adherence. The results should be interpreted with caution because all measures were self-reported. Weight in subsequent surveys could have been reported on different times of the day or different weekdays, which can mask small actual changes in weight. Furthermore, there was no control group and participant attrition was high. Since only 25% of participants who registered to the website

returned to the follow-up surveys, it is possible that the intervention effect is overestimated. Yet even in the absence of a control group, in this kind of a setting, the behavior of the participants was likely to resemble behavior of ordinary users of online weight loss and healthy eating programs; some of the people who registered may have just been curious and had no serious intention to start the program. Moreover, since data were collected across 2 full years, the results are generalizable across seasons and cannot be explained by seasonality (ie, people might lose more weight over the summer or gain more over the holidays). In the general population, all reports of changing weight point to a general increase and not a decrease [39-42].

In the analyses of the most and the least effective suggestions, the potential influence of the other suggestions that participants received cannot be ruled out. The pool of different suggestions was so large that only a relatively small number of participants received individual suggestions, which limits the possibilities to identify significant differences. To discover the most suitable and effective tips for different individuals, further studies would be needed.

Conclusions

This study illustrates that an online intervention based on a small-changes approach can help individuals lose weight, especially if they adhere to changes consistently. Participants who were adherent to their suggested changes 25 or more days per month reported an average loss of 2 lbs each month. What is not fully known is how long this rate of slow and steady weight loss would continue. In general, adherent participants

who continued past the 3-month mark lost a small but significant proportion of their weight. It's important to note that these people were self-selected and may be much more diligent or motivated than the average person who joins a small-change nutrition and weight loss program.

High attrition remains a challenge that can potentially be solved with further tailoring to individual needs and tighter connection to participants' everyday lives. For instance, asking more detailed screening questions during the initial profiling survey could provide more tailored suggestions and increase perceived relevance and anticipated adherence. Ensuring that changes are easy and require little effort from participants provides them opportunities to experience success and increased awareness of their eating habits and benefits of healthy eating, motivating them to continue on the chosen path. In addition, encouraging participants to place concrete cues and reminders in their environment could work even better than notifications through email or mobile devices. Such changes in a person's food environment could lead them to become slimmer by design [43].

Long-term follow-up is needed to evaluate the maintenance of habit changes and weight loss. Of particular interest would be to better predict how likely a participant would be to adhere to a particular suggestion. Being able to better predict adherence could lead to more relevant and effective advice. Further research could also expand the small-changes approach to other important health behaviors such as physical activity or stress management.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

The Mindless Eating Challenge home page.

[[PNG File, 2MB - jmir_v14i6e168_app1.png](#)]

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STUDY II

**Factors related to sustained
use of a free mobile app
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Retrospective cohort study**

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Original Paper

Factors Related to Sustained Use of a Free Mobile App for Dietary Self-Monitoring With Photography and Peer Feedback: Retrospective Cohort Study

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Abstract

Background: Healthy eating interventions that use behavior change techniques such as self-monitoring and feedback have been associated with stronger effects. Mobile apps can make dietary self-monitoring easy with photography and potentially reach huge populations.

Objective: The aim of the study was to assess the factors related to sustained use of a free mobile app (“The Eatery”) that promotes healthy eating through photographic dietary self-monitoring and peer feedback.

Methods: A retrospective analysis was conducted on the sample of 189,770 people who had downloaded the app and used it at least once between October 2011 and April 2012. Adherence was defined based on frequency and duration of self-monitoring. People who had taken more than one picture were classified as “Users” and people with one or no pictures as “Dropouts”. Users who had taken at least 10 pictures and used the app for at least one week were classified as “Actives”, Users with 2-9 pictures as “Semi-actives”, and Dropouts with one picture as “Non-actives”. The associations between adherence, registration time, dietary preferences, and peer feedback were examined. Changes in healthiness ratings over time were analyzed among Actives.

Results: Overall adherence was low—only 2.58% (4895/189,770) used the app actively. The day of week and time of day the app was initially used was associated with adherence, where 20.28% (5237/25,820) of Users had started using the app during the daytime on weekdays, in comparison to 15.34% (24,718/161,113) of Dropouts. Users with strict diets were more likely to be Active (14.31%, 900/6291) than those who had not defined any diet (3.99%, 742/18,590), said they ate everything (9.47%, 3040/32,090), or reported some other diet (11.85%, 213/1798) ($\chi^2_3=826.6$, $P<.001$). The average healthiness rating from peers for the first picture was higher for Active users (0.55) than for Semi-actives (0.52) or Non-actives (0.49) ($F_{2,58167}=225.9$, $P<.001$).

Actives wrote more often a textual description for the first picture than Semi-actives or Non-actives ($\chi^2_2=3515.1$, $P<.001$). Feedback beyond ratings was relatively infrequent: 3.83% (15,247/398,228) of pictures received comments and 15.39% (61,299/398,228) received “likes” from other users. Actives were more likely to have at least one comment or one “like” for their pictures than Semi-actives or Non-actives ($\chi^2_2=343.6$, $P<.001$, and $\chi^2_2=909.6$, $P<.001$, respectively). Only 9.89% (481/4863) of Active users had a positive trend in their average healthiness ratings.

Conclusions: Most people who tried out this free mobile app for dietary self-monitoring did not continue using it actively and those who did may already have been healthy eaters. Hence, the societal impact of such apps may remain small if they fail to reach those who would be most in need of dietary changes. Incorporating additional self-regulation techniques such as goal-setting and intention formation into the app could potentially increase user engagement and promote sustained use.

KEYWORDS

healthy eating; food journaling; food photographing; adherence; mobile app; self-monitoring; peer feedback; control theory

Introduction

Dietary Self-Monitoring and Feedback

Despite various efforts to curb the growth of obesity, a significant part of the population still eats unhealthy food in excessive quantities. Knowledge about healthy eating is not sufficient on its own to change eating behavior [1]. On an individual level, one behavioral strategy recommended in weight control and improvement of dietary habits is self-monitoring of food intake [2,3]. Moreover, healthy eating interventions that use self-monitoring combined with other self-regulation techniques from control theory, such as feedback [4], appear to be more effective than interventions that do not include these techniques [5]. Smartphones and photography can be used to make self-monitoring easy and convenient [6-9]. Due to the wide penetration of smartphones in the population, this approach could reach a large number of people with small cost. However, it is not known whether such mobile apps for independent use would engage people and reach those who could benefit the most from dietary monitoring.

Dietary self-monitoring prompts people to reflect on their current behavior and compare it to ideal behavior [4,10]. In weight loss studies, consistent recording of food intake appears to be one of the most effective methods [3,11]. Yet it is not clear how consistent self-monitoring needs to be for the method to be effective. The degree of monitoring is typically reported as the number of food diaries/entries completed per day and/or week, and the duration of the monitoring period has varied from eight weeks to two years in different studies [3]. For example, a six-month intervention study found that the average number of food records per week was 3.7 and greater weight loss was associated with more frequent monitoring [12]. Another study on members of a free online weight loss program found that more frequent weight monitoring was associated with greater weight loss, but no association was found between dietary monitoring frequency and weight loss [13]. Overall, it is not clear whether these results tell more about an individual's engagement to the program or specifically about the effect of monitoring. Studies have also mostly focused on weight loss, not on prevention of weight gain through improvement of eating behavior.

Traditional methods for dietary self-monitoring include more or less detailed food diaries and calorie counting [14]. These methods can be burdensome to people [6,7,15-17] and suffer from underreporting and recall issues [15-19]. Methods that can minimize the temporal distance between eating and recording food intake are likely to improve outcomes; the percentage of food records made within 15 minutes of eating has been found to be associated with weight loss [20]. Recently, smartphone cameras have made just-in-time food journaling possible by taking a photo of food. A pilot study using disposable cameras suggests that recording food before eating can lead to increased consideration of dietary habits and alter food choices better than

written diaries [21]. Capturing images of food may improve adherence and accuracy in some groups, such as among adolescents who may be less motivated to keep detailed food diaries [8].

Feedback on performance is a self-regulation technique that either reinforces the current behavior or creates a discrepancy between current and ideal behavior [4]. Individualized feedback has been found to be associated with higher adherence to online interventions promoting healthy lifestyles [22,23]. In terms of the content of feedback, encouraging reflection and self-monitoring may be more important than detailed analysis of nutritional contents when the target is to change eating behavior [10,24,25].

Mobile apps can provide automated feedback on the healthiness of the food based on the photo and also leverage other users to provide feedback through crowdsourcing [6]. Although it is still difficult to estimate food ingredients and portion sizes from a photograph, efforts to develop estimation algorithms based on image processing or crowdsourcing are underway [6,16]. One such app is PlateMate, which crowdsources nutritional assessments from Amazon Mechanical Turk, where individuals assessing the food pictures receive a nominal payment for each picture [6]. Evaluation of the app suggested that these crowd-generated assessments were almost as accurate as those done by professional nutritionists, although pictures containing ambiguous items such as beverages or salad dressing received inaccurate ratings [26]. Beyond nutritional assessments, technology can be used to share advice and feedback on healthy eating between users [27].

Adherence to Mobile Apps

Numerous mobile apps for healthy eating are available in application markets. Although they are easily within anyone's reach, attrition is likely to be a significant challenge, since there is usually very little external pressure or incentive to continue usage [28]. Little research exists about usage behavior of health-promoting apps, but reviews on Web-based interventions have found that adherence is generally lower outside randomized controlled trials and some observational studies have reported adherence rates as low as 1% [29]. One of the few articles published about mobile app usage examined data that was collected from 4125 users between August 2010 and January 2011 [30]. The study found that sessions with apps were short, averaging a little more than a minute, and that different types of apps were used during different times of the day. Communication apps were the most frequently used, 49.50% of app launches, whereas the proportion of health apps was only 0.26% of all app launches [30]. More studies into health app usage behavior are thus warranted. Considering that people's eating patterns and daily routines vary over the week [31,32], analyzing the temporal context of app usage may help identify the best times to start using an app that promotes lifestyle changes.

Study Objectives

This study assesses the overall usage and reach of a free mobile app for healthy eating (“The Eatery”) over a period from October 2011 to April 2012. Specifically, we examine the indicators of sustained use of the app, especially focusing on the initiation of self-monitoring and the influence of peer feedback.

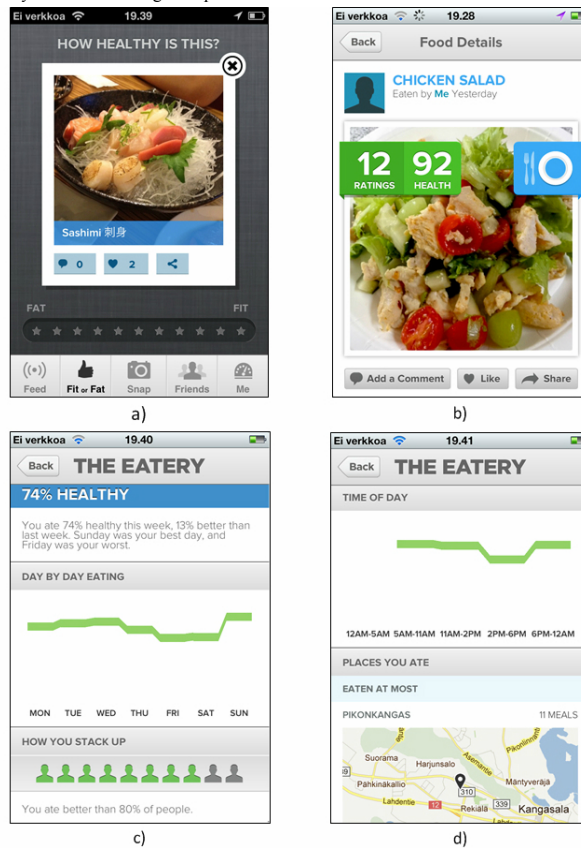
Methods

Mobile App

The Eatery was a free iPhone app developed by the company Massive Health. The app was officially launched on November 1, 2011 in Apple’s application market [33]. It was targeted toward English-speaking people and presented as an easy and fun way to eat healthily. Its main functions were photographic food recording, self-evaluation of foods, and crowdsourced peer feedback. Users were asked to take a picture of the foods they were going to eat, rate the picture on an arbitrary healthiness scale from fat (unhealthy) to fit (healthy) (Figure 1), and

optionally write a description for the picture. In addition to self-evaluation, users were prompted to rate another user’s food pictures every time they opened the app. They could rate as many successive pictures as they wanted (Figure 1a). Each of the user’s own food pictures received an average healthiness rating that was calculated from ratings given by other users (Figure 1b) and displayed as a number between 0 (“fat”) and 100 (“fit”). Other social support features of the app included the option to follow other users and provide feedback for their pictures in the form of comments and “likes”. The app provided automated feedback on the user’s past eating behavior by showing the past week’s day-to-day healthiness ratings and overall rating (Figure 1c), allowing the user to note the worst times as potential improvement points. Feedback was also given on week-to-week progress in healthiness ratings and on social comparison to other users (Figure 1c). Moreover, the app provided information on past behavior by displaying the most frequent eating locations (Figure 1d) and highlighting the best and worst meals of the week. The only background information asked from the users was their dietary preference on the first launch of the app.

Figure 1. Screenshots of The Eatery app: a) rating other people’s food with fat-fit scale, b) feedback received for photographed food, c) weekly summary, and d) summary of user’s time-of-day healthiness ratings and places eaten at most.



Study Sample

Altogether 189,770 users downloaded and used the app, The Eatery, at least once between October 15, 2011, and April 3, 2012. During this time, they generated 429,288 pictures and 7,946,447 ratings. In May 2012, Massive Health, the developer of the app, decided to make the anonymized dataset available for research purposes upon contact. The authors obtained the dataset from Massive Health in June 2012.

Data of users, pictures, and ratings included timestamps that represented the local time of the user’s mobile phone. The timestamps that were stored when the user first used the app included time zone information for 98.51% (186,933/189,770)

of the users: 68.41% (127,884/186,933) of them were from the main US time zones (UTC-8 to UTC-5) and 12.48% (23,335/186,933) were from the main European or African time zones (UTC+0 to UTC+3).

Definition of Variables

Table 1 lists the variables used in the analyses of factors related to usage of the app. As the focus of this study is on dietary self-monitoring, the usage period was defined as the time that elapsed between the first and the last picture taken by the user, even though the users who stopped taking their own food pictures could still continue to rate other users’ pictures.

Table 1. Variables related to the usage of the mobile app “The Eatery”.

Category	Variable	Description
Usage activity		
	Number of pictures	Total number of pictures taken by the user
	Usage period	Time elapsed between the first picture and the last picture (ie, the duration of self-monitoring)
	Pictures per day	Average number of pictures the user took per day during the usage period
	Ratings given for peers	Total number of ratings the user gave for other users’ pictures
Context of use		
	Registration time	Day of week (Sun-Sat) and time of day when the user first used the app
	Dietary preference	The response the user gave to “How do you eat?” question during the first launch of the app. The preference categories are listed in Table 2.
Self-evaluation		
	Own healthiness rating	Healthiness rating the user gave for an own picture (0 to 1) ^a
	Picture description length	Number of characters written in the picture description
Peer feedback		
	Average healthiness rating	Mean peer rating given for the picture (0 to 1) ^a
	Number of ratings	Total number of peer ratings given for a picture
	Number of comments	Total number of comments from peers for a picture
	Number of likes	Total number of peers who “liked” a picture
	Difference to peer ratings	Difference between the user’s own healthiness rating and average healthiness rating for a picture

^aHealthiness ratings were stored as a decimal number from 0 (“fat”) to 1 (“fit”), whereas the user saw the ratings as numbers from 0 to 100, as in Figure 1b. The rating that was displayed to the user was a non-linear mapping from peer ratings and user’s own rating.

Exclusion Criteria in Analyses

Pictures that did not contain an actual image (3.13%, 13,433/429,288 were such “empty pictures”) were removed from the data, resulting in a sample of 415,855 pictures for analysis. The overall quality and content of the pictures was screened by the researchers by examining a random sample of pictures. The examination revealed that, for some users, the first picture served as a test picture (for example, they took a picture of a chair to test out the application). Further examination showed that pictures obtaining a low number of peer ratings were typically something other than food, and therefore should be removed from further analysis. By manual inspection, the threshold of a valid picture was adjusted to 10 ratings: if the

first picture taken by a user had received less than 10 ratings, the picture information was excluded and the second picture was used instead. If the user had taken only one picture or the second picture had received less than 10 ratings, the user was excluded from the analyses concerning the peer feedback for the first picture. The total number of pictures for each user was adjusted after the picture validity check of the first two pictures. This decreased the total number of pictures by a user by two pictures at most. Latter pictures were not examined. In total, 398,228 pictures (92.76% of all pictures and 95.76% of non-empty pictures) were classified as valid pictures.

Some users had not rated their own first picture—these users were excluded when analyzing the difference between their own and average peer healthiness ratings.

Adherence Levels

Individual users in the dataset were divided into groups based on their adherence, for the analysis of different indicators of adherence (initiation context of self-monitoring and peer feedback). The level of adherence was defined based on the total number of pictures taken and the length of the usage period of the app.

Two types of adherence classifications were formed for different analyses. In the first case, two user groups were formed: (1) users who had taken no valid pictures or only one valid picture ("Dropouts", 86.39%, 163,949/189,770), and (2) users who had taken more than one valid picture ("Users", 13.61%, 25,821/189,770). For users who had taken at least one valid picture, three activity levels were defined: (1) "Actives" who had taken at least 10 pictures and had used the app at least one week (2.58%, 4895/189,770), (2) "Semi-actives" who had taken at least two pictures, but less than 10 pictures or whose usage period was less than one week (11.03%, 20,926/189,770), and (3) "Non-actives" who had taken only one valid picture (17.36%, 32,948/189,770).

The proportion of users who had downloaded the app less than one week before the sampling period ended (on March 28, 2012 or later) was 2.01% (3812/189,770). Hence, they could not be classified as Actives. They were still included in the analyses due to their small number.

Initiation of Self-Monitoring

The association between users' registration time and adherence level was analyzed to determine whether the temporal context of initial use could have an influence on subsequent usage activity. Registration time was categorized into seven weekdays and each day was divided into five time intervals: time between 0-5 (night), 5-10 (morning), 10-15 (daytime), 15-19 (late afternoon), and 19-24 (evening). These time intervals were chosen to correspond to the natural periods of the day and based on the assumption that most users were from Anglo-American culture, since the app was in English and roughly 68% (127,884/186,933) of the users registered from the main US time zones. The number of Dropouts and Users who had started using the app on each weekday and time of day intervals were

calculated. The chi-square (χ^2) test was used to compare whether the proportions of Dropouts and Users in weekday and time of day intervals (35 options) were equal to each other. Bonferroni correction was used to adjust for multiple comparisons and the adjusted significance level was set at $P=.0014$. Further comparisons were exploratory and were made based on initial results. Registration time was not available for 1.49% of the users (2837/189,770).

Dietary preferences were divided into four categories based on the users' response to "How do you eat?" question on the first use of the app. Table 2 lists the answer options to the question and the numbers of users in each category: (1) "Not defined" included users who had not given any preference (42.22%, 80,118/189,770), (2) "Everything" included users who chose the option "I eat everything" (46.33%, 87,912/189,770), (3) "Strict" included users who had at least one of the following options chosen: "Low carb, no carb, or paleo", "Low fat", or "Vegan/vegetarian", (8.97%, 17,025/189,770), and (4) "Other" included users who had chosen or written an option that was not included in the first three classes (2.48%, 4715/189,770). For example, the variations of "I eat everything!" response such as "I eat everything except..." were categorized as "Other".

The associations between dietary preferences and adherence were analyzed by calculating the proportion of (1) Actives out of Users + Non-actives (ie, out of all users who took at least one valid picture), and (2) Users out of Users + Non-actives for each dietary preference category. The chi-square test was used to examine whether the proportions were equal between different dietary preference categories. Tukey's HSD (honestly significant difference) multiple comparison test among proportions was used to analyze which dietary preference categories differed from each other after obtaining significance value $P<.05$.

Finally, the existence and length of the textual description given for the first picture taken by the user were compared between Active, Semi-active, and Non-active user groups. One-way ANOVA (analysis of variance) was used for description length and the chi-square test for the existence of the description. This analysis was done to assess the engagement level of the user during the initiation of self-monitoring.

Table 2. Numbers of users according to their dietary preferences based on “How do you eat?” question.^a

“How do you eat?”	Category	Number of users, n (%) n=189,770
Not defined	Not defined	80,118 (42.22%)
“I eat everything!”	Everything	87,912 (46.33%)
“Low fat”	Strict	7778 (4.10%)
“Low carbs, no carbs, or paleo”	Strict	7146 (3.77%)
“Vegan or vegetarian”	Strict	6223 (3.28%)
“Complex carb diet”	Other	2388 (1.26%)
“Other”	Other	2427 (1.28%)
“Gluten free” or “gluten free”	Other	229 (0.12%)
None of the above	Other	1714 (0.90%)
Total	Strict	17,025 (8.97%)
Total	Other	4715 (2.48%)

^aNote that some users provided multiple responses to the question.

Peer Feedback

The amount and quality of peer feedback given for the first picture (average healthiness score, number of likes, number of comments, and difference to peer ratings) were compared between Active, Semi-active, and Non-active user groups to determine whether higher level of feedback on the initiation of self-monitoring was connected with adherence. Only those who had at least one valid picture among the first two pictures they had taken were included because the focus was on the initial feedback. For continuous variables, one-way ANOVA was used and for binary variables, the chi-square test was used to compare whether the proportions were equal between user groups. The numbers of ratings given by the users in each dietary preference category were also calculated to determine whether the stated dietary preference would have a connection to the user’s activity in providing peer feedback to others.

Changes in Healthiness Ratings

Changes in healthiness ratings were analyzed only among Active users who had at least one valid picture among the first two pictures they had taken (99.35% of Actives, 4863/4895). Other user groups used the app for such a short time that no trend could reliably be identified. First, a correlation coefficient between the average healthiness rating of the first picture and all subsequent pictures was determined. A change (linear regression coefficient) in healthiness ratings as a function of picture index and corresponding *P* value was calculated for each Active user. The dependent variable was the healthiness rating of a picture and the independent variable was the picture index $1, 2, \dots, N$ where *N* was the number of pictures taken by the user. Note that the ordered list of pictures was used instead of real

time axis. If a significant ($P < .05$) positive linear coefficient was found, the user was categorized into “Improvers” (improvement in diet), and negative into “Decliners” (deterioration in diet). Student’s *t* test was used to compare whether usage activity (number of pictures, usage period, and pictures per day) differed between Improvers and other Actives.

Changes in eating behavior among users with different dietary preferences were also examined. One-way ANOVA was used to compare the average healthiness rating for the first picture and the healthiness rating for all pictures between different dietary preference categories. The number of Improvers or Decliners in each dietary category was determined. The chi-square test was used to examine whether there were an equal proportion of Improvers and Decliners in each dietary preference category.

Results

Overall Adherence and Healthiness Ratings

Table 3 shows the numbers of users divided into different adherence levels based on their usage activity. The average number of pictures and usage period in days is also shown for Semi-actives and Actives. Only 2.58% (4895/189,770) of the users became Active users, whereas more than two-thirds of the users did not take any valid pictures. On average, Actives took 1.6 pictures per day and 14.99% (734/4895) of them took more than three pictures per day.

Table 4 summarizes the statistics of valid pictures (92.76% of all pictures, 398,228/429,288) in the dataset from The Eatery. Their average healthiness rating, 0.58, was slightly above the midpoint of the fat-fit scale from 0 to 1.

Table 3. Adherence data for users who downloaded the free dietary self-monitoring app between October 15, 2011 and April 3, 2012 (n=189,770).

User group	Activity level	Description	Count, n (%)	Pictures per user, mean (SD)	Usage period in days, mean (SD)
Dropouts	Non-users	No pictures or no valid pictures	131,001 (69.03%)	-	-
Dropouts	Non-actives	Only 1 valid picture	32,948 (17.36%)	-	-
Users	Semi-actives	At least two valid pictures and less than 10 pictures or usage period shorter than 7 days	20,926 (11.03%)	4.1 (3.7)	9.3 (19.2)
Users	Actives	At least 10 pictures and usage period longer than 7 days	4895 (2.58%)	58.9 (99.5)	46.6 (37.7)

Table 4. Statistics for the 398,228 valid pictures taken by 58,769 users of the dietary self-monitoring app “The Eatery”.

Variable	Description	Value, mean (SD; range) or n (%)
Self-evaluations		
	Number of pictures with textual description	293,692 (73.75%)
	Average length of textual description (if existed) as number of characters	26.1 (18.1; 1-248)
Peer feedback		
	Average healthiness rating	0.581 (0.195; 0.0261-0.986)
	Number of pictures having at least one like	61,299 (15.39%)
	Average number of likes (if existed)	1.3 (0.9; 1-21)
	Number of pictures having at least one comment	15,247 (3.83%)
	Average number of comments (if existed)	1.7 (1.4; 1-28)

Initiation of Self-Monitoring

The associations between users’ registration time and adherence level are presented in Figure 2, which compares the proportions of Users and Dropouts who started using the app on each day of week and time of day interval. A higher proportion of Users started using the app during the daytime on weekdays than Dropouts (20.28%, 5237/25,820 vs 15.34%, 24,718/161,113; $\chi^2_{1}=356.3, P<.001$). Moreover, a higher proportion of Users started using the app especially during Tuesdays than Dropouts (17.66%, 4561/25,820 vs 14.88%, 23,974/161,113; $\chi^2_{1}=133.4, P<.001$).

Most common dietary preferences (see Table 2) reported by users during the first use of the app were “I eat everything” (46.33%) or undefined (42.22%). In total, 8.97% of the users were considered to have Strict diets. Table 5 presents the differences in adherence levels between dietary preference

groups among users who took at least one valid picture. Users with Strict diets were the most likely (14.31%, 900/6291) and users who had not defined any diet were the least likely (3.99%, 742/18,590) to use the app actively. A similar trend was observed when Semi-active users were included in the comparisons: half (50.45%, 3174/6291) of the users with Strict diets were Semi-active or Active, a significantly higher proportion than among users who had not defined their diets.

Engagement of the user during the initiation of self-monitoring was also assessed by examining the textual description given for the first picture. A textual description for the first picture was given by 26.09% (15,179/58,170) of users who had at least one valid picture among the first two pictures they had taken. Table 6 presents the comparisons between different adherence groups. Active users had written a description for the first picture more often than Semi-actives or Non-actives, and the average description was also longer in the number of characters.

Table 5. Proportions of Semi-active and Active users in each dietary preference category out of all users who took at least one valid picture.

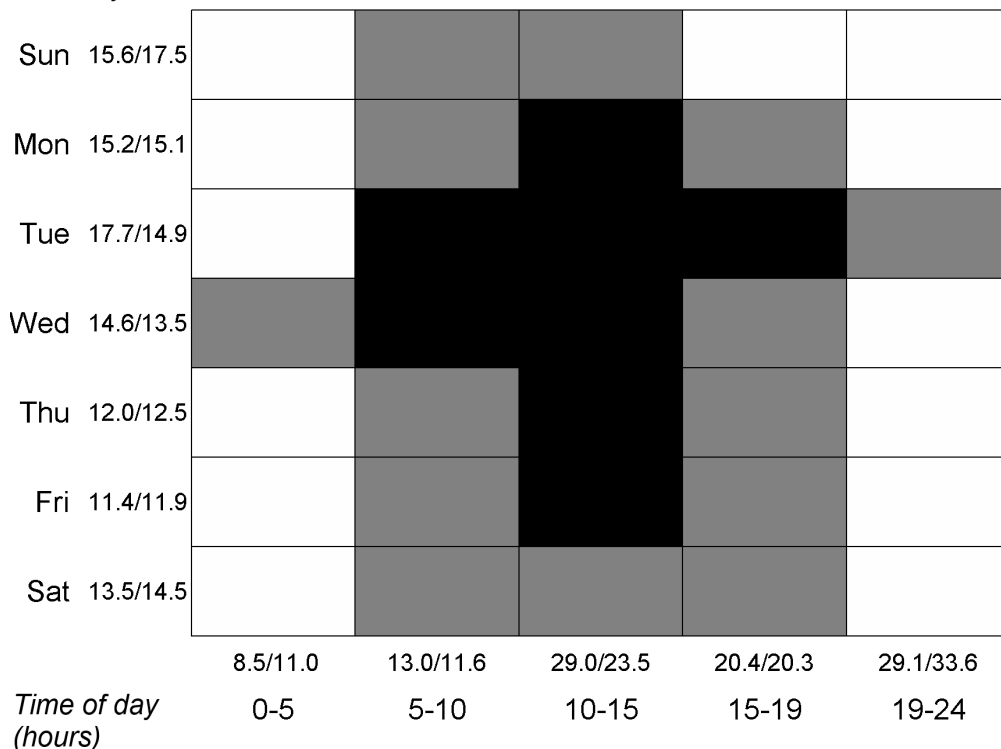
Users	1. Not defined, n (%) n=18,590	2. Everything, n (%) n=32,090	3. Strict, n (%) n=6291	4. Other, n (%) n=1798	Test statistics	Differences in post hoc comparisons
Actives / Users+Non-actives	742 (4.0%)	3040 (9.47%)	900 (14.31%)	213 (11.9%)	$\chi^2_{3}=826.6, P<.001$	All groups
Users / Users+Non-actives	7188 (38.67%)	14,560 (45.37%)	3174 (50.45%)	899 (50.0%)	$\chi^2_{3}=371.8, P<.001$	All but not 3 and 4

Table 6. Comparison of user engagement in the first self-monitoring entry between different adherence groups as measured by the presence and length of textual description for the picture.

First picture characteristics	1. Non-actives (n=32,648)	2. Semi-actives (n=20,659)	3. Actives (n=4863)	Test statistics	Differences in post hoc comparisons
Presence of textual description, n (%)	5783 (17.71%)	6824 (33.03%)	2572 (52.89%)	$\chi^2_2=3515.1, P<.001$	All groups
Number of characters in description (if existed), mean (SD)	20.1 (15.8)	23.4 (17.5)	26.8 (19.1)	$F_{2,15176}=150.1, P<.001$	All groups

Figure 2. Correlations between users' adherence level and their local registration time. Black=higher proportion of Users ($P<.0014$); White=higher proportion of Dropouts; Grey=no difference. Numbers separated by slashes next to weekday and time of day labels are percentages of Users/Drop-outs for corresponding rows and columns.

Weekday



Peer Feedback

Feedback received by the users' first pictures was examined to determine whether higher level of feedback on the initiation of self-monitoring was connected with adherence. The first picture had at least one like among 7.68% (4470/58,170) of the users and at least one comment among 3.85% (2240/58,170) of them. Table 7 presents the comparisons of variables related to peer feedback between different adherence groups. Small but significant differences were found between Active and less active users for all variables: the average healthiness rating was

higher and the proportion of pictures having comments and likes was higher. Still, comments and likes were relatively rare even among Active users.

Peer feedback was also examined from the perspective of users who gave the ratings to others. Analysis of dietary preferences and rating activity found that users in the "Not defined" diet group gave 21.81% (1,732,976/7,946,447) of all ratings, users in the "Everything" group gave 52.83% (4,198,272/7,946,447), users with Strict diets gave 20.70% (1,645,134/7,946,447), and users with some Other diet gave 4.66% (370,065/7,946,447) of all ratings.

Table 7. Amount and quality of peer feedback for the initial self-monitoring record in the app between different adherence groups.

First picture characteristics	1. Non-actives (n=32,648)	2. Semi-actives (n=20,659)	3. Actives (n=4863)	Test statistics	Differences in post hoc comparisons
Average healthiness rating, mean (SD)	0.49 (0.21)	0.52 (0.20)	0.55 (0.19)	$F_{2,58167}=225.9, P<.001$	All groups
Difference to peer ratings, mean (SD)	0.04 (0.22)	0.04 (0.21)	0.05 (0.18)	$F_{2,57738}=5.1, P=.006$	1 and 3, 2 and 3
Having at least one like, n (%)	2031 (6.22%)	1792 (8.67%)	647 (13.30%)	$\chi^2_2=343.6, P<.001$	All groups
Number of likes (if at least one), mean (SD)	1.1 (0.3)	1.1 (0.4)	1.2 (0.4)	$F_{2,4467}=13.6, P<.001$	1 and 3, 2 and 3
Having at least one comment, n (%)	663 (2.03%)	1088 (5.27%)	489 (10.06%)	$\chi^2_2=909.6, P<.001$	All groups
Number of comments (if at least one), mean (SD)	1.2 (0.6)	1.3 (0.9)	1.4 (1.1)	$F_{2,2237}=15.1, P<.001$	1 and 3, 2 and 3

Changes in Healthiness Ratings

Among the 4863 Active users who had at least one valid picture as their first or second picture, 481 (9.89%) had a significant positive trend in healthiness scores. These “Improvers” differed from other Actives by having a higher total number of pictures (mean 126.68, SD 183.73 vs mean 51.41, SD 82.16; $t_{4861}=16.19; P<.001$), a longer usage period in days (mean 68.17, SD 42.95

vs mean 44.16, SD 36.34; $t_{4861}=13.54; P<.001$), and a higher number of pictures per day (mean 1.80, SD 1.70 vs mean 1.55, SD 1.58; $t_{4861}=3.25; P=.001$). In other words, they used the app for a longer time and did dietary self-monitoring more frequently.

Users with Strict diets had higher healthiness scores than users in other dietary preference categories and they also had the highest proportion of Improvers (Table 8).

Table 8. Average healthiness rating and number of users (Actives) that had a significant linear coefficient in their healthiness rating in each dietary preference category.

Scores/users	1. Not defined (n=732)	2. Everything (n=3023)	3. Strict (n=896)	4. Other (n=212)	Test statistics	Differences in post hoc comparisons
Average healthiness rating (first picture), mean (SD)	0.54 (0.19)	0.53 (0.19)	0.60 (0.18)	0.56 (0.18)	$F_{3,4859}=29.3, P<.001$	1 and 3, 2 and 3, 3 and 4
Average healthiness rating (all pictures), mean (SD)	0.56 (0.08)	0.57 (0.09)	0.63 (0.08)	0.60 (0.10)	$F_{3,4859}=149.8, P<.001$	All groups
Number of Improvers, n (%)	55 (7.51%)	281 (9.30%)	125 (13.95%)	20 (9.43%)	$\chi^2_3=22.5, P<.001$	1 and 3, 2 and 3
Number of Decliners, n (%)	14 (1.91%)	72 (2.38%)	32 (3.57%)	6 (2.83%)	$\chi^2_3=5.4, P=.15$	None

Discussion

Overall Adherence and Changes in Healthiness Ratings

Almost 190,000 people downloaded the app, The Eatery, between October 2011 and April 2012, but attrition was very high: less than 3% were active users, that is, used the app for more than a week and took 10 or more food pictures. Most of the users did not take any pictures (69%) or took only one picture (17%), which means that they only downloaded the app and experimented with it once without starting dietary self-monitoring. This is similar to most free apps, which are easy to join and try out even if there is no serious intention or

commitment to start using the app [13,25]. Given the short usage period for majority of the users, many probably tried out the application for fun.

The Eatery was not marketed as a weight loss app but instead as a method to eat healthier (“Stop counting calories, start eating better”), and hence may have attracted a large number of users with no real interest in dietary improvements and thus lacking motivation for dietary self-monitoring. However, the few active users used the application on average 1.5 months. Dietary self-monitoring for this amount of time would be enough to lead to increased awareness of eating habits and changes in behavior, if done diligently. The average healthiness rating of

all pictures was 0.58, slightly above the midpoint on the scale of 0 (“fat”) to 1 (“fit”). Hence, users did not photograph only healthy foods and there was room for improvement. A positive trend in healthiness ratings was still observed among only 10% of active users (0.3% of all users). Even if we assume that this trend reflects changes in their real-life eating behavior, the impact of the app on eating choices (or choosing which foods to record) appears to have been very small. Active users took less than two pictures per day on average, which means that a large portion of their eating was left unrecorded. Thus, the positive trend among some users could also mean that they started “gaming the system” by selectively photographing their foods to get better ratings and comments.

Initiation of Self-Monitoring

Users who used the app for the first time on weekdays (especially on Tuesdays or Wednesdays) and during morning or daytime became semi-active or active users more often than those who started using the app during evenings or weekends. People’s varying eating patterns that depend on their schedules during workdays and outside work [34] can help explain this finding. Prior studies have found that diet quality is generally poorer during weekends than on weekdays and calorie intake is higher, especially in the form of fat and alcohol [31,32,35], so people do not necessarily want to start tracking their eating at these times. Moreover, people are generally less work-oriented in the evening and during weekends and may try out different apps just for fun. In contrast, someone who downloads a healthy eating app in the middle of the week during daytime probably has the intention to start keeping track of their eating. This time period could also be a fruitful time to suggest initiation of lifestyle changes, although everyone does not have the same work schedules.

The dietary preferences reported on the initial use were also connected to adherence level. Users who reported a “strict” diet (low fat, low/no carbs, or vegan/vegetarian) were most likely to become active users. They also gave 21% of all ratings, although only 9% of all users belonged to the strict group. Hence, it is possible that users with strict diets were already most interested in healthy eating. This is also supported by their healthiness ratings: active users with strict diets had higher average healthiness ratings for their first picture and also higher average healthiness ratings for all pictures than users in other dietary preference groups.

The motivation of sustained users might already be seen on the initiation of self-monitoring by looking at how much time and cognitive capacity they devote to it. This is supported by the finding that more than half of the active users (53%) gave a textual description for their first picture whereas less than one-fifth of the non-active users (18%) did so. In addition to pre-existing intention to start dietary self-monitoring, the initial user experience of the app most likely influenced the users’ intention to continue using it. Positive feedback received from peers for the first picture taken by the user was associated with higher adherence; active users had higher average healthiness ratings for the first picture than less active users. This begs the question—did they happen to take a picture of a healthy food and were encouraged by the good feedback to continue using

the application or were they already healthy eaters, thus naturally photographing a healthy food? Because a higher proportion of active users also used the app for the first time during weekdays and daytime, the food that they chose to photograph first was probably their workday lunch, which is often healthier than foods that are eaten during weekends [35]. Hence, the timing of the initial use of the dietary self-monitoring app may be important both in terms of the users’ pre-existing motivation and the type of reinforcing feedback generated by the app.

Peer Feedback

Although active users obtained more comments and likes for their pictures from peers than those who took only few pictures, the total percentage of pictures with comments (4%) and likes (15%) was quite low. Thus, most users had no connection to other users other than receiving and giving anonymous ratings. The social network formed in such a way is very loose: users neither know whose pictures they rate nor have any knowledge of who rates their pictures. The app itself did not offer explicit advice on what to do to improve eating habits or what constitutes a healthy diet. It may be that if users are merely told that their meal is unhealthy but not given any advice on what to do to make it better, they do not get enough value out of the experience and subsequently lack motivation to continue using the app [36]. People may also have very different ideas about what healthy or “fit” food is, but these differences do not seem to have influenced adherence in this study. Although the difference between the user’s own rating and average peer ratings was highest among active users, in practice this difference was very small.

An app like this relies on its users to provide one of its core functions, that is, peer feedback. It would be interesting to study what motivates people to participate in this crowdsourcing activity of giving ratings to others. One explanation is the reciprocity of the action: when a user rates someone else’s pictures, they also get ratings for their own. However, engaging in this activity for a long time might require an existing community or formation of stronger ties between users [27].

Limitations and Challenges

The most significant limitation of the study is the lack of information about user demographics, behavioral outcomes, and initial motives. For example, the association between outcomes and adherence to dietary self-monitoring has been found to differ between race and gender groups in weight loss interventions [12], and it would have been interesting to see if similar patterns had emerged in this context. In this study, the application only provided data about the users’ dietary preferences. The general statistics about smartphone users in early 2012 suggest that iPhone users were slightly older than Android users and downloaded more apps in a month than users of other smartphone systems [37]. Users of The Eatery owned an iPhone so it is possible that their characteristics followed the same pattern. Collecting comprehensive data about users’ background may be challenging in free apps, which aim for fluent user experience, but creative ways to gather data such as asking one question per usage occasion could be devised in further studies.

The reliability of healthiness ratings is questionable because they were entirely crowdsourced. The idea of crowdsourcing is to take an average of many individuals' estimates resulting in an estimate that can be surprisingly close to the truth, although individuals' separate values may lie far from it. Crowdsourced ratings can be biased, resulting from cultural differences [26] or rater's own food preferences. When pictures are rated as in this study, the quality of the picture is also likely to make a difference. Portion size estimation is difficult even when measurement aids are present in the picture [18,19,38]. Moreover, users did not photograph everything they ate so there is no way of knowing how healthily people ate in general and whether the observed positive trend in healthiness ratings among 10% of active users meant anything in practice.

Dietary decisions are often unconscious and affected by environmental factors more than people believe [39]. In this study, the location information of where the pictures were taken was available, but was not exploited, although dietary behaviors are likely to be linked with locations. In a recent study [40], volunteers used Twitter to report their food and were encouraged to add a photo and contextual information, such as company, mood, and reasons for eating. The data was used visualize the relationships between dietary and behavioral factors.

Some updates were released to the app during the six-month timeframe of data collection. These updates consisted of minor modification and fixes in the user interface of the app. They may have had a minor influence on the user experience of the app, but they were not included in the analyses since the main features and functions remained the same.

Finally, the app utilized self-regulation techniques of self-monitoring and feedback, but lacked other techniques

derived from control theory [4,5]. The app did not prompt users to set specific goals or review behavioral goals and only implicitly prompted intention formation ("eat healthy"). Implementing these techniques could have given users a more specific purpose for using the app. Practical advice for healthy eating could also have been given by formation of implementation intentions through if-then planning, which has been shown to increase effectiveness of healthy eating interventions [10].

Conclusions

As with most mobile apps, the majority of users tried the dietary self-monitoring app only once. Adherence was higher among users who had diets that were likely to restrict at least some unhealthy foods, and these kinds of users were also more active in rating other users' foods. This could mean that this kind of an application attracts users with special diets and/or those interested in food. Moreover, initiation of self-monitoring in the middle of the week during daytime and the amount of feedback from peers were connected to higher adherence.

Even though the findings show that the app reached a large number of people, its actual impact among users remained small because most did not even start dietary self-monitoring with the app. If people would use the app as intended for dietary self-monitoring on a regular basis, they could experience some benefits through heightened awareness of their eating habits. Still, the app did not implement all self-regulation techniques that could have strengthened its impact and it lacked means to track changes in eating behavior systematically. Reaching those users who could benefit the most from dietary self-monitoring and maintaining their adherence remains a challenge.

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Conflicts of Interest

None declared.

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Abbreviations

ANOVA: analysis of variance

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STUDY III

**Feasibility of a personal
health technology-based
psychological intervention
for men with stress and mood
problems**
Randomized controlled pilot trial

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Original Paper

Feasibility of a Personal Health Technology-Based Psychological Intervention for Men with Stress and Mood Problems: Randomized Controlled Pilot Trial

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Abstract

Background: Work-related stress is a significant problem for both people and organizations. It may lead to mental illnesses such as anxiety and depression, resulting in increased work absences and disabilities. Scalable interventions to prevent and manage harmful stress can be delivered with the help of technology tools to support self-observations and skills training.

Objective: The aim of this study was to assess the feasibility of the P4Well intervention in treatment of stress-related psychological problems. P4Well is a novel intervention which combines modern psychotherapy (the cognitive behavioral therapy and the acceptance and commitment therapy) with personal health technologies to deliver the intervention via multiple channels, including group meetings, Internet/Web portal, mobile phone applications, and personal monitoring devices.

Methods: This pilot study design was a small-scale randomized controlled trial that compared the P4Well intervention with a waiting list control group. In addition to personal health technologies for self-assessment, the intervention consisted of 3 psychologist-assisted group meetings. Self-assessed psychological measures through questionnaires were collected offline pre- and post-intervention, and 6 months after the intervention for the intervention group. Acceptance and usage of technology tools were measured with user experience questionnaires and usage logs.

Results: A total of 24 subjects were randomized: 11 participants were followed up in the intervention group (1 was lost to follow-up) and 12 participants did not receive any intervention (control group). Depressive and psychological symptoms decreased and self-rated health and working ability increased. All participants reported they had benefited from the intervention. All technology tools had active users and 10/11 participants used at least 1 tool actively. Physiological measurements with personal feedback were considered the most useful intervention component.

Conclusions: Our results confirm the feasibility of the intervention and suggest that it had positive effects on psychological symptoms, self-rated health, and self-rated working ability. The intervention seemed to have a positive impact on certain aspects of burnout and job strain, such as cynicism and over-commitment. Future studies need to investigate the effectiveness, benefits, and possible problems of psychological interventions which incorporate new technologies.

Trial Registration: The Finnish Funding Agency for Technology and Innovation (TEKES), Project number 40011/08

KEYWORDS

stress; technology-supported mini-intervention; personal health technologies; cognitive behaviour therapy; acceptance and commitment therapy; mhealth; mobile health; smartphone; Internet

Introduction

Work-related stress is one of the biggest health challenges that the world faces at this moment. According to the 2009 European Risk Observatory Report, stress is the second most frequently reported work-related health problem and affects 22% of working Europeans [1]. Long-term exposure to work-related stress has been linked to an increased risk of psychological problems, such as depression, anxiety, emotional exhaustion, and may lead to long-term absenteeism, work disability, and early retirement [2].

Several studies have investigated work-related mental health [3,4]. Psychological interventions based on cognitive behavioral therapies (CBT) have a proven effectiveness for a range of common mental health disorders [5-7]. CBT is also an effective intervention for occupational stress [8-11]. Besides traditional CBT methods, research suggests that stress management interventions based on the acceptance and commitment therapy (ACT) have a positive impact on employees' psychological health, well-being, and stress management skills [12-19]. Research implicates that psychological acceptance promoted by ACT is associated with not only mental health variables but also with a performance-related variable.

Lifestyle-related chronic conditions are an increasing problem in the developed world. Most existing health services do not have sufficient resources to support long-term individual interventions. The delivery of current disease prevention and management models are not feasible due to their high cost and they do not always reach those who need them. Therefore, new models of prevention and treatment measures based on self-management are needed. Personal health systems including Web-based programs, mobile devices, and other health monitoring tools may be used for self-management of chronic conditions and behavioral change [20].

Internet-based and computer-aided treatments have been shown to be effective in treating a wide range of psychological problems, and have effect sizes (ES) comparable to those found for more traditional types of psychological treatments [21-32]. Seymour and Grove [33] have pointed out that accessibility and acceptability are key issues for further research in addition to effectiveness. To address these issues, Web-based treatment programs can be complemented by mobile and wearable technologies for self-monitoring to best suit the user's needs and preferences and also to potentially enhance the effect of the intervention. In addition, technology delivered interventions may be complemented by traditional intervention methods such as individual or group face-to-face meetings and phone counseling.

P4Well is a novel CBT- and ACT-based intervention which combines personal health technologies (mobile, Web, and self-monitoring technologies) to an intervention program which

is based on group meetings [34,35]. In intervention design, our aim was to combine the cost-effectiveness of the group meetings to a personalized intervention enabled by technology tools. We designed the intervention program content and technology toolkit in parallel, matching them to each other. The P4Well intervention utilizes a variety of technology tools which allow personalization of the intervention methods and feedback. This may increase the acceptance and efficacy of the intervention by giving the users the possibility to choose appropriate self-management tools according to their personal interest.

The objective of this study was to study the feasibility and effectiveness of the developed P4Well intervention among working age males who experienced mild to moderate symptoms of stress and/or depression. We assessed the effects of the intervention using depression, psychological symptoms, and stress as primary outcome measures and compared these effects to a control group without intervention. Secondary outcome measures included quality of life, psychological flexibility, and job strain. Furthermore, we studied the acceptability and usage of the intervention and its components.

Methods**Recruitment and Allocation**

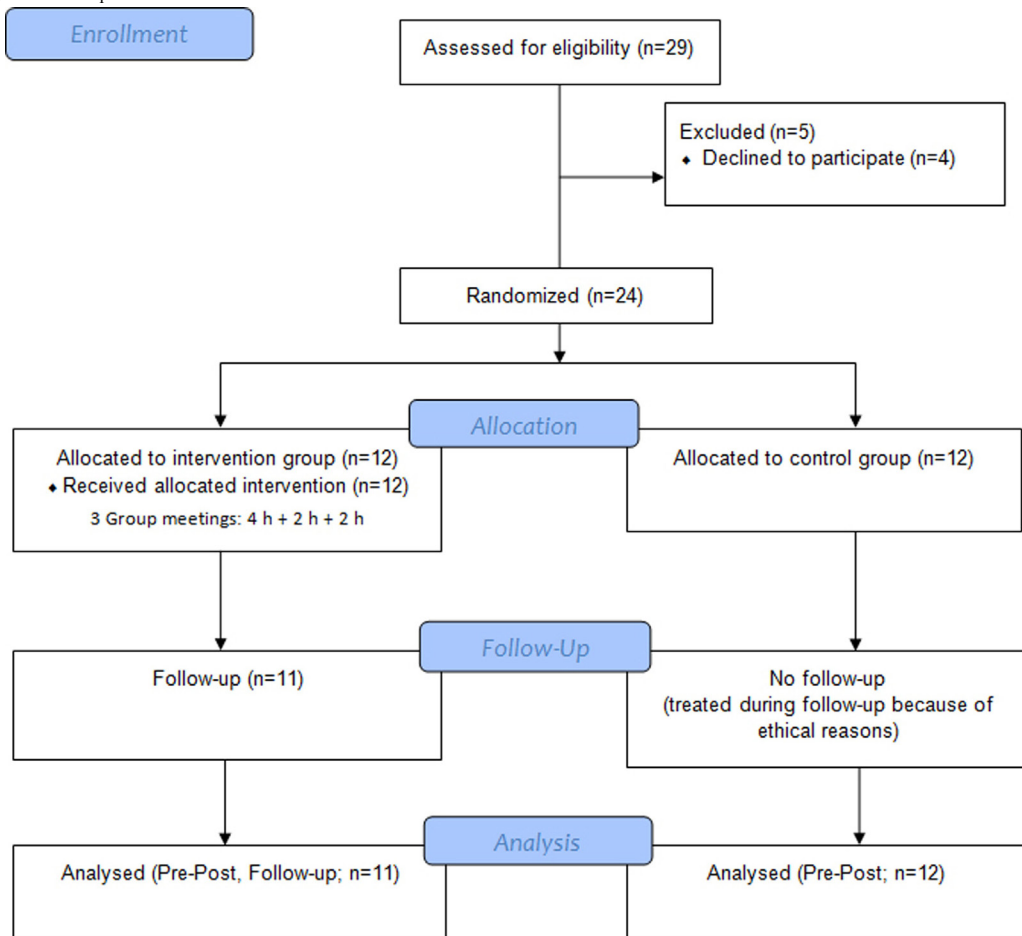
Participants were recruited through an advertisement in a local newspaper, seeking males aged 25 to 45 years old with exhaustion, stress symptoms, or sleeping problems. Other inclusion criteria were full time employment, basic computer skills, and access to Internet. Exclusion criteria included diabetes and simultaneous attendance in other stress management programs. We focused this study on male adults because men have a lower tendency to seek treatment for psychological problems compared to females [36,37]. The psychotherapy clinic of the University of Jyväskylä was contacted by 29 respondents via telephone or email. Before randomization of subjects into the research groups, 4 men dropped out. Since fewer participants responded to the advertisement than expected, we also included respondents older than 45 years of age in the study. The adjusted age range was 28 to 58 years. Of the 25 male participants, we excluded one participant from analysis because he did not fulfill the inclusion criteria (because of age and retirement) and one participant who did not participate in the follow-up measurements. One participant in the intervention group was lost at follow-up (Figure 1). Thus, the total number of participants included in the study was 23. Dropout (n=1) was treated with an intention-to-treat-analysis using the data missing principle of last observation carried forward. We then randomly allocated participants either to the intervention or the waiting list control group (intervention group=11, control group=12). The sample was first divided into pairs based on participants with similar depression scores, measured by Beck's Depression Inventory (BDI) [38]. Second, the order of pairs was randomized. Third, participants within pairs were randomly

assigned either to intervention or control group. Thus, the groups were made equal on the basis of reported depressive symptoms and the researchers generated the randomization. Consent from participants was obtained offline in paper format at pre-measurement. Participants received detailed information about the study procedure and their rights.

The study took place at the psychotherapy clinic of the department of psychology at the University of Jyväskylä, Finland, from January 2009 to October 2009. The Research

Ethics Committee of the University of Jyväskylä approved this study. The study was funded by the Finnish Funding Agency for Technology and Innovation (TEKES). The study was not registered in a public trials registry, because the study was a phase 1 small-scale pilot study including no participants with medical or psychiatric diagnosis. The study tested a psychological and technical intervention without any side effects. The funding of the project required that participants with diagnoses should not be included in the study.

Figure 1. Participant flow chart.



Participants

The mean age of the participants was 47.1 years (SD 4.72) in the intervention group and 39.4 (SD 7.96) in the control group

(Table 1). The intervention group was older, $t_{21}=2.78, P=.011$, and had a lower BMI, $t_{21}=2.42, P=.025$, than the control group. The groups did not differ in regard to education, type of work, shift work, or reported depressive symptoms.

Table 1. Participant characteristics.

Background variable	Intervention (n=11)	Control (n=12)
Age	47.1 (4.7)	39.4 (8.0) ^a
Body Mass Index	24.4 (3.1)	28.1 (4.2) ^a
Education (yrs)	7.1	7.2
Married (%)	7 (63)	10 (83)
Permanent employment (%)	9 (82)	11 (92)
Fulltime work (%)	10 (91)	12 (100)
Shift work (%)	11 (100)	11 (92)
No physical work (%)	8 (73)	8 (67)
Depressive symptoms (%) ^c	7 (63)	6 (50)
Medication (%) ^d	4 (44)	1 (8)

^aP=.011^bP=.025^c score is 10 or greater in Beck's Depression Inventory^d use of antidepressants and/or hypnotics

Intervention

The P4Well intervention integrated different personal health technologies, including a Web portal, mobile phone applications, personal monitoring devices, and analysis software, with a CBT- and ACT-based intervention program which was specifically designed to utilize personal health technologies (Figure 2). The main idea behind the intervention concept was to combine cost-efficiency of group meetings, personalization and self-monitoring capabilities provided by technologies, and, technology use between the group meetings to increase the continuity and impact of the intervention. The intervention program consisted of 3 group meetings held by a psychologist. The main CBT- and ACT-based methods used in the intervention included clarification of personal values, goal setting, self-monitoring, relaxation, mindfulness, and acceptance procedures. Furthermore, regular physical activity was encouraged and emphasized as means for stress reduction, mood elevation, and improved well-being.

Participants placed in the control group did not receive any technical tools or group meetings during the study period. Pre-measurement consisting of self-assessed questionnaires in paper format and heart rate variability recording was done for both the control and intervention groups before the first group meeting. Both groups had an individual assessment meeting during the pre-measurement phase where they received questionnaires and were given a wearable beat-to-beat heart rate (HR) recording device (Suunto Memory Belt, Suunto Ltd, Vantaa, Finland) with instructions to do a 3-day HR variability (HRV) recording. One week after the assessment meeting, the questionnaires and the heart rate belts were collected and analyzed. Feedback was given to both groups by an exercise physiologist. The intervention group received feedback for the HRV recording (1 hour individual discussion of topics concerning stress, sleep and relaxation, and exercise habits) after the first group meeting. Two weeks after the intervention

group finished its third and last meeting (ie, after 3 months), both groups were measured for the second time (post-measurement). Follow-up questionnaires were sent to the intervention group 6 months after the intervention ended (intervention group follow-up, n=11). We offered the control group 1 mini-intervention meeting after the post-measurement. Feedback of the recordings for the control group was given during the mini-intervention.

The first intervention group meeting was an informative and motivating session that consisted of: (1) measurements (background information questionnaire, technology literacy and attitude questionnaire, and psychological questionnaires), (2) general background information about the P4Well intervention and introduction to the wearable technologies, and (3) the psychological mini-intervention (90 minutes). Participants were provided with credentials to the Web portal, mobile phones (Nokia E51) with preinstalled mobile applications (Wellness diary, Fitness coach, and Relaxation assistant; Figure 3), pedometers, heart rate monitors, and actigraphs. The ACT value analysis method was used to initiate the intervention by motivating behavioral changes in the participants [39,40]. Participants were asked to define their valued directions and goals, as well as actions to accomplish these goals. Additionally, a mindfulness exercise was carried out and participants were instructed to practice mindfulness and relaxation by doing exercises in the Web portal and with a mobile phone application. A self-observation worksheet was presented to encourage participants to begin their self-observations. As a homework assignment, participants were asked to further clarify their personal values and select actions based on these values and to conduct mindfulness exercises. Participants were also asked to start monitoring their sleep with the actigraph. The participants were encouraged but not required to start using one or more mobile applications and begin their self-observations after the group meeting.

The second group meeting (2 hours) was given 4 weeks later. The psychological assessment Web tool in the portal including individual problem analysis was presented and participants were asked to reflect over their situation (eg, stressors in their daily life, sleep, exercise habits, and variables affecting these factors). Participants were encouraged to continue working with the assessment tool at home. The session was ended with a mindfulness exercise. Actigraphs were collected from the participants and analysis reports about sleep and activity were sent to them through the Web portal after the meeting. The participants were encouraged to continue their self-observations with the technology tools.

The third group meeting (2 hours) took place 4 weeks after the second group meeting. The theme of the meeting was acceptance, which involves a willingness to experience all psychological events (thoughts, feelings, and physiological sensations), especially negatively evaluated events, without avoiding, changing, or controlling them [39,40]. Experiential exercises, such as metaphors and exercises related to acceptance, were carried out and discussed. At the end of the group meeting, all of the provided technology tools were collected from the participants. After the meeting, the 3-day HRV recording was repeated, accompanied by an individual stress and recovery analysis. The participants completed the final psychological and user experience questionnaires (sent through mail) 2 weeks after the last group meeting (post-measurement).

Figure 2. P4well intervention process.

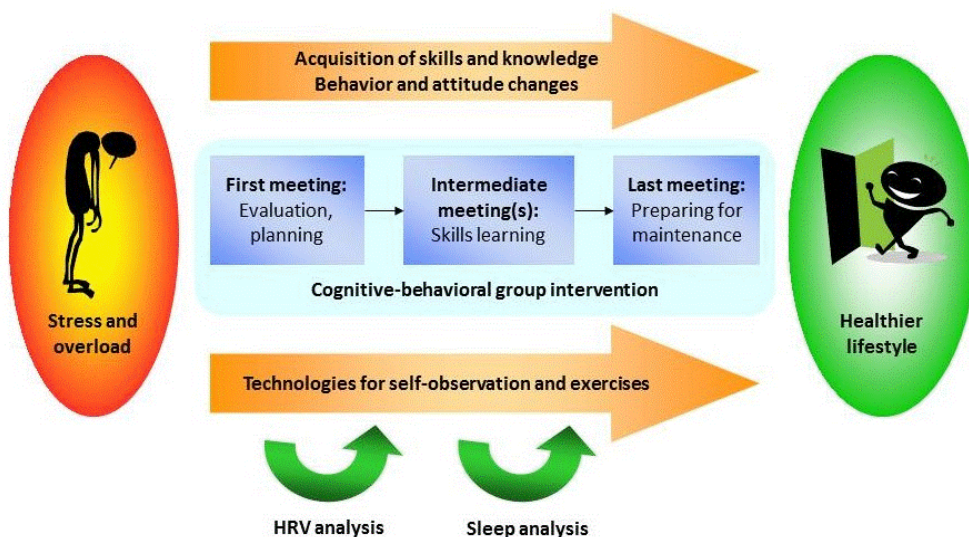


Figure 3. Screenshots of the 3 mobile applications.



Technology Tools

The personal health technologies that were provided to the participants formed a wellness toolkit from which the participants could choose the most appropriate ones for their needs and preferences. The toolkit included a Web portal, a mobile phone with 3 preinstalled applications, a pedometer and a heart rate monitor. Additionally, the participants wore heart rate belts (Suunto Memory Belt, Suunto Ltd, Vantaa, Finland) for 3 days before and after the intervention period to obtain HRV recordings and actigraphs (Vivago Personal Wellness Manager, Vivago Ltd, Helsinki, Finland) for 4 weeks during the intervention to obtain sleep recordings. Based on these recordings, individual feedback reports were given to the participants. Full details of the P4Well technology toolkit have been described elsewhere and so only a brief outline will be provided here [34,35,41].

The secured Web portal (Figure 4) provided the participants access to information, exercises, self-assessment and self-reflection tools, Web-based wellness services, peer support, and expert consultation. The content of the portal was divided into modules focusing on different areas of well-being—sleep,

exercise, mood, stress and recovery, and good life. The modules consisted of 5 phases: information, evaluation of personal status, planning of lifestyle changes, putting the plans into action, and follow-up. In addition, the portal included a discussion forum and a messaging client for expert consultation. Mobile wellness diary entries were made available through portal interface (Nokia Wellness Diary Connected, Nokia Corp, Espoo, Finland) and access to an adaptive Web-based fitness training program was also included (Firstbeat WebTrainer, Firstbeat Technologies Ltd, Jyväskylä, Finland). Finally, the participants could utilize a library of evidence-based health-related information through the portal (Duodecim Health Library, Duodecim Medical Publications Ltd, Helsinki, Finland).

The purpose of the 3 mobile phone applications (Figure 3) was to better integrate wellness management and self-monitoring into the participants' daily lives. The first application was a mobile wellness diary (Nokia Wellness Diary (WD), Nokia, Espoo, Finland) that could be used to make daily self-observations on wellness related parameters. The second application was a mobile phone version of the fitness training program (Firstbeat Mobile Coach, Firstbeat Technologies Ltd, Jyväskylä, Finland), and the third one was a mobile phone

relaxation assistant which included personalized relaxation programs (SelfRelax, Relaxline, France).

The participants were encouraged to monitor their physical activity with a heart rate monitor (Suunto Ltd, Vantaa, Finland) or a pedometer (Omron, Kyoto, Japan). Heart rate monitors

were primarily meant for participants who were interested in fitness training, whereas pedometers were used to measure and encourage everyday activity. Participants could enter step counts and other exercise parameters manually as daily self-observations into WD.

Figure 4. The main screen of the P4Well web portal.



Measures

Primary Outcome Measures

We measured symptoms of depression using BDI, a widely used 21-item self-report measure of depression [38].

Psychological symptoms were measured using the general symptom index (GSI), which is based on the 90-item symptom checklist (SCL-90). The SCL-90 has been validated for the Finnish population. In a Finnish community sample ($n=337$) [42], the mean GSI was 0.60 ($SD=0.44$).

The primary stress measure was the Finnish 15-item version of the Bergen Burnout Indicator (BBI-15) [43], based on the original 25-item Bergen Burnout Indicator [44]. The BBI-15 measures 3 aspects of professional burnout: exhaustion, cynicism, and sense of inadequacy.

Secondary Outcome Measures

Quality of life included 5 items: mood, self-rated health, life satisfaction, self-confidence, and working ability. Participants' perceptions of each item were measured using a visual analogue scale (VAS) from 0 to 100 [45-47].

We measured psychological flexibility and experimental avoidance using the Acceptance and Action Questionnaire-2 (AAQ-2), a 10-item questionnaire that involves both the ability to accept difficult thoughts and feelings as well as to engage in valued activity in their presence (a 7-point Likert-type scale). High scores indicate high psychological flexibility (range 0-70). The AAQ-2 is a revised version of the original AAQ [48].

We measured job strain and over-commitment using the effort-reward imbalance (ERI) questionnaire, which measures extrinsic effort with six items and reward with 11 items. The ratio of effort to reward (ER-ratio) expresses the amount of effort-reward imbalance. High scores indicate high job strain. The ERI questionnaire also includes 6 items that measure over-commitment [49].

User Experiences and Usage

User experiences were measured post-intervention with a questionnaire about perceived utility and acceptance of each individual technology tool, and the perceived usefulness of different intervention components. The perceived utility of the intervention as a whole was assessed with questions about perceived benefits from participation in the study. Usage logs were collected from the portal and the mobile applications after the end of the intervention. For pedometers and heart rate monitors, usage frequency was assessed through the post-intervention questionnaire. Participants were defined as active users of a given tool if they had used it during at least half of the study weeks (based on log data) or reported having used it at least weekly (questionnaire data).

Statistical Analyses

We performed statistical analyses using SPSS 15.0 for Windows (SPSS, Inc, Chicago, IL). A repeated-measures ANOVA evaluated the intervention effect with group (intervention vs control) as the between-subjects factor, and pre- and post-measurements as the within-subject factor. When analyzing pre-, post-, and follow-up measurements of the intervention group, a repeated-measures ANOVA was used. The level of

statistical significance was set at $P < .05$; however, due to the small sample size, we took into account interactions where $P < .10$. The ES, measured by Cohen's d , were calculated to measure clinically significant between group differences and within group changes. We calculated the post-treatment between-group ES by dividing the difference between the treatment mean and the control mean with the pooled standard deviation of the two conditions. The within-group ES was calculated by dividing the mean change from pre- to post- with the pre-treatment SD and the mean change from pre- to follow-up with the pre-treatment SD [50,51]. Between-group ESs of 0.2, 0.5, and 0.8 were considered small, medium, and large, respectively. Within-group ESs of 0.5, 0.8, and 1.1 were treated likewise [7,52].

Results

Acceptance and Usage

All participants in the intervention group stated that their well-being had improved as a result of the intervention. The

Table 2. Usage and user experiences of technology tools.

	Web portal	Wellness diary	Exercise coaching	Relaxation application	Pedometer	Heart rate monitor
Active users (n)	3	1	4	5	4	4
Easy to use ^a	6	5	5	8	11	0
Useful ^a	5	5	7	6	7	8
Personally suitable ^a	5	3	7	6	8	7
Motivating ^a	3	5	6	7	6	6

^aValues are the numbers of users who agreed or strongly agreed with the statement.

Efficacy

Depressive symptoms, as measured by BDI, decreased more in the intervention group compared to the control group (Table 3). There was a marginally significant group by time interaction effect for BDI ($P = .072$). The mean BDI value decreased with more than 8 scores (CI 4.92-11.99) in the treatment group compared to four scores (CI 0.62-7.38) in the control group. We found a medium ES ($d = 0.57$) between groups in favor of the intervention group. Participants maintained positive changes at the 6-month follow-up. We found a significant within-group effect over time for the intervention group ($P = .001$): both post- and follow-up measurements were significantly lower compared to the BDI pre-measurement. Pre- to follow-up BDI measurements indicated a large within-group ES ($d = 1.11$). An analysis of the number of the participants who reported depressive symptoms at pre-, post-, and follow-up measurements also suggested that the intervention had a positive effect on mood. At the beginning of the study, 64% (7/11) of the participants in the intervention group and 50% (6/12) in the control group reported at least mild depression (a BDI of at least 10). Only 9% (1/11) reported depressive symptoms in the intervention group after the intervention ended. In the control

group, 50% (6/12) were still depressed at post-measurement. At follow-up, only 1 person (9%) in the intervention group reported BDI values greater than 10.

Psychological symptoms (SCL-90) decreased in the intervention group but remained at the same level in the control group (Table 3). We found a marginally significant group by time interaction effect in psychological symptoms ($P = .053$). The between-group ES was small ($d = 0.39$). The within-group ES from pre- to follow-up measurement was medium ($d = 1.07$). Again, we found a significant within-group effect for the intervention group—both the post- and follow-up measurements were significantly lower compared to pre-measurement scores. A significant group by time interaction effect was found for health ($P = .008$) and working ability ($P = .016$). The between- and within-group ESs were small for both health ($d = 0.38$ and 0.56 , respectively) and working ability ($d = 0.21$ and 0.60 , respectively). Furthermore, for these variables we found a significant within-group effect in the intervention group. Thus, health was rated higher after treatment, and participants estimated their working ability to be higher at follow-up compared to the beginning of the treatment. As we can see from Table 3, there was some indication that life satisfaction increased from pre-measurement to follow-up, as well.

Table 3. Psychological symptoms and life quality for the intervention and control group.

		Pre Mean (SD)	Post Mean (SD)	95% CI for the difference		Follow-up Mean (SD)	Pre-Post group x time	Intervention within effect
				Lower	Upper			
Depression BDI								
	Intervention	14.64 (7.61)	6.18 (3.31)	4.92	11.99	6.18 (3.28)	F _{1,21} =3.59 P=.072	F _{2,20} =17.45 P=.001
	Control	13.33 (9.24)	9.33 (7.10)	0.62	7.38	-	d=0.57	d=1.11
Symptom SCL								
	Intervention	0.64 (0.27)	0.40 (0.18)	0.11	0.37	0.35 (0.18)	F _{1,21} =4.22 P=.053	F _{2,20} =10.28 P=.001
	Control	0.57 (0.30)	0.51 (0.36)	-0.07	0.18	-	d=0.39	d=1.07
Psych Flex AAQ								
	Intervention	52.46 (10.00)	55.73 (6.25)	-7.95	1.40	55.45 (7.26)	F _{1,21} =1.74 P=.201	F _{2,20} =0.93 P=.41
	Control	54.50 (7.82)	53.67 (9.60)	-3.64	5.31	-	d=0.25	d=0.30
Life Satisfaction								
	Intervention	59.91 (15.55)	66.09 (10.51)	-14.78	2.42	69.27 (13.45)	F _{1,21} =0.04 P=.838	F _{2,20} =5.68 P=.01
	Control	59.92 (17.29)	64.92 (15.50)	-13.23	3.23	-	d=0.09	d=0.60
Self-rated Health								
	Intervention	63.27 (13.86)	74.91 (11.64)	-18.89	-4.38	71.09 (15.41)	F _{1,21} =8.57 P=.008	F _{2,20} =5.18 P=.02
	Control	72.42 (10.26)	69.92 (14.49)	-4.44	9.44	-	d=0.38	D=0.56
Mood								
	Intervention	60.27 (17.35)	66.82 (8.34)	-14.38	1.29	66.09 (13.32)	F _{1,21} =0.08 P=.783	F _{2,20} =1.50 P=.25
	Control	57.08 (16.51)	65.08 (14.18)	-15.50	-0.50	-	d=0.15	d=0.34
Self-Confidence								
	Intervention	63.55 (15.63)	70.27 (15.85)	-15.80	2.34	74.73 (16.41)	F _{1,21} =0.07 P=.788	F _{2,20} =2.49 P=.11
	Control	69.58 (13.76)	74.67 (9.21)	-13.77	3.6	-	d=0.34	d=0.72
Working Ability								
	Intervention	64.36 (20.25)	74.00 (15.93)	-16.93	-2.34	75.45 (13.48)	F _{1,21} =6.86 P=.016	F _{2,20} =5.48 P=.01

	Pre	Post	95% CI for the dif-		Follow-up	Pre-Post	Intervention within
	Mean (SD)	Mean (SD)	ference Lower	Upper	Mean (SD)	group x time	effect
Control	74.00 (7.79)	70.92 (12.91)	-3.9	10.07	-	d=0.21	d=0.60

We did not observe a significant group by time interaction for burnout (Table 4). However, the burnout scores decreased from pre-measurement to follow-up and showed a medium ES ($d=0.91$). In the intervention group we found a significant within-group effect on cynicism, although there was no significant group by time interaction. However, we obtained a

medium (between group) ES for cynicism. There were marginally significant interaction effects on effort ($P=.07$) and over-commitment ($P=.08$). The scores for over-commitment were lower at follow-up compared to the beginning of treatment. The within-group ES from pre-measurement to follow-up was small for over-commitment ($d=0.61$).

Table 4. Burnout and stress for the intervention and control group.

		Pre Mean (SD)	Post Mean (SD)	95% CI for the difference		Follow-up Mean (SD)	Pre-Post group x time	Intervention within effect
				Lower	Upper			
Burnout								
	Intervention	3.52 (0.70)	3.03 (0.83)	0.16	0.82	2.88 (0.73)	F _{1,21} =1.02 P=.32	F _{2,20} =6.67 P=.006
	Control	3.64 (0.70)	3.38 (0.64)	-0.5	0.59	-	d=0.47	d=0.91
Exhaustion								
	Intervention	3.96 (1.10)	3.67 (1.15)	-0.09	0.67	3.42 (1.06)	F _{1,21} =0.01 P=.93	F _{2,20} =3.08 P=.07
	Control	4.13 (0.67)	3.87 (0.84)	-0.10	0.63	-	d=0.20	d=0.49
Cynicism								
	Intervention	3.15 (0.93)	2.42 (0.96)	0.32	1.14	2.22 (0.75)	F _{1,21} =2.63 P=.12	F _{2,20} =10.94 P=.001
	Control	3.22 (0.78)	2.93 (0.73)	-0.11	0.68	-	d=0.60	d=1.00
Sense of Inadequacy								
	Intervention	3.46 (1.10)	3.00 (0.96)	-0.1	0.92	3.00 (1.02)	F _{1,21} =0.44 P=.51	F _{2,20} =2.04 P=.16
	Control	3.58 (1.04)	3.33 (0.95)	-0.19	0.69	-	d=0.35	d=0.41
Effort								
	Intervention	3.39 (0.82)	3.21 (0.95)	-0.9	0.45	3.04 (0.90)	F _{1,21} =3.74 P=.07	F _{2,18} =2.08 P=.15
	Control	3.26 (0.66)	3.43 (0.40)	-0.43	0.09	-	d=0.36	d=0.41
Reward								
	Intervention	3.69 (0.68)	3.88 (0.95)	-0.56	0.18	4.18 (0.48)	F _{1,21} =0.59 P=.45	F _{2,18} =2.21 P=.14
	Control	3.64 (0.89)	4.02 (0.72)	-0.73	-0.03	-	d=0.04	d=0.62
Effort-reward imbalance								
	Intervention	0.96 (0.29)	0.91 (0.43)	-0.10	0.19	0.74 (0.25)	F _{1,21} =0.02 P=.89	F _{2,18} =2.43 P=.12
	Control	0.94 (0.27)	0.89 (0.23)	-0.08	0.19	-	d=0.13	d=0.69
Over commitment								
	Intervention	2.92	2.64	0.05	0.53	2.48	F _{1,20} =3.53	F _{2,18} =4.03

	Pre	Post	95% CI for the difference		Follow-up	Pre-Post	Intervention
	Mean (SD)	Mean (SD)	Lower	Upper	Mean (SD)	group x time	within effect
Control	(0.64)	(0.61)			(0.57)	<i>P</i> =.08	<i>P</i> =.04
	2.79	2.80	-0.25	0.22	-	<i>d</i> =0.44	<i>d</i> =0.61
	(0.53)	(0.44)					

In the group intervention, the amount of therapist face-to-face contact time was 8 hours (4 + 2 + 2), totalling 480 minutes (including measurements). Thus, the therapist contact time used for each participant during the intervention was 44 minutes.

Discussion

The objective of this study was to assess the feasibility of the P4Well intervention in the target population of working-age adults who experience mild psychological and stress-related symptoms. Our results confirm that the intervention was acceptable and personal health technologies were actively used by the participants. The results also suggest that the intervention had a positive effect on our primary outcome measures (depressive and psychological symptoms) as well as on self-rated health and working ability. The intervention was also cost-effective. The total professional time used during the active intervention period was less than 1 hour per person.

Before the intervention, the majority of participants reported symptoms of depression; after the intervention only 1 reported symptoms of depression. The intervention group's within-group ES (measuring clinical significance) from pre-measurement to the follow-up was large and the between-group post-treatment ES was medium. These effects are in line with other studies investigating the effects of cognitive-behavioral methods. Meta-analysis from Gloaguen et al [53] found that the between-group ES between CBT and controls was typically $d=0.82$. In our study, the ES was somewhat smaller ($d=0.57$), however the ES was at least the same or larger compared to groups taking anti-depressant medications. Our data also indicated that the intervention might have positive effects on burnout symptoms: participants' BBI-15 scores were lower at the 6-month follow-up compared to the beginning of the treatment. Moreover, the results suggest that there were positive effects on cynicism and over-commitment related to recovery from stress and burnout.

Participants perceived the intervention as beneficial and useful, and reported reduced amount of stress, increased physical activity, and greater motivation to improve their well-being. Almost everyone took some of the technology tools into active use and each tool was considered useful, motivating, and personally suitable by several participants. These results suggest that offering several tools and techniques to support changes in multiple behaviors may be a promising approach in interventions that address psychological problems. Most interventions to this date have tailored their content to individual needs, but few have used multiple applications or delivery channels that could be freely chosen by participants based on their preferences.

There is a wealth of applications and devices available for self-monitoring of stress, mood, physical activity and sleep, and for relaxation and mindfulness skills training. Nevertheless, individuals struggling with psychological problems and stress may not be aware of the existence or usefulness of these tools. Based on the wide variety of reasons and behavioral treatment options for psychological problems, intervention outcomes and adherence may be improved by matching and recommending specific applications and/or devices to different needs and preferences of participants [54]. An intervention program should be designed with careful consideration of appropriate technology tools that best serve the purposes of the intervention.

Even though personal monitoring devices and mobile applications were received favorably and used actively, human contact was still highly valued. Personal feedback and advice based on physiological measurements was considered the most useful component of the intervention, and group meetings were also appreciated. Peer and counselor support may be crucial factors that increase participant engagement and motivation in technology-based interventions [55]. Interestingly, measurements and personal monitoring devices were evaluated as useful as group meetings. Technology can facilitate remote consultation regardless of time and place, hence reducing the costs and widening the reach and accessibility of interventions. Furthermore, leveraging technology tools in intervention delivery optimizes the use of professionals' time, since it allows participants to complete routine exercises and tasks independently with automated and personalized guidance.

There is an acute need to improve people's psychological well-being, especially depression and various stress-related problems. These problems are widespread and can lead to long-term absenteeism and work disability, which include a significant economic burden [4,56]. Our data suggest that it is possible to positively affect psychological well-being by using interventions that combine face-to-face meetings and technology. Our intervention may be a noteworthy tool for self-management, health-related prevention and general well-being in health care settings. Prevention and early intervention based on self-management are especially important given that healthcare resources are limited. In addition, our intervention offers considerable flexibility, and requires only little professional guidance. In accordance with earlier studies that have investigated the combination of technology and multimodal intervention methods to promote health, our results suggest that interventions using technologies can extend the reach of preventive care to many people at a relatively low cost [57-61]. Our findings are also in line with other studies that

show positive effects using Web-based stress management approaches [11, 62].

This study had several limitations. First of all, the number of participants was small and therefore the statistical power of the study is weak. This lack of power affects our ability to detect differences between the intervention and control group as well as our ability to generalize the results. Also, most participants reported a small number of psychological problems at the beginning of the study. Thus, the possibility for improvement was small (eg, for AAQ, BDI and SCL-90) suggesting that other measurements may have been more appropriate for observing the changes. The control group showed also some improvement that was possibly due to assessment procedures at the beginning. The effectiveness and the acceptability of this intervention need also to be investigated in other populations reporting more severe problems. Furthermore, longer follow-up periods may be needed to ensure the sustainability of the effect. Overall, because all the participants in this study were male, our results can be generalized to only middle-aged men who seek help for stress-related problems and mild to moderate depression. Additionally, participants were provided several technology tools within a short period of time, which caused cognitive load that may have hindered participants' capability and motivation to discover personally suitable tools. Some tools also had usability problems, data entered in one application was not synchronized to others, and most of self-monitoring was done manually. Since the time the study was conducted, there have been considerable advances especially in smartphone

technology, which would allow a more integrated and usable technology toolkit.

In conclusion, this study supports the idea that personal health technologies, when combined with a brief psychological group intervention program, may have a positive impact on mild psychological problems and stress-related symptoms. Our intervention provides a potential solution to the demand for accessible and affordable empirically-supported psychological treatments [63]. Our approach is potentially cost-efficient, flexible and accessible, and may help people to prevent and manage stress-related problems and to adopt a healthier lifestyle. However, due to the limitations in the design and procedure, our results may be spurious, and must be interpreted with caution. Furthermore, because the intervention included several components and it was not possible to control all of them within our design, we cannot rule out that these effects were caused by the group sessions alone. Although there are several limitations in this study, this intervention nevertheless shows promising effects. Future studies need to investigate the effectiveness, benefits, and possible problems of psychological interventions which incorporate new technologies. Our aim is to enhance and simplify the presented concept, and evaluate it in a larger, more comprehensive research study using mobile technology. A fully powered RCT using partly the same concept is under way. In the ongoing study, a brief group ACT-based intervention is compared with an ACT-based mobile intervention.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

CONSORT-eHealth Checklist V1.6.1 [64].

[PDF File (Adobe PDF File), 881KB - [resprot_v2i1e1_app1.pdf](#)]

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Abbreviations

AAQ-2: acceptance and action questionnaire
ACT: acceptance and commitment therapy
BBI-15: Bergen Burnout Indicator
BMI: body mass index
CBT: cognitive behavioral therapies
ER-ratio: effort to reward ratio
ERI: effort-reward imbalance
ES: effect sizes
GSI: general symptom index
HR: heart rate
HRV: heart rate variability
SCL-90: 90-item symptom checklist
TEKES: Finnish Funding Agency for Technology and Innovation
VAS: visual analogue scale
WD: wellness diary

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STUDY IV

**Web, mobile and
monitoring technologies
in self-management of
psychophysiological wellbeing**
Usage and user experiences

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WEB, MOBILE AND MONITORING TECHNOLOGIES IN SELF-MANAGEMENT OF PSYCHOPHYSIOLOGICAL WELLBEING: USAGE AND USER EXPERIENCES

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ABSTRACT

Stress and insufficient recovery from workload may lead to chronic diseases and mental health problems. Early intervention with the focus on self-management is necessary in prevention of these problems. This paper reports the results of an initial evaluation of a service concept which combines personal health technologies with psychological group interventions to support self-management of wellbeing focusing on stress, sleep and exercise. The approach is to provide a buffet of carefully chosen self-management methods and personal health technologies to support different individual needs and to allow a personalized approach to self-management. In the evaluation, the usage activity and perceived utility of the technologies were studied to analyze the feasibility of the approach and to determine improvement needs. The concept was well-accepted by the participants, and they reported having gained better understanding of their health and motivation to improve it. Improvements related to stress and exercise levels were also reported. Based on the differing technology selections of the participants and the high acceptance of technologies, providing an assortment of technologies to support self-management was proven successful. However, care must be taken in the introduction of such system to avoid burdening the users and to aid selection of personally relevant tools.

KEYWORDS

Personal health technologies, intervention, self-management, stress, sleep, exercise.

1. INTRODUCTION

Stress-related mental and physical health problems are increasingly prevalent in the Western society. Mental health problems affect at least one in four people at some point in their lives (WHO, 2005). Modern hectic lifestyle and growing demands of working life lead to stress and shortened sleep times. Prolonged exposure to harmful stress can ultimately trigger the onset of mental disorders such as depression and anxiety (WHO, 2005). Work-related mental health problems are a leading cause of sick leave and disability in OECD countries (OECD, 2008) and high job strain is a predictor of subsequent work disability pension (Laine et al., 2009).

Psychological, physical and social factors are interrelated in the management of personal wellbeing. In addition to its effect on mental conditions, stress is associated with poor health behaviors such as unhealthy diet and lack of exercise. Moreover, elevated stress hormone levels have a harmful effect on metabolism (Chandola et al., 2008), making prolonged stress a significant risk factor for cardiovascular diseases and metabolic syndrome (Rosmond, 2005; Chandola et al., 2008). These problems place a high burden on the society.

The resources in healthcare to treat stress-related problems are limited especially considering early interventions. There is a need for methods to support self-management of wellbeing with the focus on early

prevention and health promotion. In self-management, the role of motivation is essential for successful lifestyle changes and their maintenance.

Personal health technologies are promising in supporting individuals in the self-management of their health and wellbeing. For example, computer-aided interventions delivered via the Internet have been shown to be effective in the treatment of mental health problems such as depression and anxiety (Marks et al., 2007). Web interventions are accessible mostly regardless of time and place, can be personalized and adaptable to each user's needs, and eliminate the stigma related to therapist visits. Two computer-aided cognitive behavioral therapy (CCBT) systems are established treatment options in routine care in the UK (National Institute for Health and Clinical Excellence, 2006). However, the Internet may not be the most suitable and motivational media for daily observation and maintenance of wellbeing (Mattila et al., 2008). Available mobile and wearable technologies, such as mobile wellness applications and pedometers, can be introduced to integrate self-management into daily life.

To empower self-management of psychophysiological wellbeing, a service concept which combines psychology and technology has been developed (Happonen et al., 2009a). The P4Well concept involves a holistic approach towards personal wellness management by combining personal health technologies with psychological intervention methods. The principal idea of the concept is to provide a range of carefully selected self-management methods and technology tools for the user to choose from to enable a personalized approach to wellbeing management. The methods and technologies are provided to the user in a guided manner, but the final selection depends on the user's personal preferences and motivation.

The initial experiences on the first user evaluation of the concept were promising (Happonen et al., 2009b). This paper presents the final results on the technology usage, perceived utility and acceptance from the evaluation study. The evaluation was carried out during spring 2009 with two user groups consisting of 35 participants in total. The main research questions of this study were:

- Are the concept and especially the personal health technologies feasible and acceptable to the users?
- Can users find and adopt personally relevant and useful self-management tools in a buffet of technologies?
 - Which factors facilitate and hinder the usage of the technologies in the system?
 - Do the personal health technologies help and motivate the users to manage or improve their wellbeing?

2. RESEARCH SETTING

2.1 P4WELL CONCEPT

The P4Well concept (see Figure 1) aims to help people to adopt a healthier lifestyle by providing them tools, skills, motivation and support. The focus areas are recovery from stress, sleep quality and quantity, and exercise habits. The personal health technologies in the concept include personal and wearable monitoring devices, mobile applications and a web portal. The group intervention program utilizes cognitive behavioral therapy (CBT) (Dobson, 2009) and acceptance and commitment therapy (ACT) (Hayes et al., 2006) processes.

The target group of the concept are people who either suffer from stress and overload symptoms or are at risk to develop them. Since there are several ways to tackle these issues and people have different life situations, preferences and personalities, one solution cannot be expected to be optimal for everyone. Therefore all the methods and tools included in the concept were designed to be suitable for varying needs. A person is not expected to take all of the tools or methods into use, but is instead guided to select the most relevant ones in his/her personal situation. The emphasis is on personal motivation and freedom of choice.

The group intervention teaches participants necessary cognitive skills to evaluate their lifestyle and plan and carry out changes in personally problematic areas. Technology tools support the intervention by providing means to assess personal status with the help of self-appraisals and objective measurements, to plan changes, and follow up progress by self-monitoring and feedback.

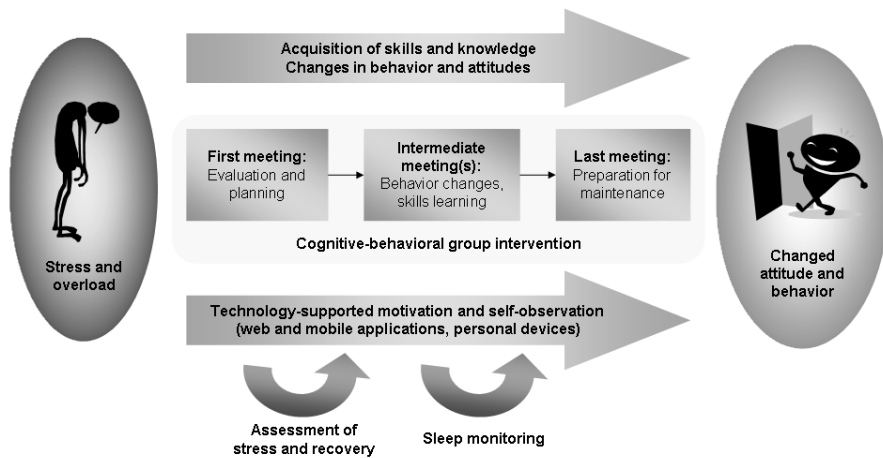


Figure 1. The intervention process for self-management of stress and overload in the P4Well concept

2.2 Evaluation Participants

The concept was evaluated in spring 2009 in an evaluation study. The study procedures were approved by the appropriate ethics committee. The study had two user groups consisting of 35 middle-aged participants in total (Table 1). Twelve participants (the Mild Depression Group) were the treatment group of a randomized controlled trial (RCT), consisting of altogether 25 male subjects. The subjects were recruited through a newspaper advertisement. The inclusion criterion to the study was having sleep problems or stress-related symptoms. It turned out that, on average, the group members also showed symptoms of mild depression (Table 1). The randomization to treatment and control groups was balanced based on the depression (BDI, Beck Depression Inventory) scores. The purpose of the RCT was to analyze psychological and physiological changes resulting from the intervention in comparison to the control group who received no treatment.

Table 1. Background information of the participants

	Mild Depression Group (N=12)	Stress Group (N=23)
Gender	12 male	11 male, 12 female
Age	48 (32-59)	54 (37-62)
BDI ¹	14.6 (6-30)	6.3 (0-14)

The other group of participants (the Stress Group) consisted of 23 entrepreneurs (Table 1), recruited through an email invitation for a wellbeing program. The participants suffered mainly from stress symptoms or lack of time for recovery. The program was organized by an occupational pension insurance company and occupational health provider for their customers.

Having two user groups participating in the evaluation in different settings served a twofold purpose. The RCT (the Mild Depression Group) produced information about the validity of the concept, testing its effectiveness in the prevention and treatment of stress and depression problems in a controlled setting. The entrepreneur group (the Stress Group) tested the feasibility of the concept in a less controlled, more real-world setting which would be a realistic arrangement for an occupational health situation to prevent stress-related problems from arising.

The two groups had different profiles in their mental health status. Members of the Mild Depression Group were more depressed than those of the Stress Group (Table 1). There were also slight differences in

¹ BDI limits: 0-9 no depression, 10-16 mild depression, 17-29 moderate depression, 30-63 severe depression. For the Stress Group, BDI has been calculated based on the data from 22 subjects.

what the participants perceived to be their personal challenges in wellbeing. In the Mild Depression Group, the most important or challenging aspects of personal wellbeing were reported to be sleep quality and quantity (10 participants), management of mental wellbeing (9) and stress management (8). In the Stress Group, the focus was somewhat different: weight control and eating habits were the most important topics for 13 participants, exercise activity and fitness level for 12 and stress management for 11.

Four participants in the Mild Depression Group and 11 participants in the Stress Group had a Masters level or higher university degree. Prior to the study, all participants had a habit of using a computer on a daily basis, and most (32/35) also used the Internet daily. Everyone used a mobile phone for text messaging and many also used its calendar (11 in both groups). Other advanced features of a mobile phone were used less often. Thus, the participants represented the target group of the concept, being fairly fluent Internet and mobile users.

2.3 Group Intervention

The evaluation period lasted for 9 to 10 weeks for the Mild Depression Group and 14 weeks for the Stress Group. The intervention process is summarized in Figure 2. The process consisted of three (the Mild Depression Group) or four (the Stress Group) group meetings held by a psychologist at about one-month intervals. The meetings included informative and motivating lectures, discussions and exercises related to mental wellbeing. Homework assignments such as self-assessments or self-observations related to stress, sleep or exercise were given to be carried out between the meetings.

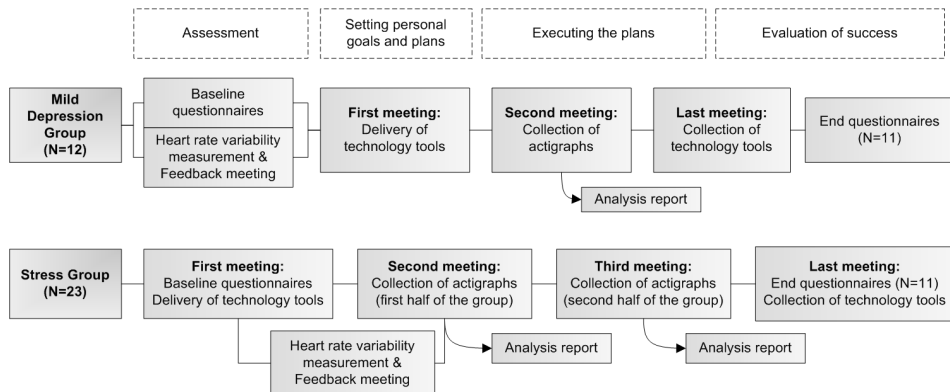


Figure 2. The intervention processes and timings of technology usage for the two participant groups in the evaluation

The participants were provided all technologies and accounts to the web portal in the first meeting. They were offered a mobile phone (Nokia E51, Nokia Corp., Helsinki, Finland) with pre-installed applications to be used as their personal phone during the evaluation, or they had the possibility to install the applications in their own phone. Phones and devices were collected from the participants during the last meeting. The purpose of different technology tools was introduced and usage instructions were given during the intervention meetings. The participants were instructed to take the most relevant technologies into use according to their personal situation and needs.

Due to practical reasons (the groups were located in different geographical regions), the duration and the specific content of the two interventions had some differences, but all participants in both groups had access to all technologies during the study period. For the Mild Depression Group, the group size in intervention meetings varied from five to six participants. The duration of each meeting was two hours. During the course of the meetings, the participants analyzed their life situation and were taught methods, such as relaxation and mindfulness exercises, to better cope with stress. The methods were general in nature and the participants were encouraged to analyze their personally relevant problem areas and to determine personal goals towards which to strive. The intervention meetings for the Stress Group consisted of discussions focused on specific themes such as time management.

2.4 Technologies of the Concept

The participants of the evaluation study had four kinds of technologies which they could choose to use during the evaluation period: a web portal, mobile applications, personal devices and monitoring devices. The web portal was designed and developed during the project, whereas the other technologies were commercially available solutions. The technologies are described in detail by Happonen et al. (2009a).

The technologies provided to the participants were chosen to support the themes of the intervention (stress, sleep and exercise). Different kinds of technologies had different purposes. The web portal was designed as a source of information and for in-depth analyses, contemplation and evaluation. In contrast, mobile applications and personal devices were meant to be used in the course of daily life to support short- and long-term monitoring of various physiological and psychological measures, and to aid in stressful situations. Specific monitoring devices were used for a limited time period to collect data about sleep and stress, based on which the participants received professional feedback.

The P4Well web portal was built upon Mawell S7 portal platform (Mawell Ltd, Oulu, Finland). The content was divided into modules focusing on different themes of wellbeing. The modules consisted of five phases loosely following the Transtheoretical Model of stages of change (TTM) (Prochaska & Norcross, 2001): educational material, evaluation of personal status, planning of lifestyle changes, putting the plans into action, and follow-up. Each phase contained relevant tools and methods. In addition, the portal included a discussion forum and a messaging functionality between users and experts. Persuasive design strategies such as tunneling and reduction (Fogg, 2003) were applied in the design of the portal. A web-based exercise coaching application (Firstbeat WebTrainer; Firstbeat Technologies Ltd., Jyväskylä, Finland), was integrated to the portal.

The mobile applications included a wellness diary (Wellness Diary; Nokia Corp.), an exercise coaching application (Mobile Coach; Firstbeat Technologies Ltd.), and a relaxation application (SelfRelax; Relaxline, Mantes La Jolie, France). The wellness diary is a personal diary application for the follow-up of various psychological and physiological factors through self-monitoring and feedback. The exercise coaching application creates a personal exercise plan for the user and adapts it to actualized activity. The relaxation application is audio-based and has several relaxation programs with different lengths and purposes, such as sleep and stress.

The participants were provided with pedometers (Omron Walking Style II, Omron, Kyoto, Japan) and heart rate monitors (Suunto T1C; Suunto Ltd., Vantaa, Finland) for supporting the self-monitoring of daily activity and exercise.

In addition to the aforementioned technologies intended for regular use, the concept included two monitoring technologies for intermittent use. A three-day measurement of heart rate variability was carried out in the beginning of the study period by using a heart rate belt and analyzed with analysis software (Firstbeat HEALTH; Firstbeat Technologies Ltd.) to assess the balance between stress and recovery. The participants were given face-to-face feedback on the analysis. Wrist-worn sleep and activity monitoring devices (Vivago Personal Wellness Manager; Vivago Ltd., Helsinki, Finland), were given to the participants to be used for one month. The activity data was analyzed with actigraphy analysis software (Vivago Pro; Vivago Ltd.) and reports on sleep quantity and daily activity were sent to the participants through the P4Well web portal.

2.5 Data Collection and Analysis Methods

The participants filled in three questionnaires during the study: baseline questionnaires in the beginning of the first meeting, one-month questionnaires after approximately one month of study period in the second meeting, and end questionnaires during the last meeting. The baseline questionnaires were composed of questions about previous technology usage and general attitudes towards wellness technologies. The one-month questionnaire focused on the usage, perceived utility and acceptance of each individual technology used in the concept. The end questionnaire included the same questions about each technology as the one-month questionnaire, and contained additional questions about the usefulness of the entire concept. The questionnaires included quantitative multiple-choice questions and open-ended questions.

To obtain an objective view of the usage frequency of the technologies, usage logs were collected from the mobile applications and the portal. The participants returned the borrowed mobile phones during the last

meeting and log files were manually downloaded from them. If the participants had installed applications to their own phones, log files were downloaded from them during the meeting and phones were then returned to their owners. Log data could not be collected from one participant in the Mild Depression Group and 9 participants in the Stress Group, because they had installed the applications in their own phones and did not participate in the last meeting.

End questionnaires were available from 11/12 participants of the Mild Depression Group and 11/23 participants of the Stress Group. For reliable examination of the results, only these participants are included in the analysis. They are referred to as respondents. Log files from the mobile phones were available from 11/11 respondents in the Mild Depression Group and 9/11 respondents in the Stress Group.

The data from the questionnaires were transferred manually to spreadsheets for analysis. The qualitative data from open-ended questions were analyzed by categorizing the answers under different themes based on their content.

Log files were analyzed to determine the number of usage days of different technologies for each subject. For portal logs, also the duration of usage sessions was determined. “*Active user*” of a technology was defined as someone who used a technology at least during half of the study weeks (log data; for mobile applications and portal) or reported having used a technology at least on a weekly basis (questionnaire data; for pedometer and heart rate monitor). “*User*” of a technology was defined as someone who tried a technology at least once.

3. RESULTS

This chapter presents the main findings of the user experience study. The results are reported for the group of 22 respondents from whom the end questionnaires were received. The concept as a whole and its technologies are analyzed regarding acceptance, usage activity and perceived utility, ease of use and barriers of use, and motivational aspects. The two user groups are combined in the results, but their differences are assessed after reporting the results in general. The technology usage of the non-responders according to the available log data is also described.

3.1 Feasibility and Acceptance of the Concept

According to the end questionnaire results, every respondent felt they had gained some benefits related to their personal wellbeing from participating in the study. Nineteen respondents reported at least two benefits. The most common benefit was the increase in willingness to improve personal wellbeing (16 respondents). Other common benefits were a better understanding of personal health state (12), increased amount of exercise (12), better understanding of own fitness (8) and decreased level of stress (8). In general, the concept was well accepted.

All respondents also recognized at least one useful component in the concept as a whole. None of the components was recognized to be useless, since each component received support in the responses. However, some components were more popular than the others: intervention meetings and monitoring devices with professional feedback were valued the highest (Table 2). Devices or applications were also considered useful by the majority of the respondents. Web portal and group support were not as clearly favored, but their usefulness was still acknowledged by almost half of the respondents.

Table 2. The perceived usefulness of the different components of the concept (N of respondents = 22)

Component of the concept	N of respondents who considered the component useful
Intervention meetings	18
Monitoring devices with professional feedback	18
Personal devices	16
Mobile applications	12
Web portal	10
Group support	9

3.2 Technology Usage and User Experiences

The results of technology usage and user experiences are summarized in Table 3. All respondents (N=22) used at least one of the technologies at least once. Pedometer was the most commonly used technology, with the highest number of active users and users overall. Almost every respondent took some of the technologies into active use: nineteen respondents were active users of at least one technology, 14 respondents used two or more of the technologies, and eight respondents used three or more. Out of those who used only one technology actively, four were users of pedometer and one used the mobile wellness diary.

Table 3. The usage activity and user experiences for the technologies in the concept (N of respondents = 22)

	Mobile applications				Personal devices	
	Portal	Wellness diary	Exercise coach	Relaxation application	Heart rate monitor	Pedometer
Usage activity						
Active users	5	6	8	8	8	13
Users overall	20	15	12	18	17	21
User experiences						
Easy to use	9	11	9	17	3	21
Useful	10	12	13	15	16	17
Helps to achieve goals	9	10	12	8	10	13
Motivates in maintenance or improvement of wellbeing	8	12	12	15	14	16

Almost every respondent who used more than one technology had a different combination of technologies in their use. For example, some respondents were active users of several mobile applications and pedometer, whereas some used actively e.g. portal and the wellness diary, or heart rate monitor and the exercise coach.

Most of the respondents tried several technologies in the beginning and chose one or two which they continued using actively. A lot of respondents cited that they lacked time to get familiar with all available technologies; the number of devices and applications provided to the users was quite high and the duration of the intervention was relatively short.

Perceived usability also affected the willingness to use the applications and devices. A couple of respondents did not in general like using a mobile phone to make self-observation entries. Some commented that the user interface in mobile applications, devices or portal was unpleasant for them.

3.2.1 Web Portal

Out of the different technologies, the portal had the lowest number of active users (Table 3). On average, the respondents spent 71 minutes (range 0-300, median 58) logged in to the portal during the entire study. Average duration of a single visit was 16 minutes (range 0-55, median 14). The usage of the portal declined over the study period regarding both the number of weekly users and the average login durations. During the first week of the study, 13 respondents visited the portal, whereas during later weeks the number of visitors varied between two and nine. The average time the respondents spent in the portal declined from 14 minutes during the first study week to two minutes during the last.

Almost every active user of the portal had both brief and long visits. On long visits, the respondents spent their time filling in analyses, doing exercises and reading educational material. Brief visits consisted mainly of checking of private messages and discussion forum. The less active users of the portal mainly browsed the content and filled in a couple of questionnaires, but did not delve deep into the material. Two of the users who were not active and frequent visitors nevertheless spent more than two hours in total in the portal.

Nearly half of the respondents said that the portal was useful and motivating. Its information content was considered helpful. Filling in questionnaires and analyses in the portal was seen to be fairly useful, but their feedback was not sufficient enough for most respondents.

The responses revealed several barriers to the usage of the portal, including usability issues. The presentation was quite text-heavy and some commented that it took effort to find personally relevant content and tools, and that self-examination tools were not intuitive to use. In addition, several respondents said they were reluctant to visit the portal in their free time, since they spent a lot of time using a computer in their work.

3.2.2 Mobile Applications

All three mobile applications had a fairly similar number of active users, from six to eight. The relaxation application had a slightly larger number of users overall than the wellness diary and the exercise coach. Thirteen respondents in total used one or more mobile applications actively, and two respondents were active users of all three applications.

All of the six active users of the wellness diary application used it throughout the study period. The number of weekly usage days stayed fairly constant throughout the study period: the average number of usage days was 5.2 during the first three study weeks and 5.4 during the last three study weeks. The non-active users tried the diary a few times in the beginning of the study. Approximately half of the respondents overall considered the diary to be useful, motivating and helpful in goal achievement. It was also seen as relatively easy to use.

Five of the eight active users of the exercise coaching application used it throughout the study period. The other three who used it either stopped or began its regular use in the middle of the study. The number of weekly usage days declined slightly over the study period, from 2.8 days during the first three weeks to 1.9 days during the last three weeks. Although the exercise coach was seen as the most difficult to use out of the mobile applications, it was considered useful and motivating by its users.

Four of the eight active users of relaxation application used it regularly throughout the study period. The number of weekly usage days was highest in the beginning, with as much as five weekly usage days, and declined towards the end to one or two days per week. Out of the mobile applications, the relaxation application was considered easiest to use, the most useful and the most motivating.

3.2.3 Personal Devices

Pedometer was the most actively used technology. According to the comments, it had become a part of the daily routine for many respondents. Pedometer received the highest scores in all categories of user experience presented in Table 3 and it was clearly the most popular technology. Some commented about its usefulness that it gave objective results of the actual number of steps taken during the day, sometimes surprisingly small. Pedometer was also perceived as the easiest technology to use.

In contrast, the usage of heart rate monitor was considered difficult by half of the respondents. Several respondents felt that its user interface was complicated and functions were difficult to learn. Some already owned a heart rate monitor they were accustomed with and did not switch to the model provided in the study. Despite the usability issues, heart rate monitor was perceived to be the second most useful technology and about one third of the respondents used it actively. The heart rate monitor was considered useful since it provided objective measurement of physical condition.

3.2.4 Monitoring Devices

For stress and recovery analysis based on heart rate variability, a specific heart rate belt was worn for two to three days and then returned. All respondents completed this measurement and received face-to-face feedback from it. Eighteen respondents felt that the feedback they had received from heart rate variability analysis had been useful. Many commented that it revealed the effects that stress, exercise and sleep had on their recovery and wellbeing.

Activity monitoring device was instructed to be worn continuously for one month. Eighteen of the respondents followed this instruction. Out of the rest, three tried the device but did not take it into use. The feedback report based on the activity data from the device was considered useful by nine respondents – half of those who had worn the device. It should be noted that at the time of filling in the end questionnaire, six respondents had not yet received their feedback report. This is due to the return date of the activity monitoring devices, which was for several respondents the same date when they filled in the end questionnaire.

3.3 Differences between the Groups

The technology choices were slightly different between the two groups. On average, the respondents in the Stress Group used actively a slightly wider combination of technologies (median 3) than in the Mild Depression Group (median 2). The number of active users per each technology differed regarding the mobile

wellness diary, the mobile relaxation application and pedometer; pedometer and the wellness diary were somewhat more popular in the Stress Group, and the relaxation application in the Mild Depression Group. Pedometer was used actively by nine respondents in the Stress Group and four in the Mild Depression Group. The wellness diary was taken into active use by five respondents in the Stress Group, but only one in the Mild Depression Group. For the relaxation application, the Mild Depression Group had five active users, whereas the Stress Group had three.

The most useful components of the concept were also slightly different. In the Mild Depression Group, monitoring devices with professional feedback were seen as the most useful (ten respondents), whereas the Stress Group considered intervention meetings the most useful (ten respondents).

For the Mild Depression Group, the most commonly cited benefits from the participation in the study were decrease in stress level (six respondents) and increase in the amount of exercise (five respondents). In the Stress Group, the most common benefits were a clearer understanding on personal health and personal fitness (eight respondents for both).

3.4 Analysis of Non-Responders

Except for one, non-responders were all from the Stress Group. According to the log entries, some of the non-responders had used mobile applications (4/13) or portal (7/13). However, they were not active users; none of them used the portal or any of the applications on more than one third of the study weeks. Based on an intention to treat analysis, 54% (19/35) of the participants in the study were active users of some technology.

4. DISCUSSION

The concept was received favorably and the combination of psychology and technology was proven to be promising. All respondents tried some of the provided technologies and almost every respondent took some of them into active use. Thus, the “buffet” style of providing an assortment of self-management tools from which the users can choose appears to be feasible. The brief intervention supported by technologies also seems to improve psychological wellbeing, indicated by the results of the randomized controlled trial which measured psychological changes in the Mild Depression Group compared to a control group. The depressive symptoms of the Mild Depression Group decreased more than in the control group and the positive changes were maintained after six months. The detailed results regarding psychological changes are reported in a separate article.

The diversity of the technology tools that were selected for the evaluations also seemed to be appropriate for the target group, since there were active users and positive experiences for each of the technologies. Different users found different devices or applications relevant and suitable for their personal needs, and most technologies received positive user experience ratings from more than half of the respondents. Typically, the users took two of the provided technologies into active use, and the most common usage combination was pedometer with one of the three mobile applications.

The two user groups had somewhat different profiles and needs in the beginning, which probably partly explains their slightly different technology selections. Management of mental wellbeing, sleep and stress were more important to participants in the Mild Depression Group, who used the mobile relaxation application somewhat more commonly. Weight control and exercise activity were more pressing issues to the Stress Group, among whom pedometer and the mobile wellness diary were more popular. Gender differences may also play a role in how the two groups perceived the concept and the technologies. The exclusively male Mild Depression Group considered monitoring devices with professional feedback the most useful component of the whole concept, but the Stress Group, out of whom half were female, valued intervention meetings the most. The different emphasis is also reflected in the perceived benefits: members of the Mild Depression Group had decreased their stress levels and started exercising more, whereas the Stress Group had most importantly gained a better understanding of their health and fitness. The role of the technologies in self-observations and self-management was discussed in more depth in the meetings with the Mild Depression Group, which may have had an impact on the resulting actions and lifestyle changes.

Out of the different technologies, personal devices and mobile applications were more actively used and appreciated higher than the web portal. The portal attracted the lowest number of active users and received less positive ratings of user experience than the other technologies. One possible reason for this was that the portal was the only technology which was developed from scratch during the project. Thus, compared to the other, mostly commercial technologies, it was much less tested and iterated, and had weaknesses in usability. It was also described by the respondents as having too much content and a confusing structure. The evaluations provided plenty of feedback which was used to improve the portal for the second round of evaluation, which took place during autumn 2009 and is currently in its follow-up stage.

In addition to usability issues, the reluctance to use a computer after a workday was a significant barrier for the usage of the web portal. Moreover, the portal had a different role in the concept than mobile applications and personal devices. It is likely that several users got the most out of its material and self-examination tools already during a couple of visits, and contrary to mobile applications and personal devices, it was not meant to be a daily self-monitoring tool. The portal is being redesigned to be more suitable for intermittent use and to increase motivating features and personally relevant content (Kaipainen et al., 2010).

The received positive feedback and comments about the personal devices and mobile applications indicate that the strength of the technologies is in their ability to provide objective information about personal physiological status and to enable easy and illustrative ways to follow up the progress. They were considered motivating by the majority of the respondents in maintenance or improvement of their wellbeing in their daily life. It is possible that many may have already been aware of the various means for stress management, such as exercising and relaxation, but had lacked proper tools and motivation to apply their knowledge in practice in their personal context prior to the study.

Even though the technologies were received favorably, the importance of personal contact was still emphasized in the results. Intervention meetings and monitoring devices with professional feedback were perceived as the two most important components of the concept. The interpretation of measurement data by a professional was essential for thorough understanding of the results, and it is likely that the face-to-face meeting in itself had a positive impact on mental status as well. In addition, group support was considered useful by several respondents, which was also reflected in the fact that the discussion forum was one of the most actively visited sections in the portal.

The users were provided a large number of technologies in a short time, and the study revealed that the delivery of all technologies to the users at once was suboptimal. More gradual introduction of devices and applications would probably have eased the cognitive load needed to learn and get familiar with new applications and devices and to figure out which of the technologies would be the most suitable for personal needs. The concept could also be improved by personalizing the intervention through developing a simple profiling of the users to recognize their personal needs and preferences and to find out which technologies should be recommended. Usability of the applications is obviously important as well; if a technology is not intuitive to learn and use, a stressed person may rather walk away from it than spend a lot of effort in taking it to use. The large number of technologies may partly explain the relatively high dropout rate of this study. However, it is also likely that the non-responders had less need and motivation to adhere to the entire intervention, since they were almost all from the Stress Group who mainly sought help for their time management issues.

The increasing prevalence of problems caused by stress and the lack of resources for their treatment call for approaches which emphasize the personal role and motivation of an individual in management of his/her wellbeing. Based on the results of this study, a brief group intervention combined by self-management technologies and possibility for online peer and professional support appears to be a feasible and cost-effective way to prevent and treat emerging stress-related problems. The results have many similarities to an earlier study analyzing user experiences of mobile applications as a part of a similar toolbox of technologies for health promotion in occupational healthcare (Ahtinen et al., 2009). In both studies, ease of use and personal relevance of the technologies appeared to be the main factors supporting use, but all technologies gained active user groups. However, the effect of the background of the user, personal preferences and interests, wellness goals, and the intervention or support needs on the technology choices and usage patterns needs to be studied further.

5. CONCLUSION

A service concept which combines personal health technologies with psychological interventions has been designed and validated with real users in an evaluation study. The approach was well-accepted by the participants of the evaluation and nearly every respondent began to use some technology actively. The differing technology selections of the respondents indicate that the approach of providing an assortment of tools to accommodate different needs is successful in self-management of stress-related problems. However, introduction of the technologies requires careful consideration to avoid unnecessary cognitive burden for the users and to ease the adoption of the tools.

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STUDY V

**Facilitation of goal-setting
and follow-up in an Internet
intervention for health and
wellness**

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STUDY VI

**Mobile mental wellness training
for stress management**
**Feasibility and design implications based on
a one-month field study**

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Original Paper

Mobile Mental Wellness Training for Stress Management: Feasibility and Design Implications Based on a One-Month Field Study

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Abstract

Background: Prevention and management of work-related stress and related mental problems is a great challenge. Mobile applications are a promising way to integrate prevention strategies into the everyday lives of citizens.

Objective: The objectives of this study was to study the usage, acceptance, and usefulness of a mobile mental wellness training application among working-age individuals, and to derive preliminary design implications for mobile apps for stress management.

Methods: Oiva, a mobile app based on acceptance and commitment therapy (ACT), was designed to support active learning of skills related to mental wellness through brief ACT-based exercises in the daily life. A one-month field study with 15 working-age participants was organized to study the usage, acceptance, and usefulness of Oiva. The usage of Oiva was studied based on the usage log files of the application. Changes in wellness were measured by three validated questionnaires on stress, satisfaction with life (SWLS), and psychological flexibility (AAQ-II) at the beginning and at end of the study and by user experience questionnaires after one week's and one month's use. In-depth user experience interviews were conducted after one month's use to study the acceptance and user experiences of Oiva.

Results: Oiva was used actively throughout the study. The average number of usage sessions was 16.8 (SD 2.4) and the total usage time per participant was 3 hours 12 minutes (SD 99 minutes). Significant pre-post improvements were obtained in stress ratings (mean 3.1 SD 0.2 vs mean 2.5 SD 0.1, $P=.003$) and satisfaction with life scores (mean 23.1 SD 1.3 vs mean 25.9 SD 0.8, $P=.02$), but not in psychological flexibility. Oiva was perceived easy to use, acceptable, and useful by the participants. A randomized controlled trial is ongoing to evaluate the effectiveness of Oiva on working-age individuals with stress problems.

Conclusions: A feasibility study of Oiva mobile mental wellness training app showed good acceptability, usefulness, and engagement among the working-age participants, and provided increased understanding on the essential features of mobile apps for stress management. Five design implications were derived based on the qualitative findings: (1) provide exercises for everyday life, (2) find proper place and time for challenging content, (3) focus on self-improvement and learning instead of external rewards, (4) guide gently but do not restrict choice, and (5) provide an easy and flexible tool for self-reflection.

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KEYWORDS

stress; mental health; mobile phone; acceptance and commitment therapy; field studies; user experience; design

Introduction

Background

Work-related mental health problems are the most common cause of disability in the countries of the Organization for Economic Cooperation and Development [1]. Stress is strongly associated with mental health problems, such as depression [2]. In 2005, 22% of European workers reported suffering from stress [3], and stress is estimated to be a significant factor in 50-60% of lost working days [4].

Preventative interventions targeted at individuals at risk may be used to contain the costs and suffering related to stress and mental disorders [5,6]. Occupational stress management programs usually focus on teaching individuals techniques to cope with stress, and are delivered in sessions over several weeks [7,8]. Especially interventions based on cognitive-behavioral techniques have been found effective, but as they are usually delivered in group sessions by trained professionals, they are also relatively costly [5,8].

Technology-assisted prevention programs enable easier, earlier, and more flexible access to care at a lower cost, and many of them have been shown to reach equal effectiveness to face-to-face therapies in the treatment of psychological problems [9]. In the past few years, due to the wide availability of smartphones and mobile apps, mobile delivery of interventions has become feasible. Mobile phones facilitate integrating interventions into the daily lives of the citizens, allow unobtrusive monitoring of their activities and contexts, and make it possible to provide interventions at opportune moments, that is, when most needed and desired [10].

Acceptance and Commitment Therapy in Stress Management

Most computerized therapies build on psychological therapy methods, usually cognitive-behavioral therapies (CBT) [9]. The so-called third wave of CBT includes mindfulness and acceptance based behavioral and cognitive therapies, such as acceptance and commitment therapy (ACT). ACT aims to increase the individual's psychological flexibility, which is "the ability to contact the present moment more fully as a conscious human being, and to change or persist in behavior when doing so serves valued ends" [11].

Psychological flexibility can be increased through the six core processes of ACT [11,12]. *Acceptance* means embracing feelings and events without trying to change them. *Cognitive defusion* techniques try to change the way one relates to thoughts, for example, by observing one's thoughts and feelings without being caught up in them. The skill of *being present* helps to experience psychological and environmental events in a non-judgmental way and bringing full awareness to the present moment. The *self-as-context* process aims at becoming aware of the flow of personal experiences with an understanding that they are not one's essence. *Values* determine what is truly important and help choose life directions. *Committed actions* are concrete actions chosen based on personal values. [11,12] To train the skills, an eclectic mix of metaphor, paradox, and mindfulness methods, along with a wide range of experiential

exercises and value-guided behavioral interventions are used [11,13].

Psychological flexibility is associated with better mental health and behavioral changes [11,12]. ACT-based interventions have been found effective in reducing work stress and increasing work performance and the ability to innovate [14-17].

Mobile Apps for Mental Wellness

Mobile interventions have been used effectively to promote physical health, but despite increasing activity in the area, mobile mental wellness apps are still in their infancy [18]. Most apps developed thus far are not guided full-length programs, but rather implement a range of intervention techniques, including mood assessments, experience sampling, and small exercises. The trials have mostly been carried out with small samples, making the efficacy of different interventions and generalizability of the results difficult to assess. Still, previous studies yield several useful insights to inform the design of mental wellness interventions that utilize mobile technology in preventative or therapeutic context.

CBT-based interventions commonly use monitoring of symptoms and mood states as a strategy to develop self-awareness and coping abilities [19]. Mood charting with a mobile and online symptom tracking tool, Mobile Mood Diary, has been explored in a series of small studies carried out with teenagers with mental health problems. The findings suggested that mood charting with mobile phones could increase adherence to therapy and improve self-awareness. In addition, coupling mood charts with a diary could help to support recall and to broach difficult topics with a therapist [19].

Several mobile interventions, such as Mood Map and PRISM, have combined monitoring of mental states with brief exercises [20,21]. Mood Map is a mobile app for increasing emotional self-awareness [20]. The app consists of mood-related experience sampling and CBT-inspired psychological exercises that could be completed in a minute or less. The app has been evaluated in a one-month study among 8 working-age adults who reported moderate or high level of stress [20]. The participants increased their emotional awareness and started practicing new strategies to cope with stress, although some of the impact may be due to the weekly interviews conducted during the study rather than the app. The findings indicated that exercises were more likely to be used when experiencing intense emotions.

In therapeutic context, PRISM is a mobile intervention that was evaluated in a two-week study among 10 outpatients with bipolar disorder [21]. The intervention, delivered via a personal digital assistant and based on Life Goals psychoeducation, prompted users to engage in personally selected self-management behaviors as a response to specific self-reported mood states. The trial resulted in a decrease in depressive symptoms and high satisfaction with the intervention. Several improvements to support long-term use were also brought up, including the ability to enter text entries and offering a broad collection of self-management strategies.

Some interventions have combined mobile and Web apps that serve different functions. Mobilize! is a mobile phone and

Web-based intervention for depression [22]. It uses phone sensors and experience sampling to gather data on users' contexts and moods and to remind them to use the website. The intervention consists of behavioral skills training through 9 weekly 15-minute lessons on an interactive website, and telephone coaching to increase adherence. The system was trialed with 8 participants who had a diagnosis of major depressive disorder [22]. Their depressive symptoms decreased over the course of the intervention and they were generally satisfied with the program. Despite several technical difficulties such as battery drainage and inaccuracy of sensor data, context-aware interventions seem potentially promising in helping a person gain self-awareness and encouraging behavioral changes at right moments.

One of the few larger studies is the trial of myCompass, a mobile phone and Web-based program for stress, depression, and anxiety [18]. The program consists of self-tracking, reminders, and tips on the phone and CBT-based 10-minute self-management modules on the website. Participants of the 6-week trial were 44 adults experiencing a current episode of depression, anxiety, or stress. The results showed a reduction in psychological distress, and improvements in functional impairment and self-efficacy. The participants appreciated the accessibility and convenience of the app, but wished for more personalized instructions.

Randomized controlled studies of mobile mental wellness apps, especially in preventative context, appear to be scarce. One of the few examples is the evaluation of MEMO, a 9-week mobile intervention for preventing teenage depression consisting of mobile messages and a mobile website [23]. The evaluation of the intervention involved 418 teenage participants in the intervention group. Good user acceptance and perceived usefulness were found, but measured outcomes related to depression have not been published yet. A common critique of the intervention was the large amount of messages; the intervention delivered 2 messages per day over 9 weeks, which appeared to be too frequent for most.

To our knowledge, the only ACT-based mobile intervention reported thus far was by Ly et al [24] who presented a program with Web and mobile components, aimed at supporting individuals to live consistently with their values. The Web component includes psychoeducation and exercises for analyzing personal values. The mobile app reminds the user to perform behaviors in line with their values, gives feedback on their progress, and allows them to view other users' actions. The 4-week trial of the app included 11 participants with no diagnosed mental disorders. Increased psychological flexibility and value-based actions were measured at post-test, but no effects were found for depression, anxiety, or stress. The qualitative findings of the study suggest that the mere presence of the icon of the app on the mobile phone screen may have increased awareness of values and behaviors [24].

Conclusive evidence of effectiveness of existing mobile mental wellness apps is not yet available, but the results have been promising and several large-scale randomized controlled trials are currently underway [18,23,25]. Based on the studies so far, mobile phone interventions appear to be feasible and convenient

for the users, and the mobile phone might in itself have a small positive effect on self-awareness. Nevertheless, there is insufficient knowledge available of what works in mobile mental health promotion and what makes an app successful in producing a lasting change in the user's wellness. Lessons learned from apps used as a part of therapy may not necessarily translate directly to preventative context.

Guidelines for Mental Wellness Apps

Several guidelines exist for designing technological apps that engage, motivate, and support behavior and attitude changes. Systems "designed to change people's attitudes or behaviors" are called persuasive technologies [26] and some guidelines for their design have been developed [26-28]. Gamification, that is, using game-like elements has also been proposed in the domain of wellness apps to increase adherence and engagement [29,30]. However, the guidelines that are based on apps promoting physical health and thus they may not be directly applicable to the domain of mental wellness.

The guidelines that are more closely related to mental wellness apps include Morris' 7 guidelines for behavior change [31]: (1) remind people who they want to be, (2) foster an alliance (empathy, coinvestigation, joint problem solving), (3) apply social influence, (4) show people what they could lose, (5) put the message where the action is, (6) raise emotional awareness, and (7) reframe challenges. In addition, Doherty et al [32] introduced and explored a set of design strategies to reduce attrition in Web-based interventions and concluded that the interventions need to be: (1) interactive, (2) personal, (3) supportive, and (4) social. Furthermore, using naturally calming elements and providing positive feedback on user actions can minimize stressors for users [33]. Finally, technology should be seen as a tool to assist in the change process; engagement with the treatment rather than with the technology should be the overall aim [34].

Objectives of the Current Study

In this paper, we describe Oiva, a mobile app for stress management, and present results of a one-month field study that was performed to assess the feasibility of Oiva and validate its design choices. To the best of our knowledge, Oiva is the first ACT-based, stand-alone mobile intervention for self-administered preventative training of stress management skills. Most of the previous studies of mobile mental wellness apps have either focused on mood charting or combined mood charting with brief exercises that have been Web-based in some of the studies. Although mood charting appears to increase adherence and improve self-awareness among certain target groups, none of the studies so far have done a detailed analysis of how mental wellness exercises on a mobile platform should be designed to maximize adherence, user satisfaction and outcomes. To shed light specifically on this matter, the current study excluded the mood-charting component and focused on a structured training program with experiential exercises. The detailed objectives of this study were to: (1) investigate how the participants used the app, (2) study the effects of Oiva on the participants' mental wellness, (3) explore the user experiences of Oiva and its functions, and (4) derive preliminary design implications for mobile mental wellness apps.

Methods

Mobile App

Oiva is a mobile mental wellness-training app targeted at working-age people who suffer from stress. Oiva is a stand-alone app for Android mobile phones and tablets, and it was designed in cooperation of experts in psychology, user needs and technology. The content and logic of Oiva were built upon ACT principles and methods, and the app delivers a complete ACT-based intervention program in bite-sized daily sessions.

Oiva contains 4 intervention modules or “paths” named *Aware Mind*, *Wise Mind*, *Values*, and *Healthy Body*. The first 3 paths teach the user the 6 core processes of ACT and the fourth path focuses on physical wellness, but with an ACT-based approach. The paths consist of altogether 46 text and audio exercises. *Aware Mind* contains exercises on awareness of the present moment, breathing, and observing one’s body, mind, and surroundings. *Wise Mind* teaches skills related to observation and acceptance of one’s thoughts and feelings. *Values* focuses on clarifying one’s personal values and committing to concrete actions to pursue them. *Healthy Body* includes relaxation, mindful eating, and mindful physical activity exercises.

Figure 1 presents examples of the user interface of Oiva. The main screen (Figure 1a) of the app contains a flower-shaped menu through which the different paths can be accessed. The main screen also provides an access to the diary (Figure 1b), list of favorite exercises, and an introduction to the app as text and video (Figure 1c). The introduction video informs the users about the purpose of the app and motivates them to use it. The video features an expert in ACT and thereby aim to increase the credibility of the app, as suggested by the persuasive systems design model [27], and creating a feeling of therapeutic alliance, proposed by Morris [31].

Each petal represents one of the paths, which are numbered according to their recommended order. Each path consists of 1–4 subsections (“steps”), which include 5–8 exercises (Figure

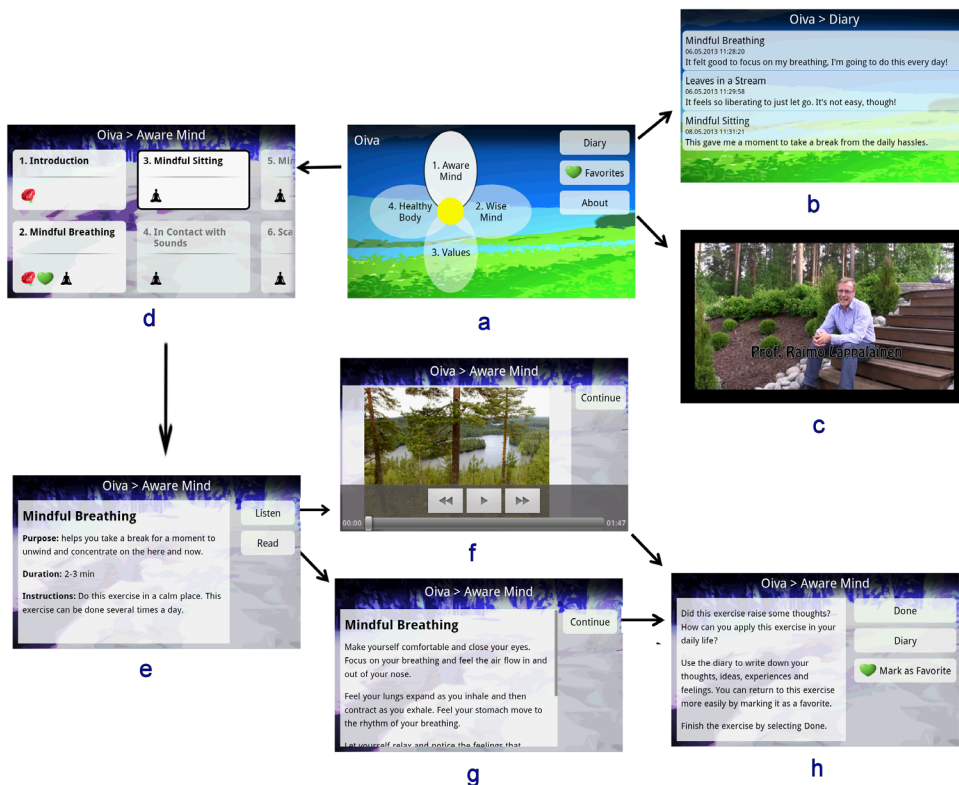
1d). An introduction as text and video is included in each path and step, informing the user about the processes and skills taught in them.

Oiva gently steers the user through the intervention program without restricting free navigation. Paths, steps, and exercises are numbered in the recommended order and the next suggested item is dynamically highlighted (Figure 1a and d). However, all paths and exercises are accessible from the very beginning. This design solution follows the tunneling and reduction principles of persuasion [26,27], but in a non-restrictive way.

Most of the exercises are short and take about 1-3 minutes to complete (Figure 1e-h). This aims at making them easy to perform in any situation. Each exercise begins with an introduction presenting the purpose, duration and instructions of the exercise (Figure 1e). The user can choose to do the exercise by listening (Figure 1f) or reading (Figure 1g). After each exercise, a reflection screen (Figure 1h) summarizes the skills learned in the exercise and enables the user to write notes and reflections in the diary (Figure 1b). The notes are saved in the diary and can be accessed later to encourage self-reflection as well as raise emotional awareness, as suggested by Morris [31]. The user can also mark the exercise as a favorite, thus adding it on the list of favorites, which is accessible quickly through the main view.

Progress in the program is presented in several ways. First, the number of completed exercises is displayed for each step. Second, the background color of steps and exercises changes once they are completed. Each completed exercise is rewarded by a virtual rose (Figure 1d), providing immediate graphical feedback of progress [32]. The visual theme of Oiva draws from nature. The graphics and background images depict nature, animals, and landscapes to provide calming elements, as proposed by Moraveji and Soesanto [33]. Pictures, audio, and video are used to make the experience of using Oiva pleasurable and less demanding, reducing the amount of text in a similar manner as done by Ly et al [24].

Figure 1. Screenshots of Oiva. (a) the main screen, (b) diary, (c) introduction video, (d) top menu of Aware Mind, (e) exercise introduction screen, (f) audio exercise, (g) text exercise, (h) exercise reflection screen.



Study Participants and Recruitment

Fifteen volunteer participants were recruited via email from the staff of the local technical university in Finland. Thirteen of the participants had not encountered Oiva and did not know the researchers prior to the study. Two of the participants had seen an earlier version of Oiva, because they had volunteered in a short usability test in a laboratory. There were no specific inclusion criteria, only that the participants needed to be interested in stress management and willing to use a prototype mobile app. The app was described as an acceptance-, value-, and mindfulness-based self-help program designed to help in, for example, stress management and relaxation, increasing physical activity, and practicing mindful eating.

The 15 participants (9 female) were university staff, including, for example, a human resources manager, a secretary, a researcher, and a laboratory engineer. Five participants were younger than 30 years old, 5 were between 31 and 40 years, and 5 were older than 40 years.

The participants signed an informed consent form prior to the study and were aware of their right to withdraw from the study at any time. Ethics committee approval was not acquired as the

study was deemed to involve minimal risk and the focus was on studying mainly user experiences.

Procedures

The participants filled in baseline questionnaires and attended a face-to-face group kick-off session, which consisted of two 10-minute presentations, one on ACT theory and one on Oiva. The aim and process of the study were explained. An Android smartphone with Oiva pre-installed was provided for each of the participants to be used for one month. The phone model was either ZTE Blade (7 participants) or Sony Ericsson Xperia ray (8 participants). A short user guide about Oiva was provided on paper. Active, preferably daily use was recommended, but finding personally appropriate ways of use was also encouraged. The study period was one month in May 2012. At the end of the study, each participant was given two movie tickets to compensate for the time spent in study procedures.

Measures

Data were collected from 3 sources: (1) online questionnaires completed at baseline, after one week's use and after one month's use, (2) interviews conducted after one month's use, and (3) the usage log of Oiva app.

Background information (eg, age and previous experience in using mobile phones and wellness technologies) was collected at baseline. Wellness questionnaires were administered at baseline and after one month's use. Psychological flexibility was assessed with a 7-item Acceptance and Action Questionnaire (AAQ-II, [35]). AAQ-II employs a 7-point Likert scale from 1 (strongly disagree) to 7 (strongly agree) and includes negative statements, such as "Worries get in the ways of my success". AAQ-II is scored from 7 to 49, and higher scores suggest less psychological flexibility. Results across seven samples with a total of 3280 participants have provided promising evidence as to the adequate structure, reliability, and validity of the AAQ-II [36]. The Satisfaction with Life Scale (SWLS, [37]) also employs a 7-point Likert scale and includes five positive statements, for example "in most ways my life is close to ideal". The SWLS is scored from 5 to 35, where higher scores suggest higher satisfaction with life. The SWLS has been found to have good validity and reliability and has been shown to correlate with measures of mental health [37,38]. The single-item stress scale [39] has one statement: "Stress means a situation in which a person feels tense, restless, nervous or anxious or is unable to sleep at night because his/her mind is troubled all the time. Do you feel this kind of stress these days?" The response is recorded on a 5-point Likert scale varying from 1 (not at all) to 5 (very much). The stress scale has shown satisfactory content, criterion, and construct validity for group level analysis [39]. Experienced wellness benefits were measured by user experience questionnaires after one week's use and one month's use. Three questions measured Oiva's perceived usefulness in the maintenance and improvement of wellness, learning new skills, and gaining new insights. These questions were recorded with scales ranging from 1 (completely disagree) to 7 (completely agree).

Qualitative data on user experiences, usage, and usefulness were gathered in individual, semi-structured, face-to-face interviews after one month's use. The interviews were designed among the authors and a discussion guide outlining the themes of the interview was created. Some of the themes included were: the situations where Oiva was used in, whether using Oiva affected the participant's wellness, the user experiences of different features of Oiva, Oiva's ability to persuade and reward usage, and desired new features of Oiva. The first author, who has several years of experience in user experience studies, conducted the interviews. Each interview lasted about 45 minutes and was audio recorded.

The usage log files were collected from the phones after the interview. The usage log contained all user actions and their time stamps. The number of characters in diary entries was also logged, but not the content of the entries.

Data Analysis

The log files of 14 participants were analyzed. One participant was excluded due to unreliable time stamps in her log file caused by a date change in her phone. Individual usage sessions were first detected and counted. Then, usage days were calculated as days containing a usage session. The durations of individual sessions were calculated based on the start and end times of each session, and the total duration of use by summing the

durations of all sessions. As the app can be always "on" and running in the background, there were no specific log events that would flawlessly indicate the start of a usage session. Thus, two criteria were used to determine the start of a session. First, if an "app started" event was detected without any prior activity for the past 10 minutes, a new session was considered to have started. Second, if there was at least a 20-minute pause between consecutive log events, a new session was marked. The 20-minute requirement was chosen to avoid marking a new session while the user was listening to or otherwise performing an exercise.

Statistical analysis of the quantitative data from the wellness questionnaires and our custom rating scales for the experienced benefits was performed as follows. First, one female participant was excluded as she omitted some of the questionnaires. Coincidentally, she was the same participant who was also excluded from log file analyses. Then, change in participants' ratings of wellness from before to after using Oiva was analyzed with paired comparisons using Wilcoxon signed rank tests. Finally, we tested if the median ratings of experienced benefits of Oiva (ie, improvement or maintenance of wellness, learning new things, and gaining new insights) were statistically significantly on the positive side (ie, above the mid-point of 4) using Wilcoxon signed rank tests.

The interview audio recordings were transcribed and analyzed with a qualitative content analysis method called thematic coding [40]. The data were categorized under three main themes (usage habits, perceived benefits, user experiences of Oiva and its functions). Under each main theme, several subthemes were identified, for example, usage situations, barriers of use, and benefits.

Results

Participant Characteristics

According to the baseline questionnaire, all except one of the participants used mobile phones daily, and all but one had used mobile phones for more than ten years. Eleven participants were currently using a smartphone. Of the participants, 67% (10/15) had already tried some mobile wellness apps (eg, for exercise tracking), and 73% (11/15) had tried wellness-related Web services (eg, for weight management). Eleven participants (73%) had some prior knowledge of ACT related topics (eg, mindfulness).

Usage

The average duration of the usage period from the first log event to the last was 34.0 (SD 5.3, range 26-46) days. The participants used Oiva, on average, on 11.5 (SD 5.8, range 4-20) days, and there were, on average, 16.8 (SD 9.0, range 5-36) usage sessions per participant during the study. The average duration of usage sessions was 12.3 (SD 5.2, range 4.4-24) minutes. The average total usage time per participant was 192 (SD 99, range 56-339) minutes.

Effects on Wellness

Table 1 presents the participants' average ratings of stress (score of Elo's stress scale), life satisfaction (score of SWLS), and

psychological flexibility (score of AAQ-II). The change from before to after using Oiva was statistically significant for ratings of stress ($z=3.00, P=.003$) and life satisfaction ($z=2.32, P=.02$). There was no statistically significant change in psychological flexibility ($z=0.06, P=.950$).

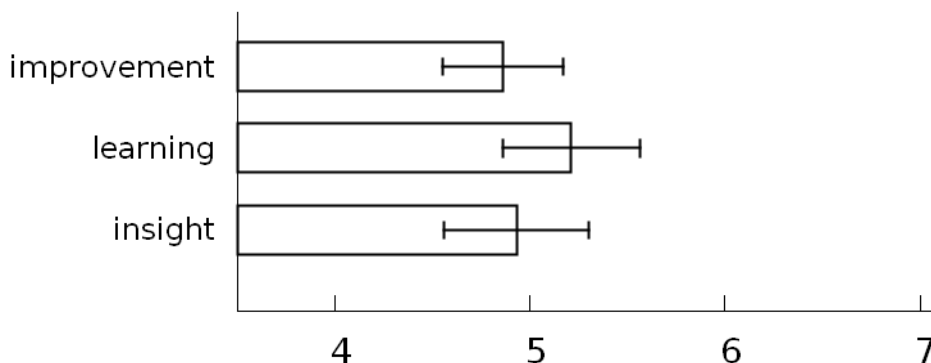
Figure 2 presents the mean ratings of benefits that the participants reported having gained from using Oiva. All mean ratings were on the positive side. Observed medians for each scale were 5 and statistically significantly higher than the mid-point of 4 for all the scales, improvement or maintenance of wellness ($z=2.29, P=.022$), learning new skills ($z=2.67, P=.008$), and gaining new insights ($z=2.17, P=.03$).

Table 1. Ratings of stress and scores in SWLS and AAQ-II questionnaires before and after using Oiva.

	Before mean (SEM ^a)	After mean (SEM)	P
Stress	3.1 (0.2)	2.5 (0.1)	.003
SWLS	23.1 (1.3)	25.9 (0.8)	.02
AAQ-II	17.2 (1.5)	17.2 (1.6)	.95

^aSEM=standard error of mean

Figure 2. Mean post-study ratings (\pm SEM) of the effects attributed to Oiva.



Usage Habits and Barriers

The most common place to use Oiva, reported by 80% (12/15) of participants, was at home. Typical usage contexts at home included: in bed before falling asleep or after waking up (5/15, 33% of participants), in the backyard (2/15, 13% of participants), or in the middle of household routines (3/15, 20% of participants). One participant who used Oiva outdoors commented that the elements of nature (eg, birds singing or fresh air) strengthened the effects of the exercises. Only 27% (4/15) of participants had used Oiva at work. Forty percent (6/15) of the participants had tried performing exercises in mobile contexts, for example, when commuting, and 27% (4/15) of them reported liking this way of use. Mobile situations were often regarded as restless and not providing a possibility for proper concentration.

Despite little actual mobile use, the mobile device was regarded as a good platform for a stress management app. Ten participants (67%) brought up the ease of carrying a mobile phone along as

the main benefit. Even at home, the mobile phone was taken along to different places, such as bed, hammock, or living room floor, where the usage of a computer would have been more difficult. Also, being able to open the app quickly and not requiring an extra device to carry were important benefits of the mobile phone for 27% (4/15) of participants (eg, compared to relaxation CDs or laptops). The mobile phone implementation was perceived especially suitable for short and easy exercises (6/15, 40% of participants) and for audio exercises (4/15, 27% of participants). Three participants specifically mentioned that some of the exercises, such as long exercises requiring concentration and tranquility, were less suitable for a mobile phone. However, not having Oiva installed in their personal phone affected use; 60% (9/15) of participants believed that, if Oiva had been installed in their own phone, they would have used it in a more versatile way and also in mobile contexts.

A typical barrier of use was being busy in everyday life (7/15, 47% of participants), which made it difficult to find suitable,

peaceful moments for exercises. For example, concentrating on the exercises in the evening when already tired was perceived challenging (3/15, 20% of participants). Forty percent (6/15) of participants also mentioned that they forgot to use Oiva unless they consciously dedicated a time slot for it in their schedules.

The participants preferred short and simple exercises that were easy to integrate into their everyday life, could be done anywhere and were easy to perform even without Oiva after learning the techniques. Forty-seven percent (7/15) of participants said that these exercises gave them immediate benefits and that they intended to continue doing them also after the study.

The one-month usage period seemed too short to 73% (11/15) of the participants. They felt that establishing profound lifestyle changes and new routines takes longer than a month, and that they only had time to explore the exercises but not to apply the skills properly to their own life. The participants who had learned to apply the skills in their life and perform the exercises even without Oiva had been familiar with the techniques already prior to the study. The short breathing and relaxation exercises were an exception as the techniques were very easy to learn.

Perceived Benefits

According to the interviews, the main benefit of Oiva was being able to take a break in the midst of daily hassles, whether at work or at home (eg, taking care of children or household chores). Especially the short breathing and relaxation exercises were found useful for this purpose. One participant described how differently her day began after doing an exercise compared to her routine mornings: “When I did an exercise in the morning before leaving for work, the day begun in a totally different way. Otherwise I would have just driven to work in a rush”. The participants who had done exercises in bed at night felt that it helped them fall asleep easier.

Four participants (27%) reported gaining more profound benefits, such as changes in their thoughts and attitudes. These included getting a new perspective on their life or starting to consider their values and actions. Two participants (13%) had also discussed their values with their spouses. One of them stated this would not have happened without Oiva. The other one had experienced value-based exercises beneficial in a new life situation, after becoming a parent for the first time. A third participant described that value exercises had helped her realize concretely that she has the power to decide how she spends her time and her life.

Four participants (27%) also reported gaining the ability to let go of their thoughts and feelings, and change their perspective to them. They reported that these skills had helped them deal with negative thoughts and feelings, distance themselves from stressful thoughts and accept setbacks. It had made them question whether some of their issues were as serious as they had thought.

User Experiences of Oiva and Its Functions

Mindfulness was considered a good philosophy for Oiva. Seven participants (47%) commented that Oiva’s exercises concretely demonstrated how they could apply mindfulness in their

everyday life. In general, the participants regarded the exercises as interesting, concrete, down-to-earth, and memorable. The stories and metaphors helped them understand the topics. In addition, as Oiva included versatile topics and exercises in a structured form, the participants were able to choose the most suitable exercises.

Audio exercises were preferred over text by 73% (11/15) of participants because they provided guidance through the exercise. They were also perceived to provide a “more personal feeling” and make it easier to concentrate and relax. An unexpected benefit, reported by one participant, was that audio exercises enabled performing them together with other people. However, text exercises were considered useful for recapitulation and therefore both formats were needed.

Eight participants (53%) performed exercises in the order recommended by Oiva. Guidance was perceived to facilitate use, as reflected in a comment: “It does not limit but provides the direction where to go, that works!” If the participants felt that the recommended exercise was not suitable for a specific situation, they skipped it at that moment. The recommended order was not taken by 47% (7/15) of participants, who chose exercises based on interesting topics, names of the exercises, or their own feelings. They did not feel that the guidance limited their freedom of choice. The app “told in a plain enough way, not with exclamation mark, where one is going and what is being suggested next”, as one participant articulated.

Although the participants liked the current guidance in Oiva, they wished for even more guidance. Six participants (40%) would have liked a scheduled program and 67% (10/15) would have liked to receive reminders to use Oiva. They felt that these features would bring order and motivation. However, they stated that scheduling should not be too restrictive. Skipping and choosing different exercises should still be possible.

Skepticism toward gamification was expressed by 60% (9/15) of participants. They thought that collecting points, rewards, and achievements would not sit well with a mental wellness app or fit the philosophy of mindfulness. They felt that the motivation to use Oiva rises from its content and wellness effects and that the real achievements and rewards come from learning and self-improvement. Instead, they wanted to see their progress in the skills they had learned and the positive changes they had accomplished.

Nine participants (60%) made entries to Oiva’s diary. The interviews revealed that the entries mainly dealt with thoughts, feelings, and insights raised by the exercises, and answers to the questions in the reflection screen. According to the participants, one of the main benefits of the diary was that it enabled the follow-up of thoughts when the same exercise was repeated. Two participants used a paper diary, because they wanted to be able to write and draw freely. Three participants wished to have more structured and guided questionnaires with pre-defined response options, as they found it difficult to know what to write. They also felt that a structured diary would enable easier follow-up and comparison of entries. In general, the touch screen text input was regarded as cumbersome, which may have caused some of the problems encountered with the diary.

At the time of the study, Oiva did not offer anything extra when the user had completed all the exercises, which 80% (12/15) of the participants saw as an inadequate end for the program. Nine participants (60%) mentioned that they would have wanted a follow-up program to remind them to continue to do the exercises, preferably focusing on the exercises that were the most beneficial for them or where there still was room for improvement. The follow-up program could also provide new content and exercises. The participants felt that the usage of Oiva should not end after completing the exercises once, but that the exercises should be repeated whenever needed. The skills learned should be integrated to one's life and Oiva could help by guiding in that.

Discussion

Principal Findings

The 4 main goals of this study were: (1) to find out how the participants used the app, (2) to study whether using Oiva improved the participants' mental wellness, (3) to explore how Oiva and its functions were experienced, and (4) to derive preliminary design guidelines for mobile stress management apps.

Oiva was used actively by the participants, on average, every third day. The sessions were relatively long for mobile use, on average 12 minutes. This result is similar to the one reported by Doherty et al [32], albeit their intervention was Web-based. Although daily use of Oiva was recommended to the participants, finding personally appropriate ways of use was also encouraged. Longer sessions may be useful for learning the skills at the beginning, whereas later on, short sessions may be enough to maintain them. This indicates that different phases of use should be identified and supported.

Statistically significant improvements in stress and life satisfaction were achieved during the study. The positive mean ratings on the subjective scales of improvement or maintenance of wellness, learning new things, and gaining new insights suggest that the participants explicitly attributed these positive effects to Oiva, although other factors (eg, changes in common stressors for the university staff) cannot be excluded in this study. Furthermore, as the study sample was small, these results should be considered preliminary and indicative.

The interview data implied that the participants had taken the first steps towards learning the skills related to ACT. Most participants reported increased mindfulness, but also learning other skills, such as skills related to acceptance, cognitive defusion, values, and committed actions. However, we did not observe significant changes in psychological flexibility, which would have been in line with such changes. One of the reasons may be that most of the sample already had some prior knowledge of ACT. Moreover, psychological flexibility has been described as a fundamental basic aspect of health [41], and changes in such basic psychological processes may take a longer period of time to manifest. However, there is evidence that gaining changes in psychological flexibility within such a short time period may be possible by concentrating on specific processes, such as values and committed actions, as in the work

by Ly et al [24]. However, in contrast to our results, they did not find any changes in life satisfaction, which may be due to their narrower coverage of ACT processes. In our study, most of the participants started with mindfulness exercises and did not have enough time to properly go through exercises related to acceptance and values, which could have a more direct impact on psychological flexibility. The comparison of the outcomes of these two studies poses an interesting question: does focusing on different processes of ACT influence different aspects of psychological wellness?

Design Implications

It is assumed that mobile devices are well-suited for wellness apps because they enable interventions in mobile contexts. In our study, we found that most of the use occurred, not in mobile situations, but in situations that were peaceful and provided an opportunity for proper concentration. The short breathing and relaxation exercises formed an exception—they were found easy to integrate into everyday life and in some cases even mobile situations. However, the strengths of the mobile platform became evident because the mobile phone was easy to carry along anywhere enabling more freedom in choosing the locations of use. Also, being fast to open for a quick session was an important benefit.

Participants appreciated guidance in both navigation and performing the exercises. They liked to hand over the responsibility of deciding the order of exercises to the app. Thus, guidance may have helped in creating a sense of therapeutic alliance between Oiva and the participants [31].

Based on our findings, we propose the following set of preliminary design implications for mobile mental wellness training apps.

Provide Exercises for Everyday Life

Most, if not all, participants understood that the purpose of Oiva was to learn skills and techniques that improve wellness, and to integrate these skills to everyday life as a process of mental self-development. The main benefit for most participants was the possibility to do exercises to calm down quickly. The short breathing and relaxation exercises were used to take a break, a "moment for me". Such exercises were well-suited to the relatively short one-month study period, since they were quick to absorb, easy to integrate into one's daily habits and everyday life, and did not require much thought or preparation.

Find Proper Place and Time for Challenging Content

The participants perceived some of Oiva's exercises as more challenging, especially the exercises that were longer or related to more challenging skills (eg, values or acceptance). They required more concentration and effort, and therefore had a high threshold to get started with. However, the challenging exercises would probably have stronger effects on psychological flexibility and thus it is essential to lower the threshold for the users to engage in them. One way to approach this could be to utilize context-awareness on mobile platforms to identify appropriate moments to engage the user [42]. In the future, the context-aware system could be able to recognize a suitable time and a peaceful place for performing the exercises requiring more

concentration, and prompt the user at that moment. Another less technical solution would be to provide an opportunity for the user to filter and search exercises for specific contexts and needs.

Focus on Self-Improvement and Learning Instead of External Rewards

Interestingly, the majority of the participants did not wish for extra rewards or game-like elements in Oiva. An achievement-oriented approach is often utilized in the apps for physical activity [30], and it is easy to assume that users would enjoy a gamified approach also in mental wellness apps. However, our participants thought otherwise. Playful interface or hunting for rewards was not seen to fit the philosophy of mindfulness, concentration, and calming down. The participants felt they were rewarded and intrinsically motivated by learning new skills and seeing changes in their lives. This is in line with the notion that it is more important to focus on meaningful experiences than rewards [43]. As argued by Doherty et al [32], the designers should emphasize the engagement with the treatment, rather than with the technology. However, at the same time we note that our participants were working age adults in a university setting. Rewards and a gamified approach might suit other types of user profiles better.

Guide Gently but Do Not Restrict Choice

In general, the preference for guidance as “giving direction but not limiting” was expressed frequently. Oiva’s way of gently recommending an exercise while still leaving the user the freedom of choice was appreciated. The participants also liked having audio narration to guide them through exercises. In self-help apps, active guidance is a way to foster a sense of alliance [31]. Even more guidance was wished for in the form of a scheduled program in the calendar and reminders for specific exercises. Furthermore, some implied that a follow-up program would be useful to integrate the skills learned in the intervention as a part of life. Based on these findings, it seems that the participants wanted to have a feeling of being guided through the program, but they did not want to follow too strict tunnels without an option to skip exercises or select more suitable ones. Therefore, the persuasive design principle of tunneling (narrowing down the choices available for the user) [26,27] should not be used excessively.

Provide an Easy and Flexible Tool for Self-Reflection

Many participants used the diary as a self-reflection tool, as they wrote down feelings and thoughts related to exercises, as well as responded to the questions that were asked at the end of the exercises. The participants emphasized the importance of raising emotional awareness through self-reflection [31]. Some of them desired a diary with structured questionnaires and pre-defined answers, revealing the need for a wider range of interactivity [32]. Not surprisingly, a mobile device was not considered ideal for free text input. Considering the successful use of self-tracking and mood monitoring in previous studies

[19,20], a structured manner of recording feelings and emotions as well as ability to view historical data could be useful.

Limitations

This study was an uncontrolled field trial involving a small number of volunteer participants, which must be taken into account in interpreting the results. Many of the participants were already somewhat familiar with ACT-based methods, which may have facilitated the adoption of the app and learning the skills. Due to the lack of a control group, common confounding factors affecting the wellness of university staff at the time of the study cannot be assessed. Also the usage patterns observed in the study may not fully reflect realistic usage patterns, as the participants were not able to use Oiva in their own mobile phones.

The study participants were not the direct target group of the app. For ethical reasons, we did not want to present a prototype app to people suffering from severe stress, and thus chose a healthy group of participants for this feasibility study. This choice limits the generalizability of the results.

Conclusions and Future Work

This article presented Oiva, a mobile stress management app based on acceptance and commitment therapy methods. We studied the usage, impact, and user experiences of Oiva in a one-month field study with 15 participants. The active usage, observed positive effects on wellness, and the generally positive user experiences of Oiva suggest that it is possible to develop engaging mobile apps that are experienced as beneficial for personal mental wellness. Our present results establish Oiva as a good starting point for continuing research on mobile support for mental wellness. We believe that the insights gained from our in-depth interviews with the participants may help future researchers to create effective and engaging mental wellness apps.

Oiva is currently being studied in a randomized controlled trial with working-age subjects suffering from stress and features of metabolic syndrome. In the study, Oiva is compared to an ACT-based face-to-face intervention with similar content, delivered as 6 group meetings during an 8-week period, and a control group. Each study condition will involve about 80 subjects. The impact of interventions will be measured by psychological, physical, and anthropometric questionnaires and measurements at baseline, after the intervention, and at 6 months after the intervention.

In future versions of Oiva, we aim to enable easier tailoring of programs to different target groups as well as individual needs and explore the possibilities of context-sensitivity in supporting better integration into the daily life. We will also study the opportunities of adding social features to the app [31,32]. However, our aim is to continue to develop and study Oiva in an iterative way, making sure that the existing features are successful before adding new ones.

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Conflicts of Interest

None declared.

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Abbreviations

- AAQ-II:** acceptance and action questionnaire
- ACT:** acceptance and commitment therapy
- CBT:** cognitive behavioral therapy
- SEM:** standard error of mean

SWLS: satisfaction with life scale

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Title	Design and evaluation of online and mobile applications for stress management and healthy eating
Author(s)	Kirsikka Kaipainen
Abstract	<p>Stress management and healthy eating are ongoing struggles for many people in the developed world. The consequences of chronic stress and unhealthy diets are borne at both individual and societal level. Currently, ischemic heart disease is the leading cause of death in the world, and depression is the leading cause of disability. Their early prevention calls for scalable and affordable means to provide support for healthy dietary choices and daily recovery from stress. Modern technology offers potential solutions for daily self-management but few health-promoting applications have reached widespread use despite promising research findings.</p> <p>The aims of this thesis were to assess the real-world use of health-promoting online and mobile applications, to evaluate their objective and subjective benefits, and to draw design guidelines for preventive applications. Six studies on online and mobile applications for stress management and healthy eating were conducted with diverse settings and target groups. Two of the studies assessed the use of an online and a mobile application for healthy eating and found that less than 10% of the almost 200,000 users they attracted remained active. Two studies evaluated the benefits of technology tools combined with group intervention for stress management and found improved well-being and active use of tools, although human contact was appreciated most. The last two studies analysed stress management applications and suggested new design principles for them.</p> <p>Based on the findings, freely available applications can reach a large number of users, but the attrition is likely to be very high and it is unclear whether the intended audience is reached. Applications can contribute to improved well-being and provide support for behavioural changes and skills learning as long as they are simple, attractive and easy to integrate into everyday life. The design of applications should support small daily actions that result in immediate benefits, emphasize self-improvement and reflection, and offer guidance while maintaining freedom of choice. The results support the feasibility and applicability of online and mobile applications for health promotion at individual level and highlight the importance of a systematic theory-driven, user-centric and business-oriented approach to intervention development. The societal impact of the applications may remain small unless real-world implementation, maintenance and dissemination are planned from the very beginning of the development process.</p>
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Nimeke	Stressinhallintaan ja terveelliseen syömiseen tarkoitettujen verkko- ja mobiilisovellusten suunnittelu ja arviointi
Tekijä(t)	Kirsikka Kaipainen
Tiivistelmä	<p>Stressinhallinta ja terveellinen syöminen ovat alituisen kamppailun aihe monille länsimaisille ihmisille. Niin yksilöt kuin yhteiskuntakin joutuvat vastaamaan pitkäkestoisien stressin ja epäterveellisen ruokavalion seurauksista. Sepelvaltimotauti on tällä hetkellä maailman yleisin kuolinsyy, ja masennus on yleisin työkyvyttömyyden syy. Varhainen puuttuminen ongelmiin edellyttää skaalautuvia ja edullisia keinoja, jotka tukevat terveellisiä syömisvalintoja ja päivittäistä stressistä palautumista. NykYTEknologia tarjoaa monia mahdollisuuksia päivittäiseen hyvinvoinnin hallintaan, mutta lupaavista tutkimustuloksista huolimatta vain harva terveyttä edistävä sovellus on päätenyt laajamittaiseen käyttöön.</p> <p>Tämän väitöskirjan tavoitteena oli selvittää terveyttä edistävien verkko- ja mobiilisovellusten käyttöä oikeassa maailmassa, arvioida niiden objektiivisia ja subjektiivisia hyötyjä sekä kehittää suunnitteluperiaatteita ennalta ehkäiseville sovelluksille. Stressinhallintaan ja terveelliseen syömiseen tarkoitettuja verkko- ja mobiilisovelluksia tutkittiin kuudessa tutkimuksessa eri asetelmissa ja eri kohderyhmillä. Kahdessa tutkimuksesta selvitettiin terveelliseen syömiseen tarkoitettujen verkko- ja mobiilisovellusten käyttöä ja havaittiin, että sovellusten tavoittamista lähes 200 000 käyttäjästä alle 10 % pysyi aktiivikäyttäjänä. Kaksi tutkimuksesta arvioi teknologiavälineiden hyötyjä yhdistettynä ryhmämuotoiseen stressinhallintaintervention ja havaitsi parannuksia hyvinvoinnissa sekä aktiivista välineiden käyttöä, joskin ihmiskontaktia arvostettiin eniten. Kaksi tutkimuksesta analysoi stressinhallintasovelluksia ja esitti niille uusia suunnitteluperiaatteita.</p> <p>Löydösten perusteella vapaasti saatavilla olevat sovellukset voivat tavoittaa suuren joukon käyttäjiä, mutta käyttö on todennäköisesti hyvin lyhytaikaista, ja on epävarmaa, saavutetaanko oikea kohdeyleisö. Sovellukset voivat edistää hyvinvointia ja tukea käyttäytymismuutoksia, jos ne ovat yksinkertaisia, kiinnostavia ja sopivia jokapäiväiseen elämään. Sovellussuunnittelun tulisi tukea pieniä päivittäisiä välitöntä hyötyä aikaansaavia tekoja, painottaa itsensä kehittämistä ja pohdintaa sekä opastaa säilyttämään kuitenkin valinnanvapauden. Tulokset puoltavat verkko- ja mobiilisovellusten hyödynnettävyyttä ja soveltuvuutta yksilötason terveyden edistämiseen, mutta niissä korostuu myös suunnitelmallisen teorioihin perustuvan, käyttäjäkeskeisen ja liiketoimintaa painottavan lähestymistavan tärkeys interventioiden kehittämisessä. Sovellusten yhteiskunnalliset vaikutukset voivat jäädä vähäisiksi, mikäli niiden käyttöönottoa, ylläpitoa ja levittämistä oikeassa maailmassa ei oteta heti alusta asti huomioon intervention kehitysprosessissa.</p>
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Design and evaluation of online and mobile applications for stress management and healthy eating

Have you ever felt stressed or had trouble sleeping, or grabbed something sugary to eat instead of a balanced meal? You are not alone. Chronic stress and poor dietary choices are global challenges with grim long-term consequences. Ischemic heart disease and depression are the leading causes of death and disability in the world and their prevention calls for affordable and accessible solutions. Online and mobile applications that are always at hand could be useful tools to support healthy eating and sufficient recovery from stress.

This work analyses the potential of health-promoting online and mobile applications through six studies that evaluate the real-world use of the applications, assess their impact on well-being, and draw design guidelines for them. The results show that freely available applications can reach a large number of users, but usage is usually short-lived and it is unclear whether the intended audience is reached. The applications can help people improve their well-being, but human contact is also highly valued. Designers should strive for simple and attractive applications that support small concrete actions, encourage self-improvement and reflection, and guide while maintaining freedom of choice.

The findings support the feasibility of online and mobile applications for stress management and healthy eating at individual level, but also highlight the importance of a theory-driven, user-centric and business-oriented approach to intervention development. The societal impact may remain small unless real-world implementation, maintenance and dissemination are planned from the very beginning of the development process.

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