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Elina Mattila

Design and evaluation of a mobile phone diary for personal health management

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Keywords self-monitoring, electronic diary, health promotion, cognitive-behavioural therapy

Abstract

The increasing prevalence of lifestyle-related health risks coupled with the lack of resources in preventative healthcare calls for novel and cost-efficient methods for supporting citizens in their independent health and well-being management. Behaviour modification is an efficient way of preventing chronic diseases and other lifestyle-related health problems, provided that the healthy behaviours are sustained over the long term. The challenge is to develop efficient methods that support citizens in their health management and empower them to take more responsibility for their health. Psychological methods, such as those based on cognitive-behavioural therapies, provide an understanding of behaviour change as well as efficient methods for supporting it. However, providing preventative face-to-face therapies for health promotion is not economically feasible and does not necessarily offer the long-term support required to establish permanent healthy behaviours.

Lately, information and communication technologies have been harnessed for use in health promotion programs. Mobile phones provide a particularly promising platform for health management applications due to their central role in people's lives as well as their technical capabilities. This thesis presents a mobile phone application for supporting the self-management of health and well-being, targeting working-age citizens. The Wellness Diary (WD) is based on a core method in cognitive-behavioural self-management, self-monitoring. The main aim was to enable the long-term self-management of well-being with the help of a mobile terminal. WD has been evaluated in several studies with different user groups and in different research settings. Three of the evaluations are presented in this thesis. Based on the results, most users found WD to be easy to use and useful. Furthermore, a significant number of users used WD regularly over several months, which shows that WD is capable of enabling long-term self-monitoring.

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Tiivistelmä

Elämäntavoista johtuvien terveysriskien lisääntyminen sekä terveydenhuollon resurssien riittämättömyys sairauksien ehkäisyssä ovat johtaneet tarpeeseen kehittää uusia, kustannustehokkaita menetelmiä kansalaisten omaehtoisen hyvinvoinnin hallinnan tukemiseen. Käyttäytymisen muuttaminen on tehokas tapa ehkäistä elämäntapoihin liittyviä kroonisia sairauksia ja terveyshaittoja, edellyttäen että terveelliset elämäntavat ovat pysyviä. Haasteena on kehittää tehokkaita menetelmiä, joilla kansalaisia voitaisiin tukea hallitsemaan omaa hyvinvointiaan paremmin ja ottamaan siitä enemmän vastuuta. Psykologiaan perustuvat menetelmät, esimerkiksi kognitiivisen käyttäytymisterapian menetelmät, antavat tietoa käyttäytymismuutoksesta ja sen tukemiseen soveltuvista keinoista. Perinteisiä, henkilökohtaisiin tapaamisiin perustuvia terveydenedistämisohjelmia ei kustannussyistä voida tarjota kaikille niitä tarvitseville, eivätkä ne välttämättä tarjoa pitkäaikaista tukea, jota tarvitaan terveellisten elämäntapojen vakiinnuttamiseen.

Viime aikoina tieto- ja viestintäteknologioita on alettu hyödyntää terveyden edistämisessä. Matkapuhelimet tarjoavat erityisen lupaavan alustan hyvinvoinninhallintasovelluksille, sillä niiden rooli ihmisten elämässä on keskeinen ja niiden tekniset ominaisuudet kehittyvät jatkuvasti. Tässä väitöskirjassa esitellään työikäisille suunnattu matkapuhelinsovellus hyvinvoinnin hallinnan tukemiseen. Wellness Diary (WD) perustuu itsehavainnointiin, joka on yksi kognitiivisen käyttäytymisterapian ydinmenetelmistä. Tärkein tavoite oli pitkäaikaisen hyvinvoinnin hallinnan mahdollistaminen mobiilin päätelaitteen avulla. WD:tä on arvioitu useissa tutkimuksissa, erilaisilla käyttäjäryhmillä ja erilaisissa tutkimusasetelmissa. Näistä tutkimuksista kolme esitellään tässä väitöskirjassa. Tulosten perusteella suurin osa käyttäjistä koki WD:n helppokäyttöiseksi ja hyödylliseksi. Lisäksi merkittävä osa käytti WD:tä säännöllisesti usean kuukauden ajan, mikä osoittaa, että WD mahdollistaa pitkäaikaisen itsehavainnoinnin.

Preface

The research presented in this thesis was carried out at VTT Technical Research Centre of Finland during 2004–2009. I want to express my most sincere gratitude to my instructor at VTT, Docent Ilkka Korhonen, who made sure that I was able to work on projects related to personal health technologies throughout these years. In addition, as technology manager, Docent Korhonen helped me with many practical issues related to finalising this thesis. Without his vision, encouragement, and guidance every step of the way, this thesis would not have seen the light of day.

My supervisor, Professor Ari Visa, has guided my studies since my second year at the university nine years ago. I want to thank him for his support and for steering me towards an area of research I could be passionate about.

I had the honour of having Professor Jukka Riekki and Docent Raija Laukkanen as the pre-examiners of my dissertation. I am grateful for their insightful and constructive comments, which helped improve this thesis significantly.

Professor Raimo Lappalainen, who has co-authored four of the five papers in this thesis and has been an important collaborator in the design of Wellness Diary (WD), has had a major impact on my research. He has enthusiastically driven the utilization of technologies in supporting psychological interventions. I thank him for the fruitful collaboration and all the encouragement.

In addition, I want to thank my colleagues at VTT. Juha Pärkkä was my closest colleague in the design of WD and a co-author in three publications of this thesis. It is difficult to say where his ideas end and mine begin. I also want to thank Antti Väätänen, Minna Kulju, Juha Kolari, and Juho Merilahti for their creditable contribution to this dissertation: they conducted the user experience studies and also co-authored papers in this dissertation. Special thanks go also to Docent Mark van Gils, who has always been ready to help with statistical ques-

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Special thanks go to the financiers and collaborators of the projects in which I have had the opportunity to work. I would especially like to thank our collaborators at Nokia Research Center, Jukka Salminen, Esa Koskinen, Aino Ahtinen, Kai Samposalo, Janne Vainio, Marion Hermersdorf, and Jussi Kaasinen, for the close collaboration in the development of WD and also in many other projects, and for co-authoring the papers. WD would not exist without them.

I am grateful to Timo Leino, Leila Hopsu, and their team at the Finnish Institute of Occupational Health for professionally organizing the randomised controlled trial in the Nuadu project and for co-authoring papers.

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I express my gratitude to the former technology managers at VTT, Jukka Perälä and Markus Tallgren, for their support for my PhD studies. The financial support by the Jenny and Antti Wihuri Foundation is gratefully acknowledged.

Finally, I want to thank my family for their support, for instilling in me the thirst for learning, and for looking after our cats during our travels. I also want to thank my friends, especially Elina Helander, for the walks, the talks and the peer support in everything. My warmest thanks go to my husband Jussi. Thank you for your loving support during this process, for keeping me sane, and for all the practical help in finalising my publications and this thesis. You mean more to me than words can ever express. My home is where you are.

Tampere, May 2010

Elina Mattila

Contents

List of publications

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

I Mattila, E., Pärkkä, J., Hermersdorf, M., Kaasinen, J., Vainio, J., Samposalo, K., Merilahti, J., Kolari, J., Kulju, M., Lappalainen, R. & Korhonen, I. 2008. Mobile diary for wellness management – Results on usage and usability in two user studies. IEEE Transactions on Information Technology in Biomedicine, Vol. 12, No. 4, pp. 501–512.

II Mattila, E., Lappalainen, R., Pärkkä, J., Salminen, J. & Korhonen, I. Use of a mobile phone diary for observing weight management and related behaviours. Journal of Telemedicine and Telecare. Accepted for publication.

III Mattila, E., Korhonen, I., Lappalainen, R., Ahtinen, A., Hopsu, L. & Leino, T. 2008. Nuadu concept for personal management of lifestyle related health risks. Proceedings of the 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society. Pp. 5846–5850.

IV Ahtinen, A., Mattila, E., Väätänen, A., Hynninen, L., Salminen, J., Koskinen, E. & Laine, K. 2009. User experiences of mobile wellness applications in health promotion. User study of Wellness Diary, Mobile Coach and SelfRelax. Proceedings of the 3rd International Conference on Pervasive Computing Technologies for Healthcare.

V Mattila, E., Korhonen, I., Salminen, J., Ahtinen, A., Koskinen, E., Särelä, A., Pärkkä, J. & Lappalainen, R. 2010. Empowering citizens for well-being and chronic disease management with Wellness Diary. IEEE Transactions on Information Technology in Biomedicine, Vol. 14, No. 2, pp. 456–463.

Author's contribution

The following describes the author's contribution to the individual publications of the thesis:

I This publication presents the design of the Wellness Diary (WD) and two studies with the aim of examining usage and user experience of WD. The author shared the main responsibility for the design of WD as well as planning the first user study with J. Pärkkä and I. Korhonen. The author performed the data analysis of the WD usage data in the first study and partly in the second study. The user experience study was performed and analysed by others. The author had the main responsibility for writing the publication.

II In this publication, the data obtained in the first study of publication I are analysed. The author had the main responsibility for designing and performing the data analysis and for writing the publication.

III The author had the main responsibility for designing the Nuadu personal health system (PHS) together with partner companies, and for writing the publication. The Finnish Institute of Occupational Health had the main responsibility for the design and execution of the randomised controlled trial in which the PHS was studied.

IV This publication presents user experience and usage results of the mobile applications included in the PHS presented in publication III. The author had the main responsibility for the study of usage patterns of the applications, and for writing the related sections in the publication. She also participated closely in the planning of the user experience study and provided several of the main study questions. A. Ahtinen had the main responsibility for the design, analysis, and reporting of the user experience study.

V This publication summarises findings from the WD studies and presents suggestions for improving the concept. The author was closely involved in most of the studies described in the publication. She had the main responsibility for the analysis of improvement needs and the theoretical framework for them. The new concepts presented in the publication were designed in collaboration with all authors. The author analysed the case data and created the feedback examples. The author also had the main responsibility for writing the publication.

Abbreviations

BMI	Body mass index
CBT	Cognitive-behavioural therapy
CT	Computerised therapy
GPRS	General Packet Radio System
ICT	Information and communication technologies
MMS	Multimedia Messaging Service
OECD	Organisation for economic co-operation and development
PC	Personal computer
PDA	Personal digital assistant
PHS	Personal health system
PmEB	Patient-Centered Assessment & Counseling for Exercise & Nutrition – Mobile Energy Balance
RCT	Randomised controlled trial
TAM	Technology Acceptance Model
TAMM	Technology Acceptance Model for Mobile Services
WD	Wellness Diary
WDC	Wellness Diary Connected
WLAN	Wireless Local Area Network

1. Introduction

The increasing prevalence of lifestyle-related health risks and chronic diseases, coupled with limited resources for early prevention in the healthcare system, calls for health promotion and disease prevention measures focused on citizens [WHO 2006]. The risk of chronic diseases begins to rise and physical capacity begins to decline after the age of 30 [World Economic Forum 2007, Ilmarinen 2001]. Therefore, working-age citizens are an important target group in terms of health promotion and early interventions. Health risks and resulting diseases have significant economic consequences such as increased healthcare costs, decreased productivity, absences from work, and high employee turnover [WHO 2006]. Most working-age citizens can be reached through their employer, who also has incentives to invest in preventative healthcare with realistic prospects to get a return on investment [Chenoweth 2007].

Sustained healthy behaviours, such as a balanced diet, regular physical activity, non-smoking, and moderate alcohol consumption, are essential to maintaining health and preventing diseases [Khaw et al. 2008, Willett 2002]. Changing behaviours and maintaining them requires long-term efforts and persistence, and often means forgoing immediate pleasures for benefits that can only be seen after months or years of living healthily [Rokke & Rehm 2001]. However, long-term individual or group-based health promotion programs are not feasible due to their high cost, and therefore citizens inevitably must take more responsibility for their own health and well-being.

Psychological therapies, such as cognitive-behavioural therapies (CBT), provide methods for supporting the self-management of health. Self-management therapies equip individuals with strategies and skills for managing their behaviour and give them the responsibility for applying the methods in real-life situations [Rokke & Rehm 2001, Kanfer 1970]. Self-monitoring, i.e., observing and recording one's behaviour, is a core method in self-management. It can be used for several purposes, such as problem identification, follow-up of progress, and maybe most importantly, as an intervention *per se* [Rokke & Rehm 2001, Foreyt & Goodrick 1993].

Information and communication technologies (ICT) have been used for supporting psychological therapies, the self-management of chronic diseases, and behavioural changes. ICT applications, especially web-based programs, have been successfully utilised to facilitate self-monitoring, the distribution of information, and communications between clients and healthcare professionals [Maheu et al. 2005, Marks et al. 2007, Ritterband et al. 2003, Davis Kirsch & Lewis 2004]. More recently, the focus has started to shift towards mobile devices, which are increasingly used in well-being and disease management. Several mobile applications: specialise in self-monitoring and data collection, use wireless mobile communications to deliver professional and peer support, and aim to motivate and empower users to adopt and maintain healthy lifestyles [Connelly et al. 2006, Kaplan 2006].

The mobile phone is a particularly promising platform for self-management applications due to its penetration in the society, its role in people's lives, and its technical capabilities [Patrick et al. 2008]. Most people carry their mobile phones with them at all times and use them for various purposes in addition to the obvious functions of calling and text messaging. For example, many people habitually use the mobile phone's calendar, music player and camera. Due to its multiple functions, the mobile phone also serves as storage for personal and private information. Harnessing the mobile phone to personal health management is a natural extension of its use.

1.1 Objectives of the thesis

The main objective of this thesis was to gain new knowledge on using a mobile phone application based on self-monitoring for supporting health and well-being management of working-age citizens. The specific objectives were:

1) To design a mobile phone application for health management and self-monitoring (I).
2) To validate the application as a self-monitoring tool (I–II).
3) To evaluate the application among the target group (III–V).

1.2 Outline of the thesis

This thesis consists of five publications from the author's research during the years 2004–2009 on the design, validation and evaluation of a mobile phone-based health management application, the Wellness Diary (WD). WD was designed to support Kanfer's CBT-based self-management model [Rokke & Rehm 2001, Kanfer 1970]. WD is a tool for self-monitoring and feedback that aims to assist citizens in their self-evaluation and self-reinforcement.

Publication I describes the design of WD and two user studies investigating the validity of WD as a self-monitoring application. The study was aimed to show that WD is apt for long-term self-monitoring through user acceptance and usage in two different target user groups.

In Publication II, the self-observation data recorded with WD in the first study of publication I were studied. The aim was to validate the correctness and usefulness of self-observed data by examining self-reported weights and behavioural patterns related to weight management.

In Publications III and IV, WD was included in a personal health system (PHS) consisting of several technologies, and evaluated in a setting where the users had the freedom to choose which technologies to use. Publication III presents the service concept, including the PHS and an occupational health promotion intervention targeting multiple health risk factors. The set-up of a randomised controlled trial, organised to study the efficacy of the service concept, is also introduced. Publication IV presents user experience and usage results for the three mobile applications in the PHS for the first months of the study. The adoption rates of different applications and an analysis of the success factors and challenges of mobile applications are included in the results.

Publication V summarises the findings from the aforementioned and other WD-related studies, where WD was used on its own or as a part of a PHS, connected to an intervention or used independently. Concepts to improve the WD by introducing persuasive and motivational features are presented.

This thesis is organised as follows. Chapter 2 introduces the need for health management and presents psychological theories and methods related to the self-management of health. Chapter 3 describes the potential and challenges of mobile technologies for health management and reviews the literature of mobile health management applications based on self-monitoring. Chapter 4 presents a summary of the publications in this thesis, including their aims, methods, main results and conclusions. A discussion of the results and their implications is presented in Chapter 5, and final conclusions are drawn in Chapter 6.

2. Health management

2.1 Health risks

Seven leading health risk factors – high blood pressure, smoking, alcohol consumption, high blood cholesterol, obesity, low fruit and vegetable intake, and physical inactivity – account for nearly 60% of the disease burden in Europe [WHO 2005]. These risk factors are common to many of the most wide-spread diseases in Europe, and often cluster and multiplicatively interact in individuals [WHO 2006]. The prevalence of many of these risks is expected to increase in the future: obesity rates, for example, are predicted to continue rising in the countries of the Organisation of Economic Co-operation and Development (OECD) [Sassi et al. 2009]. In addition to deteriorating the quality of life of individuals, health risk factors and resulting chronic conditions burden society through increased healthcare costs, absenteeism, decreased productivity at work, early retirement, and premature death [WHO 2006]. Despite their obvious potential, preventative actions are still scarce. For example, in the OECD countries, only 3% of public health expenditure is dedicated to prevention [OECD 2007].

Behaviour is the most important determinant of health, and the only one that can be controlled by individuals [McGinnis et al. 2002]. Thus, behavioural modification offers great promise for preventing the problems and diseases caused by suboptimal lifestyles. Modifiable behaviours related to diet, physical activity, and smoking account for over 70% of stroke and colon cancer, over 80% of coronary heart disease, and over 90% of type 2 diabetes [Willett 2002]. The healthcare costs for individuals who maintain healthy lifestyles are 49% lower and they can live up to 14 years longer than those with unhealthy lifestyles [Khaw et al. 2008, Pronk et al. 1999]. Even modest improvements in lifestyles, for example, weight loss of 5–10%, may be sufficient to prevent chronic diseases, such as type 2 diabetes [NHLBI Obesity Initiative Expert Panel 1998, Tuomilehto et al. 2001]. In order to gain the benefits, healthy behaviours must be sustained. This has been found challenging, for example, only about 20% of people who succeed in weight loss are able to maintain their new weight [Wing & Phelan 2005].

2.2 Self-management of health

Self-management refers to people's health-related decisions and actions on a day-to-day basis, regardless of their health condition [Lorig & Holman 2003]. Self-management skills enable individuals to sustain their healthy behaviours in the face of obstacles [Rokke & Rehm 2001]. This ability is very important in behavioural change because there are often more tempting and less healthful alternatives that offer immediate gratification, such as a chocolate bar or the couch and TV. The rewards of healthy lifestyles, such as weight loss, better physical condition, or staying healthy (i.e. free of disease), come only after months or years after initiating the change or may never become evident [Rokke & Rehm 2001].

2.2.1 Self-management models

Cognitive-behavioural therapy (CBT) is a well-established form of psychological therapy. The premise of CBT-based treatments is that behavioural change can be effected through changes in thinking. CBT originates from behavioural therapy and utilises many of the same techniques, such as exposure and self-monitoring, and in fact, some CBT-based therapies rely more on changes in behaviour than on elaborate cognitive mechanisms [Dobson 2010].

CBT treatments focus on the current factors which maintain the problems instead of their aetiology. The treatments are limited in duration, usually lasting 10-20 sessions, but abbreviated programs of less than ten sessions have also been found effective [Hazlett-Stevens & Craske 2002]. CBT treatments have proven efficacy not only in the treatment of psychological disorders, such as eating disorders, depression, and anxiety, but also in interventions to promote health with regards to, e.g., obesity and physical inactivity [Chambless & Ollendick 2001, Davidson 2006, Dubbert 2002, Shaw et al. 2005]. Self-management models based on CBT provide specific tools for supporting behavioural change and for the long-term, even life-long process of self-management.

Albert Bandura's social cognitive theory [Bandura 2004, Bandura 1977] presents a list of the core determinants of behaviour change. Information on health risks and benefits of health choices is a required precondition of change, but alone it is not enough to make people adopt and maintain new lifestyles. Outcome expectations affect behavioural decisions through the person's analysis of the benefits and costs associated with different health choices. There are also obstacles that have to be surmounted in order to succeed in behaviour change. For example, bad weather or work pressure may threaten an exercise routine. On the other hand, there are also facilitators which may help in the face of obstacles, such as personal coping skills or social support. Personal goals, plans and strategies provide the course of change and guide actions in the long and short term. Perceived self-efficacy, that is, the belief in one's ability to effect change through one's own actions, is the main determinant of initiating behaviour, expending effort, and remaining persistent in the face of obstacles [Rokke & Rehm 2001, Bandura 2004].

High self-efficacy has been associated with success in changing and maintaining health-related behaviours, and may even explain the rate of change during treatment [Rokke & Rehm 2001, Strecher & DeVellis 1986, Roach et al. 2003]. People with high self-efficacy set higher goals, commit to them more strongly, and view obstacles as surmountable [Bandura 2004].

The most important source of self-efficacy is the individual's past performance in a given situation. Repeated successes may increase self-efficacy, whereas failures may decrease it. The magnitude of the effect depends on the attributions of causation, i.e., whether the activity was perceived as easy or difficult and whether the outcome was perceived to be achieved by the individual's own actions or external factors. Self-efficacy may also be influenced by an observation of others performing an activity of interest, i.e., modelling, provided that the observer perceives the models as similar to him/herself. Verbal persuasion is another way of increasing self-efficacy, but it is easier to dismiss as it is not based on personal experience. However, if well-matched to the individual's understanding and beliefs, verbal persuasion may be effective. One's physiological state and mood may also affect self-efficacy: for example, a calm and relaxed state with a positive mood may increase confidence and the expectation of success [Rokke & Rehm 2001, Bandura 1977]. Self-efficacy is situation and behaviour-specific and varies with time [Bandura 1977].

Frederick Kanfer's self-management model [Rokke & Rehm 2001, Kanfer 1970] provides a three-stage feedback-loop model for implementing behavioural change. Figure 1 presents a schematic illustration of the model. The first stage of the loop is self-monitoring, i.e., self-observation and self-recording of one's own behaviour, thoughts, and emotions. The method of self-monitoring may vary, but the purpose is to pay conscious attention to certain aspects of one's behaviour. The second stage is self-evaluation, where the individual compares his/her performance to a criterion or standard, such as a personal weight loss goal, and determines whether the behaviour was a success or a failure. The third stage is self-reinforcement, where the individual administers rewards or punishments based on the self-evaluative judgment, thus controlling his/her behaviour. Kanfer's model assumes that the aforementioned processes are natural and internal to every individual, but that they can be externalised in therapy and that individuals can be taught new methods of self-monitoring, self-evaluation, and self-reinforcement.

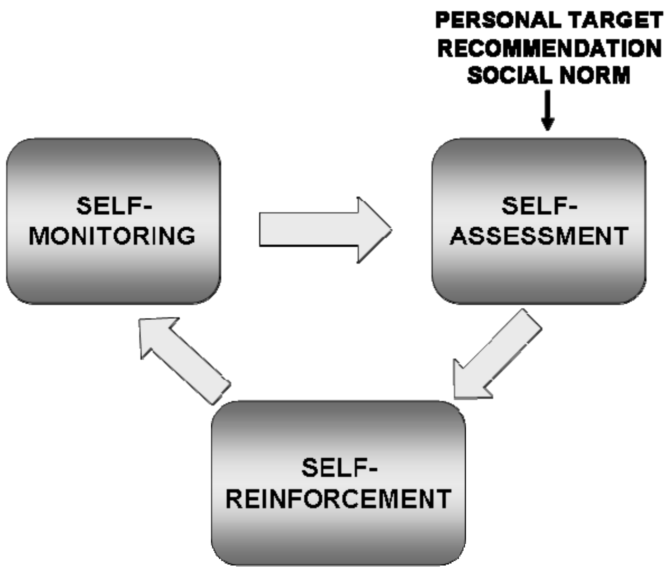

Figure 1. Kanfer's self-management model.

Kanfer's model also includes the concepts of commitment and attributions. Commitment to change is important in order to ensure persistence in the face of obstacles during the change process. Commitment may be boosted by, for example, discomfort or social disapproval expressed by others when the person does not make the necessary changes. It can also be sparked by fear of such social disapproval, the presence of others who have made the same commitment, or the support or encouragement of others. On the other hand, commitment may be hindered by difficult and distant goals or by a target behaviour that is not publicly observable or supported by others in the environment. The attribution of causality, as in Bandura’s model, determines who controls the target behaviour in the individual’s mind. If the individual thinks that he/she controls the behaviour, he/she is more likely to be successful in making the change [Rokke & Rehm 2001, Kanfer 1970].

The self-management models by Bandura and Kanfer aim to support behaviour change and change maintenance by equipping individuals with general self-management skills and giving them the responsibility for applying these skills in everyday situations [Rokke & Rehm 2001].

2.2.2 Self-monitoring

Self-monitoring is a widely used method in psychology, medicine and research, and it is also the first stage in Kanfer’s self-management model. Self-monitoring consists of self-observing certain events and self-recording those observations [Foreyt & Goodrick 1993]. Self-monitoring provides information on the progress of the individual and a means to follow processes that cannot be observed from the outside [Rokke & Rehm 2001, Foster et al. 1999]. The self-monitored events may include behaviours, thoughts, and feelings, and the circumstances surrounding them, such as the antecedents and consequences of behaviours [Foster et al. 1999]. Self-monitoring may be used to assess problems at the beginning of treatment, evaluate progress or the outcome of treatment, track the completion of homework assignments, or as therapeutic intervention [Rokke & Rehm 2001, Foster et al. 1999, Thiele et al. 2002].

Self-monitoring may focus on different dimensions of behaviour, such as the frequency, duration, intensity, or quality of the behaviour of interest. Behaviours may also be monitored through their outcomes, for example, exercise can be gauged according to the kilometres recorded on the bicycle speedometer [Foster et al. 1999]. In some applications, the frequency and timing of self-monitoring may be important, and therefore different sampling schemes are utilised. In event sampling, each instance of the behaviour is recorded and the behaviour itself serves as a reminder to self-monitor [Foster et al. 1999, Thiele et al. 2002]. In interval recording, the occurrence of the behaviour is monitored at specified intervals [Foster et al. 1999]. In momentary time sampling, signals or alarms initiate self-monitoring at random or fixed intervals [Foster et al. 1999, Thiele et al. 2002, Csikszentmihalyi & Larson 1987]. Applications of momentary time sampling include the experience-sampling method [Csikszentmihalyi & Larson 1987] and ecological momentary assessment [Shiffman & Stone 1998, Stone & Shiffman 2002].

A variety of methods may be applied to self-monitoring, for example, pen and paper, mechanical or electronic devices, or more sophisticated computerised diaries. The structure and detail level may vary as does the effort required from the observer. In clinical practice and research, the accuracy and comprehensiveness of data are important. However, as requirements of comprehensiveness increase, so does the risk of poor compliance [Foster et al. 1999]. Therefore, in order to maintain compliance and avoid over-burdening the observer, the self-monitoring task should be matched to the skill level of the observer and made simple, concise, and clearly relevant to the problem [Rokke & Rehm 2001, Foster et al. 1999]. The complexity of the self-observation diary and the duration of the self-monitoring period should also be matched; an individual cannot be expected to use a complicated tool voluntarily for more than a few days [Thiele et al. 2002]. Rewards, incentives, and regular contact with an expert may also increase compliance [Thiele et al. 2002].

In practical self-management, the effect of self-monitoring, i.e., reactivity, is more important than gathering comprehensive data. For example, self-monitoring of food intake and exercise may lead to a spontaneous decrease of energy intake and greater weight loss [Foreyt & Goodrick 1993, O'Neil 2001, Perri et al. 1989, Dubbert & Wilson 1984]. The importance of self-recording of observations to reactivity was reported by Clemes and Parker [Clemes & Parker 2009], who compared the effects of sealed and unsealed pedometers on step counts with and without self-recording and found that the self-recording of pedometer readings led to greater increases in step counts. The process of regular self-monitoring may be more important than the detail level when the aim is to induce changes. In a study by Helsel et al. [Helsel et al. 2007], participants who used detailed eating and activity diaries for the first two months and abbreviated versions for the last two months of a four-month study period achieved equal weight loss results as participants who used detailed diaries for the entire study period; although the number of completed diaries correlated with weight loss, the level of detail did not. Continued self-monitoring has been found important in weight loss maintenance [Kayman et al. 1990, Wing et al. 2006]. Wing et al.

[Wing et al. 2006] reported that daily, as opposed to less frequent self-monitoring, was strongly associated with successful weight loss maintenance. This result suggests that high compliance is required in order to gain the benefits of the reactivity effect. The mechanism by which self-monitoring affects behaviour has been associated with increased hopefulness that the treatment will be effective and with the confidence to be able to change, i.e., self-efficacy [Bandura 1977, Ilardi & Craighead 1994]. In addition, when self-monitoring journals are scrutinised by a therapist or peer, inappropriate behaviours are less likely to occur [Foreyt & Goodrick 1993].

Methods to reduce the effort of self-monitoring have been suggested, including monitoring technologies and automatic data transfer from devices like scales or blood pressure meters. These kinds of methods may be useful in long-term self-monitoring, but their use must be carefully designed as they may compromise the situation awareness of the individual and may not maximise behaviour changes [Clemes & Parker 2009, Gorman et al. 2000]. Hybrid solutions that combine manual and automatic monitoring have also been developed, for example, a heart rate monitor to support weight management through automatic monitoring of energy expenditure and manual entries of weight and energy intake [Byrne et al. 2006].

Traditionally, data obtained with self-monitoring has been used in research or therapy, and analysed only by experts. Long-term self-monitoring may reveal individual factors that affect health and well-being, such as personal rhythms of behavioural and physiological variables, interconnections between behaviours and health, and even clinically important changes in health status [Zhang et al. 2009, Tuomisto et al. 2006]. The analysis of such data is challenging and requires specific analysis methods to handle, for example, irregular sampling rates, repeated measurements, and missing or erroneous values [Pärkkä et al. 2002, Schwartz & Stone 1998, Bolger et al. 2003]. Certain rhythms have been detected in physiological and behavioural parameters and reported in literature. A weekly rhythm of weight, with weight increases on weekends and decreases on weekdays, has been found in self-monitored data [Tuomisto et al. 2006, Lappalainen et al. 2005]. Accordingly, a weekly rhythm of nutrient intake has been reported with greater caloric intake and larger meals on weekends [de Castro 1991]. Diurnal and yearly rhythms have also been reported for weight and other physiological variables [Tuomisto et al. 2006, Pärkkä et al. 2002, Lappalainen et al. 2005]. However, it has been challenging to detect connections that are known to exist, such as the link between eating, physical activity and weight loss [Burnett et al. 1992, Tate et al. 2001].

High adherence to long-term self-monitoring is required to reliably study behaviours. The level of detail in self-observations is also important in order to accurately quantify behaviours. However, in order to maintain adherence and avoid over-burdening the subjects, the complexity of self-observations needs to be matched to the length of the self-monitoring period [Thiele et al. 2002].

3. Mobile health management

Mobile computing, i.e., the use of portable computing devices capable of wireless communications, has dramatically changed work practices and social interactions, freeing them from the confines of fixed location and time [Srivastava 2005]. Practically everyone in the developed world owns a mobile phone. For example, the mobile penetration rate in the European Union was 119% in 2008 [EU 2008]. This chapter describes the potential of mobile technologies in health management and presents important design requirements for such applications. The literature on mobile technologies for self-monitoring and health management is also reviewed.

3.1 Potential of mobile technologies

3.1.1 The role of mobile phones in people's lives

Mobile phones have become an important part of people's everyday lives. Most people carry their phones with them all the time, everywhere they go, which provides opportunities for timely persuasion and pervasive reminders related to health management [Fogg 2003, Consolvo et al. 2008a]. Users consider their mobile phones personal and private, and they store various types of information on their phones, such as the contact information of family and friends, messages, photos, and videos [Srivastava 2005]. Nowadays, the functionalities of the mobile phone extend beyond calling and text messaging; for many, the mobile phone also serves as a calendar, notebook, alarm clock, web browser, music player, and camera [Srivastava 2005]. Personal health and well-being management seems like a natural extension of a mobile phone's use. A mobile health application integrates health management to the daily life of the user, and is present in the situations where health-related decisions are made. It also enables health management tasks during the idle moments of life, e.g., when riding on the bus or waiting for a friend [Srivastava 2005, Fogg 2003]. In addition, the mobile phone is a physical device, which may serve as a reminder to self-manage health [Foster et al. 1999, Barlow et al. 1984].

3.1.2 Technical capabilities

The technical capabilities of current mobile phones support their use for a variety of purposes, e.g. healthcare. Two-way communication and wireless long-range data transmission capabilities allow users to reach healthcare experts and peers, and to easily share data and experiences with them at any time. Currently, the most common data connections in the mobile phone are the General Packet Radio Service (GPRS; maximum data rate 115 kbps [Granbohm & Wiklund 1999]), the 3G network (maximum data rate 2 Mbps [Comer 2008]), and other wireless radios, such as the Wireless Local Area Network (WLAN; maximum data rates from 54 to 600 Mbps [LAN/MAN Standards Committee of the IEEE Computer Society 1999]). Storage, which is already in the order of gigabytes, is constantly increasing, and the processing capabilities of the mobile phone enable the advanced analysis of data, the creation of personalised feedback, and decision support even locally [Patrick et al. 2008].

Mobile tools offer several advantages over traditional pen-and-paper self-monitoring diaries, including methods for facilitating entry, supporting compliance, and ensuring the correctness of data. Data recording can be facilitated by opening the correct form and by storing the time and date of the entry automatically [Foster et al. 1999]. Reminders or prompts to interact with mobile applications can be implemented, and feedback on usage activity and the contents of entries may be provided in real-time to enhance compliance and amplify the effect of self-monitoring [Foster et al. 1999, Stone et al. 1991, Hufford & Shields 1992]. The actual time when an entry is made can be controlled by storing a time stamp or by prohibiting recording after a certain time has elapsed after the prompt [Foster et al. 1999]. Rules for detecting out-of-range entries may be implemented and the user can be prompted to check and correct entries [Shiffman & Stone 1998]. Interactivity is also supported; for example, branched questions or procedures contingent on previous responses can be developed [Stone & Shiffman 2002, Riley et al. 2005]. In the future, it may be possible to infer context information based on the various data collected by the mobile device, e.g., with the help of the global positioning system (GPS), accelerometers, and different environmental sensors. This provides opportunities to remind the user to self-monitor in situations directly related to the target behaviour.

Different data entry paradigms, such as touch, voice, photo, and video input as well as data retrieval from sensors may also be used to facilitate self-monitoring. The mobile phone may connect wirelessly (e.g. via Bluetooth or ZigBee) to wearable and ambient sensors and it can collect health and environmental data from them. In the future, this will become even more feasible, e.g., through the work of the Continua Health Alliance [Continua Health Alliance 2009].

Data security is an important issue in mobile health management applications. Data stored on the mobile phone can end up in the wrong hands if the device is stolen, shared or left unattended for a while. The mobile phone has inbuilt mechanisms for data security, but many people tend disable them because entering a pass code before each usage session is tedious. Data may also be jeopardised when transmitting it from the mobile phone [Patrick et al. 2008].

3.2 Design challenges

As a platform, the mobile phone presents several challenges for application designers. Dunlop and Brewster [Dunlop & Brewster 2002] list five main challenges: the mobility of usage, the widespread population of mobile phone users, limited input/output facilities, incomplete and varying context information, and multitasking. Users with a variety of backgrounds, technical skills, and needs have to perform tasks with a hand-held device that provides only a small screen and keypad and limited pointing capabilities [Dunlop & Brewster 2002]. They also have to cope with relatively slow wireless connections, prone to errors and disconnections [Forman & Zahorjan 1994]. The context of use may be far from optimal; it may even change or be subject to interruptions during a usage session. The users usually cannot dedicate their full attention to one task, but multitask while interacting with mobile devices [Dunlop & Brewster 2002]. On the technical side, the developers are challenged by the competing and incompatible mobile software platforms, e.g., Symbian, Java 2 Micro Edition, and Google Android; applications must be customised for each platform and even for different phone models within the same platform [Patrick et al. 2008]. Although many of these challenges will be alleviated in the future, some features, such as the small size to allow portability, are inherent to mobile devices.

The acceptance of mobile applications depends on several factors. The Technology Acceptance Model (TAM) was developed by Fred D. Davis [Davis

1989] for studying the acceptance of information technology applications in the workplace. The TAM defines usage behaviour as the result of intention to use, which in turn is affected by perceived ease of use and perceived usefulness. Eija Kaasinen [Kaasinen 2005, Kaasinen 2009] modified the TAM model to present user acceptance of consumer mobile services. The Technology Acceptance Model for Mobile Services (TAMM) focuses especially on the acceptance of mobile Internet and location-aware services. Kaasinen presents a set of design implications derived from the model. Figure 2 presents a schematic illustration of the TAMM model.

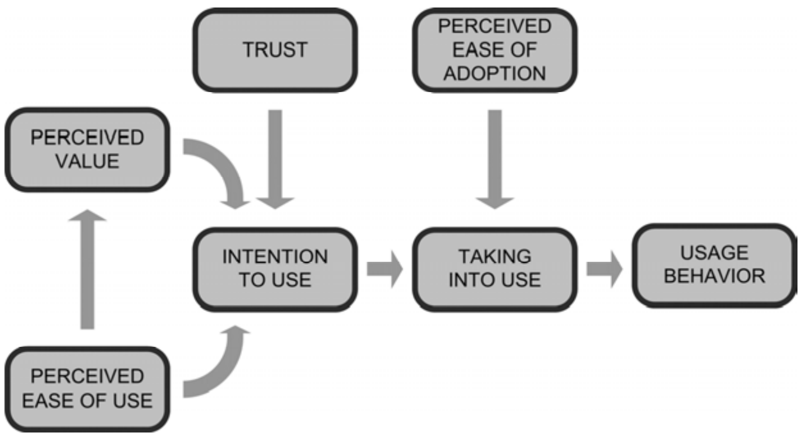

Figure 2. The TAMM model, which presents the factors that influence user acceptance and usage behaviour of mobile services. Published with permission from E. Kaasinen.

In the TAMM model, perceived usefulness is replaced by perceived value, which entails not only the utility of the service but also the users' motivation to adopt it. Value can be generated or maintained by enhancing the communication value of the mobile device and by providing sufficient topical information and seamless service entities. Perceived ease of use can be improved by providing the user with a clear overview of the service entity; fluent navigation and user interaction; personalised and contextually relevant information; support for momentary use on the move; and adaptation to the wide range of devices, networks, and technical infrastructures available. Trust is included in the model as a new component that affects the user's intention to use the service. It can be enhanced by: increasing the user's perceived control over the service; providing information on the reliability and accuracy of the service in different usage contexts; implementing strategies to prevent, predict and identify errors; informing the user of such errors and providing guidance to overcome them; and by informing the user of the collection, storage and usage of his/her personal data. Kaasinen also introduces a new phase, “taking into use”, which occurs between the intention to use and the usage behaviour. This phase is affected by the perceived ease of adoption, which can be increased by: clearly presenting what the service can provide in terms of the user’s everyday life; effortless installation and, if needed, also uninstallation; and fitting the services into the existing usage cultures of the mobile phone and providing basis for new ones [Kaasinen 2005].

3.3 Mobile applications for well-being management

Although pen-and-paper-based self-monitoring is still the norm, electronic self-monitoring diaries have been in development for over two decades. Many of the earliest diaries were designed for data gathering in clinical research, such as different fields of clinical psychology, addiction, pain, and nutrition studies [Thiele et al. 2002, Hufford & Shields 1992]. The aim was usually to gather data that was as accurate as possible without changing the target behaviours. The validity of self-reports and compliance to monitoring with the help of electronic diaries have been researched extensively [Hufford & Shields 1992, Beasley et al. 2005, Stone et al. 2003, Shiffman et al. 1997, Swendsen et al. 2000].

This section reviews a number of mobile health management applications based on self-monitoring. The focus will be on applications that: aim to induce behavioural changes in individuals, contain features for promoting adherence to self-monitoring, and provide feedback or other motivational features to support self-management. Most of these applications have been designed for promoting healthy eating and physical activity with the aim of supporting weight management and staying healthy.

A pioneering application that fits this description was developed in the eighties by Burnett et al. [Burnett et al. 1985]. They developed an obesity treatment program on a hand-held computer. A custom-made portable computer was used in the first study, but in the later studies the program was ported to a commercial hand-held computer [Burnett et al. 1985, Agras et al. 1990]. The features of the program included self-monitoring of caloric intake and exercise; daily goal setting; immediate feedback on daily energy intake and physical activity; meal planning; auditory prompting to remind the users to self-monitor; and motivational and instructional messages [Burnett et al. 1992, Burnett et al. 1985, Agras et al. 1990]. The program has been thoroughly studied in various settings with a large number of overweight female subjects [Burnett et al. 1992, Burnett et al. 1985, Agras et al. 1990, Taylor et al. 1991]. In these studies, the duration of computerised treatment was usually twelve weeks with follow-up periods from six months to one year. The weight loss results in the studies varied from high [Burnett et al. 1985] to modest [Agras et al. 1990]. Combining the program with a restricted diet was found to produce better and more sustained weight loss results than the program alone [Taylor et al. 1991]. In two studies, adherence to the program was reported to decrease significantly during the treatment. In the study by Taylor et al. [Taylor et al. 1991], the subjects made entries six to seven days a week in the beginning and three to four days a week at the end of the twelve-week period. Agras et al. [Agras et al. 1990] reported the usage frequency of the program decreasing from daily usage to about five usage days a week in a group that received bi-weekly face-to-face support and to about two days a week in a group that used the program without support during the twelve-week treatment. Burnett et al. [Burnett et al. 1992] studied the actual adherence to the program and found that the number of usage days – and especially the daily frequency of entering self-reports and viewing feedback – were strongly correlated with total weight loss.

Houston [Consolvo et al. 2006] is a mobile phone application for motivating physical activity by self-monitoring steps and social support among friends. A pedometer is used to record steps, and the step counts are manually entered into the application. Houston was studied in a three-week user study with thirteen participants divided into three groups of friends. Two groups used a version which enabled sharing step counts, comments and messages among the group, and one group used a personal version without the sharing feature. The groups who shared their data were more likely to meet their step goals, though it was noted that some of the participants did not like the idea of sharing and preferred the personal version. Chick Clique is a similar application that targets teenage girls [Toscos et al. 2006, Toscos et al. 2008]. In two user studies with altogether fifteen participants, the findings on the motivational effects of social comparison and support were very similar as those obtained for Houston.

UbiFit Garden [Consolvo et al. 2008a] is a system for encouraging different types of health-promoting physical activities. It consists of a mobile phone application for automatic and manual recording of activities; an on-body activity sensing device for detecting certain activities and transmitting them to the mobile application; and a glanceable display on the mobile phone wallpaper that gives visual feedback on physical activities as flowers blossoming in a garden. UbiFit Garden was first studied in a three-week study with twelve participants [Consolvo et al. 2008a], and later in a three-month study with twenty-eight participants [Consolvo et al. 2008b]. The glanceable display was found to be the most important component of the system. It acted as a reminder and motivator both for performing and journaling physical activities.

Shakra [Anderson et al. 2007] is an application for monitoring and sharing activity information. Shakra uses GSM cell visibility and signal strength information to classify its users' activity states. An artificial neural network is used to recognise three states: stationary, walking, and driving. Shakra displays the user's current activity state as well as accumulated walking minutes. A one-week trial with nine participants showed that the activity classification with Shakra was fairly accurate and that the participants enjoyed seeing their own activity as well as that of their group members.

PmEB (Patient-Centered Assessment & Counseling for Exercise & Nutrition – Mobile Energy Balance) [Lee et al. 2006, Tsai et al. 2007] is an application for tracking caloric balance. The self-observations on nutrition and physical activity are made with the help of a food and physical activity database stored in the mobile phone, personalised to the user's energy expenditure. The feasibility of the system was studied in two studies: first in a one-week study with six participants and then in a one-month study with fifteen participants. The application was actively used in both studies, two to four times a day in the first study and three to six times a day in the second study. Entering foods caused some frustration among the subjects because the database was not comprehensive enough. In addition, prompts were considered redundant, especially after the users got into the routine of self-monitoring, as the mobile phone itself was considered to be sufficient reminder.

The Wireless Wellness Monitor [Pärkkä et al. 2000, van Gils et al. 2001] was one of the earliest concepts for personal weight management, in which the mobile terminal acted as an interaction device that controlled others, e.g., measurement devices. The concept consisted of a mobile terminal (i.e. a pen computer or a mobile phone), wireless measurement devices, and a home server. The mobile terminal was used to handle measurements (initiating measurements, viewing results, and confirming storage on the home server); to view feedback graphs and health information; and to access food and activity databases, even remotely. The acceptability of the concept was evaluated with twelve interviewees based on paper prototypes. The participants viewed the system positively, and estimated that they would use it actively and over the long term. A prototype of the system, extended also to home automation (e.g., controlling lighting or the coffee machine), was tested with six participants in a laboratory setting [Rentto et al. 2003]. The attitudes of the participants were positive, but concerns were raised, for example, about the privacy of the system. Carrying a mobile terminal around at home was not considered feasible.

Atienza et al. and King et al. [Atienza et al. 2008, King et al. 2008] studied the efficacy of personal digital assistant (PDA) applications for improving nutrition and increasing physical activity in adults over fifty in two different eight-week studies. The nutrition application concentrated on vegetable and whole grain intake; the study involved thirty-six subjects, randomised into a PDA condition and an information-only condition [Atienza et al. 2008]. The physical activity application was studied with thirty-seven subjects with a similar randomisation [King et al. 2008]. In both studies, the PDA program prompted the subjects to reply to a questionnaire twice a day. In the nutrition study, the questionnaire consisted of forty-three items on, for example, context, foods consumed, mood, and barriers and facilitators of healthy eating. In the physical activity study, the questionnaire consisted of thirty-six items on the context, amount and type of physical activity, and behavioural and motivational factors. The PDA program also assisted the subjects in setting goals and provided daily and weekly feedback on their progress. At eight weeks, the participants who underwent nutrition intervention increased their vegetable intake more than controls [Atienza et al. 2008]. Their average adherence to PDA entries was 51%, though it declined during the study from 75% to 40% [Atienza et al. 2008]. The physical activity intervention participants reported significantly higher levels of physical activity and energy expenditure during the eight-week study period than controls [King et al. 2008]. Their average adherence rate was 68% [King et al. 2008]. The satisfaction with the PDA program was high in both studies [Atienza et al. 2008, King et al. 2008].

The question of whether to utilise mobile phones or the Internet often arises. Gasser et al. [Gasser et al. 2006] studied the effects of the delivery medium and social facilitation by comparing mobile and web-based implementations of an application intended for simple tracking of eating and physical activity habits. A twenty-eight day study with forty subjects divided into four groups (mobile or Internet, with or without social sharing), indicated that the medium or the sharing features did not affect goal attainment. Both web and mobile users were equally compliant, making on average four to five entries per day, but their usage patterns differed. Mobile users had a smoother usage pattern during the day than web users, whose usage activity was concentrated in the evening hours. Mobile entries were also made with less delay than entries in the web. The authors concluded that the mobile application was better integrated into daily activities.

Most of the systems presented in this section were based on self-monitoring. Some type of monitoring device was often used to support self-observations [Consolvo et al. 2008a, Consolvo et al. 2006, Toscos et al. 2006, Consolvo et al. 2008b, Pärkkä et al. 2000]. Self-observations were recorded either manually [Burnett et al. 1985, Consolvo et al. 2006, Toscos et al. 2006, Lee et al. 2006, Gasser et al. 2006], semi-automatically [Consolvo et al. 2008b, Pärkkä et al. 2000], or completely automatically [Anderson et al. 2007]. In most cases, the self-observations were simple, and more laborious recording schemes were found less successful in terms of compliance and user satisfaction [Tsai et al. 2007, Atienza et al. 2008, King et al. 2008]. Reminders and prompts to self-observe were used in several studies [Burnett et al. 1985, Consolvo et al. 2008b, Lee et al. 2006, Atienza et al. 2008, King et al. 2008, Gasser et al. 2006], and the reminder effect of the mobile device itself was also identified [Consolvo et al. 2006, Tsai et al. 2007]. Reactivity to self-monitoring emerged in several studies [Burnett et al. 1992, Tsai et al. 2007, Gasser et al. 2006], although feedback and, in some cases, social sharing may have also played a part [Lee et al. 2006].

Most systems provided some type of feedback with respect to goals, usually as simple statistics and graphs, individually or compared to other group members [Burnett et al. 1985, Consolvo et al. 2006, Toscos et al. 2006, Lee et al. 2006]. An example of more elaborate persuasive feedback was presented by Consolvo et al. [Consolvo et al. 2008a]. Different types of goals were used: goals based on the user’s earlier activity [Consolvo et al. 2006], fixed standards [Gasser et al. 2006], or goals set by the individuals themselves [Consolvo et al. 2008b].

Boosting self-efficacy seemed to be the purpose or product of many of the applications. Most applications acknowledged and rewarded goal attainment, either verbally or visually [Burnett et al. 1985, Consolvo et al. 2006, Toscos et al. 2006, Consolvo et al. 2008b, Lee et al. 2006, Gasser et al. 2006]. In UbiFit Garden, success from the preceding weeks was visualised along with the current status [Consolvo et al. 2008a]. Social modelling, support, and pressure were utilised in applications with the sharing feature [Consolvo et al. 2006, Toscos et al. 2006, Lee et al. 2006, Gasser et al. 2006]. Verbal persuasion was also utilised, but its effectiveness was unclear [Toscos et al. 2008].

4. Summary of publications

4.1 Design of the Wellness Diary

4.1.1 The WD Concept

WD is a mobile phone application for the personal self-management of health and well-being. WD was designed to support behavioural change and learning through the cycle of self-monitoring, self-evaluation and self-reinforcement defined in Kanfer's CBT-based self-management model [Rokke & Rehm 2001, Kanfer 1970]. The aim of WD is to support regular and long-term self-monitoring of health and well-being. In addition, it provides feedback to users, enabling them to evaluate the status and progress of their personal well-being and support them in health-related decision-making.

Mobility is a key aspect of the WD concept, allowing well-being management to be integrated to everyday life. As a mobile phone implementation, the application is always on hand, enabling users to perform health management related tasks anytime and anywhere, both during their idle moments and when making lifestyle choices. WD can be personalised by selecting the health-related variables the user wishes to self-monitor and allowing him/her to set individual goals. Thus, WD can be used to manage several aspects of personal well-being, and it can be adjusted to changing needs over time.

The primary target group of WD is working-age citizens who may already have some health risks or even lifestyle-related diseases, and who have an interest in improving their health or managing their health risks or diseases. WD is best suited to be used in connection with a health promotion program or intervention, but it may also be used independently. The following scenario illustrates one of the possible usage models of WD:

Anna is a 40-year-old secretary at a large company. She has been working long hours lately and has not been up to taking very good care of herself. As a result, she has not been exercising at all and has gained some weight. She recently visited the occupational health services for her five-year health check-up and found out that her blood pressure was a bit above the recommended limits. The nurse provided her a blood pressure monitor and gave her lifestyle advice. She suggested that Anna could use WD to keep track of her blood pressure, weight, and other interesting health parameters.

Anna started using WD and set a blood pressure target based on the nurse's recommendation. She also took the weight and steps variables into use and set targets for them. Every morning, Anna steps on a scale, measures her blood pressure and enters the data into WD. She starts using the old pedometer she received as a Christmas present for the first time and tries to walk at least 10,000 steps per day.

After two weeks, Anna checks the feedback graphs and notices that her weight is decreasing, slowly but surely. Anna is thrilled; she had thought that strict diets were the only way to lose weight. All it took was a bit more activity. "And, to be perfectly honest," she thinks to herself, "perhaps the daily walks kept me from emptying the fridge every evening as I did before." Her blood pressure has not changed, but the nurse told her that it might take some time. Anna, encouraged by the positive changes, decides to step it up a notch and calls her local gym for a personal trainer's appointment and adds an exercise target on her WD.

4.1.2 Development process

The development of WD started in 2004 and the development phases are presented in Figure 3. Two major versions (v1.0 and v2.0) and two minor versions (v1.5 and v2.5) of WD have been developed. The minor versions are very similar to their corresponding major versions, but have a different set of variables or some additional features. Table 1 presents the features included in different versions of WD and Figure 4 presents screenshots of the main functionalities in the major versions.

Version 1.0 was designed to support weight management and it contained variables related mainly to weight, physical activity, and nutrition. Version 1.5 was designed for more general well-being management, with an emphasis on stress management. Thus, some weight management-specific variables were removed and stress, sleep and blood pressure variables were included. Versions

2.0 and 2.5 were designed for overall well-being management and contain a wide selection of variables.

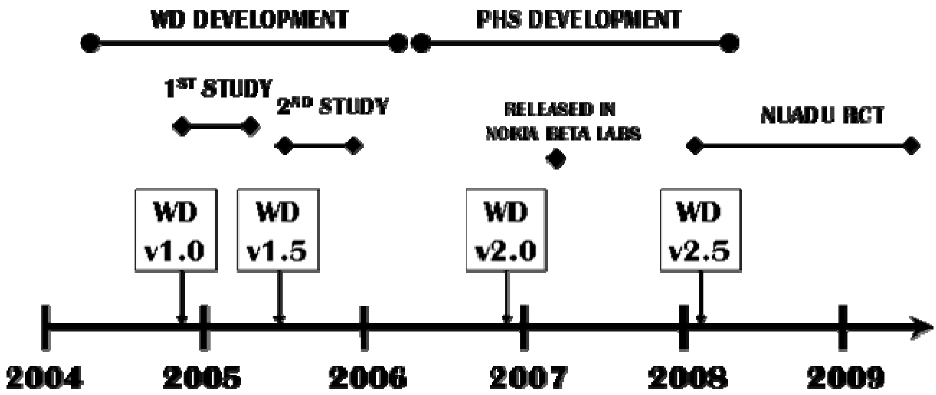

Figure 3. A timeline of WD development with the WD versions evaluated in this thesis and other relevant events.

Three evaluations with different versions of WD are included in this thesis. Versions 1.0 and 1.5 were presented and evaluated in Publications I and II, and version 2.5 was utilised in the study presented in Publications III and IV. Version 2.0 was released in Nokia Beta Labs in 2007 [Nokia Beta Labs], and was included in one of the studies presented in Publication V.

Table 1. The main features and functionalities in different versions of WD. Superscripts 1, 2, and 3 indicate features specific to versions 1.0, 1.5, and 2.5, respectively.

Features	**WD v1.0[1] and v1.5[2]**	**WD v2.0 and WD v2.5[3]**
Calendar integration	Direct integration to calendar with identical navigation, similar forms, and shared views.	Stand-alone application, but shares data with calendar. Similar forms. Month and list views with health and calendar entries combined.
Main view	Calendar-style day, week or month view combining calendar and health entries.	Main view: data summaries and shortcuts to main functionalities.
Self-observation variables	Nine variables: weight[12], steps[12], exercise[12], food and drinks[1], feelings[1], fat percentage[1], sleep[2], stress[2], blood pressure[2], illness[12], doctor visit[12], treatment[12]	Sixteen variables: weight, steps, exercise, eating, sleep, stress, alcohol, smoking, blood pressure, blood glucose, fat percentage, waist circumference, working time, illness, doctor visit, treatment.
Graphical feedback	Time ranges: 2 weeks, 1 month, 3 months. Single-parameter graphs.	Time ranges: 1 week, 1, 3 & 6 months, 1 & 5 years, all. Two-parameter graph for blood pressure. Changing/overlaying parameters in graphs, time axis scrolling, cross-hair cursor browsing of data points.
Other feedback (Main view)	Day view with calendar and self-observation entries	Weekly averages or sums of variables; date and value of last entry; or “no data”.
Goal setting	Weight[12], steps[12], exercise[12], sleep[2], blood pressure[2].	New goals: working time, alcohol, and smoking. Weight goal checked for safety.
Data transmission	Text file via Multimedia Messages (MMS) or email.	Text file via MMS, email or Bluetooth. Two-way synchronization of data between WD and Wellness Diary Connected (WDC) web service[3].
Other features	Browsing and modifying entries in day view. Languages: English[1] and Finnish[2]. Infrared transmission of step count data from pedometer to WD[1].	List views for browsing and modifying entries; adding own sports to exercise variable; empty input form detection and warning; shortcuts from main view; WDC[3]; note fields in entry forms; free selection of variables; logging data entry times.

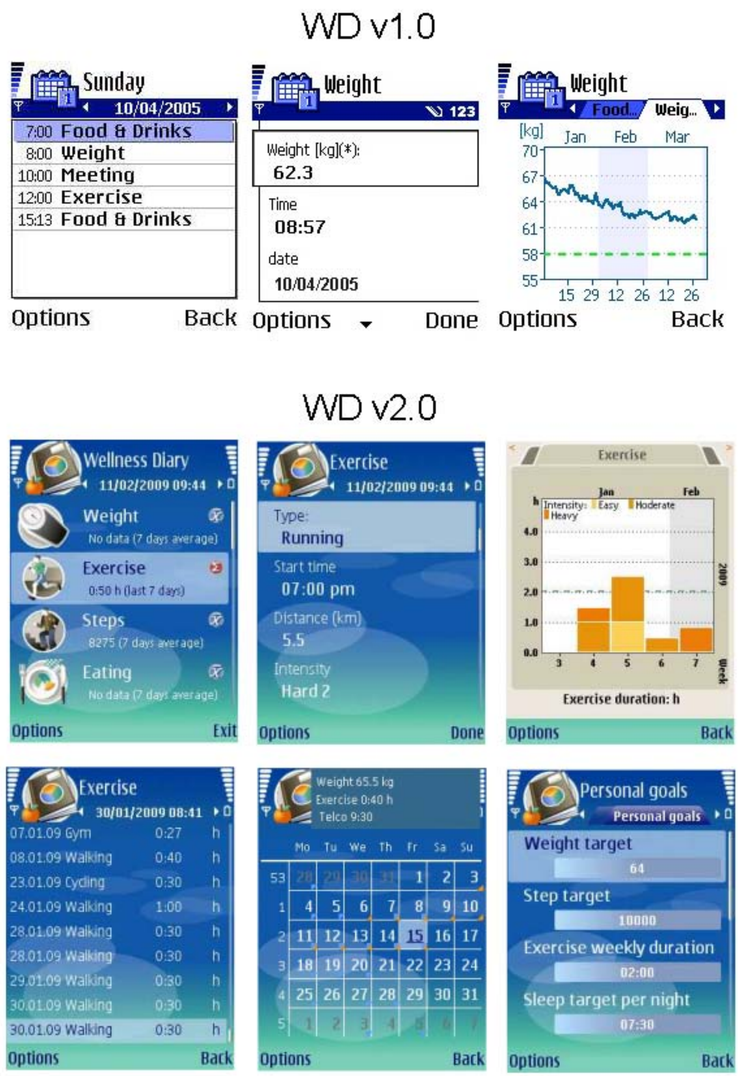

Figure 4. Screenshots of different WD versions. The screenshots of WD v1.0 represent the day view, weight input form, and weight feedback graph. The screenshots of WD v2.0 represent the main view, exercise input form, exercise graph, exercise list view, calendar month view, and goal setting.

4.1.3 Design of WD features

This section presents the design of the features of WD in more detail. The design choices are motivated by self-management theories, guidelines adopted from the TAMM, and the challenges related to mobility.

Behavioural change and well-being management are long-term tasks that require becoming aware of problematic behaviours, making a plan to change them, and actively practicing the new behaviours in one's daily life. Therefore, the fundamental features of WD are self-monitoring, feedback, and goal setting, which support Kanfer's self-management model [Rokke & Rehm 2001, Kanfer 1970].

The main design requirements for self-observations in WD were that they should support long-term usage and be clearly relevant to the issues they addressed to allow for meaningful feedback. According to Thiele et al. [Thiele et al. 2002], the complexity of self-observations has to be matched to the duration of the self-monitoring period. In addition, the challenges of mobility – namely, the limited user interface for entering data and the TAMM-based requirement for supporting momentary usage – were taken into account [Dunlop & Brewster 2002, Kaasinen 2005]. WD self-observations were designed to be simple and have only a few parameters. Most entries contain only one or two fields that are mandatory in order for the form to be considered filled. However, it was acknowledged early on that the mandatory parameters did not allow users to enter all the data they considered relevant to their issues, and so optional fields were also included. For example, in the exercise entry, duration is the only mandatory parameter, but in addition, fields for entering the sport, intensity assessment, distance, and average heart rate were included. In version 2.0, a free text note field was included in all entries to allow users to enter personally relevant information. All fields except for the free text note field were designed as numeric fields, drop-down menus, or sliders; entering text was considered too laborious when using the small keypad of a mobile phone, especially the numeric T9 keypad. Data entry was further facilitated by automatically filling in the time and date fields of the entry forms with the time that the form was opened. As a result of these design choices, each entry takes less than 30 seconds to make, which fulfils the requirement of momentary usage [Kaasinen 2005]. Entries can also be made automatically by enabling data transfer from measurement devices, which was tested in version 1.0 with an infrared-enabled pedometer. In addition, data entry in version 2.0 features a simple validation mechanism to prevent the user from unintentionally saving empty self-observation forms. The application detects if a mandatory field has not been filled in and asks the user whether he/she really wants to save an empty entry. The purpose of this feature is to improve the quality of data and to increase the user's trust in the application by helping him/her prevent errors. According to Kaasinen, error prevention is an important method for increasing trust [Kaasinen 2005].

Feedback was designed to enable efficient self-evaluation with respect to personal goals and to illustrate the effects of one's own actions on well-being in order to increase self-efficacy [Rokke & Rehm 2001, Kanfer 1970, Bandura 2004]. The main requirements for feedback were for it to be easy to interpret, to show the status and progress in health-related parameters explicitly and immediately, and to enable the evaluation of the effects of behavioural changes on well-being. Simple graphs such as line and bar charts that display the status with respect to personal goals form the basis for the feedback. Feedback graphs were organised in a tabbed view, where each tab contains a graph of one health-related variable, and different graphs can be viewed by moving left or right in the tabs. The tabbed view allows users to quickly browse the graphs of different variables, which enables a visual analysis of the relationships between variables. In version 2.0, an option to overlay graphs of different health parameters was included in order to further facilitate this. Personal targets, if the user has set them, are displayed as horizontal lines in the graphs. The graphical view allows data to be viewed over several time ranges to provide different perspectives on personal progress. Short time ranges (one or two weeks or one month) are useful when subjecting data to closer inspection or in early usage when there are only a few entries. Longer time ranges allow long-term trends to be visualised more easily and give a comprehensive view on personal progress.

In version 2.0, the feedback was further enhanced by including more flexible browsing options. For example, new time range options were included; graphs can be scrolled along time axis; and individual data points can be browsed with a cross-hair cursor. Also simple statistics of entries were included in version 2.0. Weekly sums or averages of entries are shown in the main view to provide a quick summary of the status of different health variables. The statistics are also utilised in the graphical view during cross-hair browsing on longer time ranges. Whether a weekly sum or a weekly average of entries is displayed depends on the time scale of the target. Sums are used in the case of cumulative targets, such as the weekly duration of exercise or the weekly limit of alcohol consumption. Averages are used for daily-level targets, such as daily sleep duration or step count, or single target points, such as weight target. The main view also shows if no data has been entered in the past seven days, providing a subtle reminder to self-monitor.

The purpose of goal setting is to enable the user to commit to a change by setting personal targets [Rokke & Rehm 2001, Bandura 2004]. Goal setting is enabled for variables where targets are meaningful. In order to prevent unrealistic targets, version 2.0 features an algorithm to check the weight target for safety. The algorithm uses the body mass index (BMI; weight divided by height in meters squared) calculated based on user's baseline weight and height for checking the target. The following situations lead to a warning and a suggestion for a safer target: 1) an underweight user trying to set a weight loss target; 2) a normal-weight user trying a set a target that would lead him/her to be underweight; 3) a normal-weight user trying to set a target that would result in weight loss of over 10% of his/her baseline weight; 4) an overweight user trying a set a weight loss goal of more than 10% of his/her baseline weight; and 5) an overweight user trying to set a weight gain target.

Mobility poses several challenges for designing a mobile self-monitoring application. Mobile devices have limited input and output facilities, and their usage is characterised by frequent interruptions and multitasking [Dunlop & Brewster 2002]. Therefore, WD was designed to be fast and simple to use. Facilitating self-observation entries was one way to achieve this. In addition, in version 2.0, shortcuts from the main view to the main functionalities, namely data entry, feedback graphs, and list view, were included. WD was designed as a stand-alone application, which makes its use free of charge and independent of location, time and network coverage. It also makes usage faster and minimises errors and interruptions due to network failures.

The user owns the data he/she enters in WD and has total control over the data. All data are stored locally in the mobile phone, and thus can be accessed, viewed, modified and deleted at anytime. This choice was made in order to increase the user's control and thereby enhance their trust in the application, which is one of the key factors affecting usage intention according to the TAMM [Kaasinen 2005].

One advantage of mobility is easy wireless data transfer from the mobile phone, which supports various different usage models, such as research use, professional support, and social sharing. Data transfer functionalities were included in all versions of WD. In versions 1.0, 1.5 and 2.0, the data were sent as a text file transmitted via the Multimedia Messaging Service (MMS), Bluetooth or email. In version 2.5, another data transmission option was included. Two-way data synchronisation via wireless data connection, e.g., GPRS or WLAN, was enabled between WD and its web-based counterpart, Wellness Diary Connected (WDC; Nokia Corp., Helsinki, Finland). All modes of data transmission from WD are user-initiated to ensure the user's control over his/her data and the application. This was done in order to enhance privacy and trust in the application [Kaasinen 2005].

Taking a new application into use is always a challenge requiring learning and should be made as effortless as possible [Kaasinen 2005]. To facilitate the adoption, WD versions 1.0 and 1.5 were integrated into the standard Symbian Series 60 calendar. This design choice was made to provide users with a recognisable user interface and a familiar way of using the application. For example, the data entry forms were designed based on standard calendar forms, and calendar day, week, and month views were used to present both calendar and health-related entries. Version 2.0 was redesigned in order to emphasize well-being management and prevent health entries from crowding the calendar views. However, parts of calendar integration were maintained. For example, WD 2.0 still shares data with the phone's calendar and data entry forms resembling calendar forms were maintained. Another motivation for the calendar paradigm was to provide a fit to the existing usage culture of the mobile phone (daily time management) and an opportunity to extend it to daily well-being management. Kaasinen emphasized the importance of the usage cultures for adoption [Kaasinen 2005].

4.2 Validation as a self-monitoring tool

Publications I and II aimed to validate WD as a self-monitoring tool. In Publication I, interviews, questionnaires and actual usage data were used to study user acceptance of WD and its applicability for long-term self-monitoring. The acceptance is reported in terms of three dimensions of TAMM: ease of adoption, ease of use, and value [Kaasinen 2005]. Publication II examined the validity of self-observation data recorded with WD in the first study of Publication I. The validity of self-reported weight and the usefulness of the data for weight management were investigated.

4.2.1 Validation of applicability for self-monitoring

Publication I presents two three-month user studies with WD versions 1.0 and 1.5. These studies were performed with two user groups of working-age adults. Table 2 presents the demographics of the participants. In the first study of Publication I, WD version 1.0 was studied with twenty-nine volunteers (Table 2), who were interested in weight management and owned a suitable Series 60 mobile phone. The study was started in December 2004 and ended in February 2005.

The study procedures consisted of a start-up session. two one-hour user experience interviews after one week of use and at the end of the study, and a closing session. The start-up sessions were organised in groups of about ten participants, and they included: baseline measurements of weight and waist circumference; a 1.5-hour lecture on weight management; and the installation of WD to the participants' personal mobile phones followed by a twenty to thirty minute user tutorial. The weight management lecture was based on a CBT mini-intervention program and was given by an expert in psychology and weight management [Lappalainen & Turunen 2006]. The lecture included information on behavioural variables that affect eating, tips on how to maintain weight, and instructions for self-monitoring. The user experience interviews consisted of a semi-structured interview and a questionnaire on WD and its features. A closing session was organised at the end of the study, including a summary of results and post-study measurements of weight and waist circumference.

Table 2. Participant demographics in the studies presented in Publication I.

	First study	**Second study**
Number of participants	29	17
Gender (male/female)	20/9	3/14
Age (SD; range)	39.3 (8.1; 25-54)	54.5 (5.4; 40-62)
BMI (SD; range)	28.8 (2.4; 24.8-33.6)	26.8 (3.3; 22.3-33.3)

Two participants dropped out early in the study for reasons not related to WD. The remaining 27 participants used WD actively and recorded, on average, 5.3 daily self-observations. Figure 5 a) presents the usage activity as the average daily number of entries made by the participants as a function of study weeks. The food and drinks entries are separated in the graph due to the fact that several entries per day were expected to be made in this variable. As Figure 5 a) shows, the usage activity of WD remained high throughout the study period. Most actively used variables were: food and drinks (average: 3.2 entries per day), weight (0.8 entries), and steps (0.8 entries). When asked about their usage routines, most participants reported having shifted from learning to routine use in one week. Later in the study, the participants learned to adapt use to their personal needs and stopped using variables they considered less useful. In the beginning, most participants made entries directly after the event, e.g., weighing themselves, but later, it was more common to record all the entries of the day in one or two usage sessions.

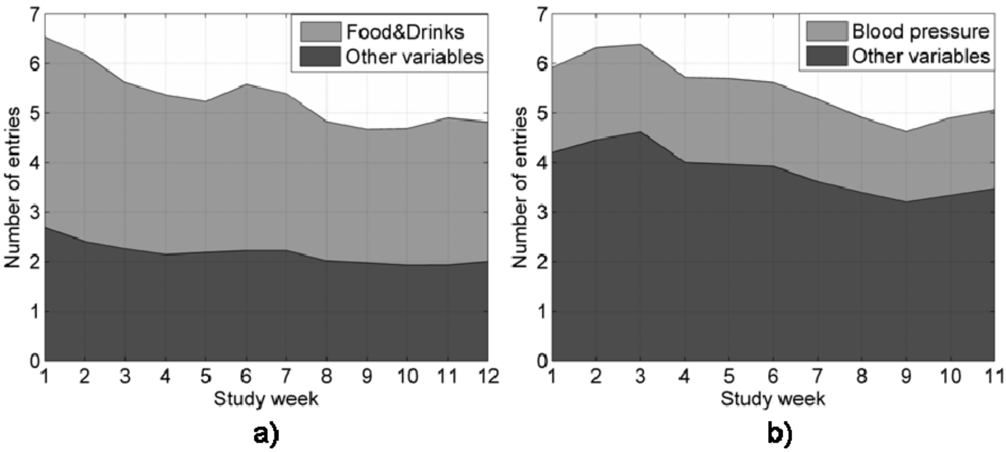

Figure 5. Usage activity in the first (a) and second (b) study of Publication I as the average daily number of entries per participant during the study weeks.

Most participants (93% in the first and 89% in the second interview) stated that WD was easy to learn to use. WD was perceived as simple by 89% of participants in the first and 93% in the second interview. Two-thirds of participants felt that WD did not complicate their regular calendar usage and about 60% felt that WD fit well on the calendar. However, some participants commented that when WD and calendar entries appeared in the same view, WD entries crowded the view, making it difficult to see other calendar entries.

WD was perceived as useful by most participants (90% of participants in the first interview; 79% in the second interview). They responded that WD motivated them to observe their eating (86%; 71%) and be more physically active (66%; 71%). At the end of the study, 79% of participants agreed that WD had helped them in weight management, and 64% wanted to continue using WD.

The participants reported that the most important variables were weight (93%; 96%), steps (86%; 82%), and exercise (86%; 86%). Visual feedback was perceived as adequate by a bit more than half of the participants (59%; 57%). To enhance the feedback, 79% would have liked to have predictions based on the data and to analyse the data with a personal computer (PC). In addition, 54% would have liked to have an expert comment on their WD feedback, and 43% would have wanted an opportunity to use WD in a group.

Twelve participants lost weight during the study, on average 2.9 (SD 2.8) kg, and the rest approximately maintained their baseline weight with a weight change of 0.19 (SD 0.9) kg. The reactivity to self-monitoring was not formally studied, but was reflected in the comments of participants. For example, some participants reported choosing healthier foods or deciding not to eat unhealthy snacks because they did not want to report unhealthy eating to WD. Furthermore, nearly all participants reported that they had gained improved self-monitoring skills from using WD. The participants appreciated the low-maintenance weight management approach, and felt that WD acknowledged and supported their own responsibility for their well-being.

In the second three-month user study, WD version 1.5 was studied as a part of a PHS which, in addition to WD, consisted of: wearable monitoring devices for measuring actigraphy and heart rate variability; ambient sensors for monitoring illumination and temperature; a bed sensor for monitoring presence, movements, breathing, and heart rate; and analysis software run on a PC for analysing heart rate variability data. The participants were seventeen volunteers (Table 2) who were simultaneously participating in a stress-related occupational rehabilitation program.

At the beginning of the study, a researcher visited all participants, provided them with a mobile phone with WD, installed the rest of the research equipment in their homes, and instructed them on the use of each device. First, the participants used the PHS at home for one to two weeks. They then participated in a one to two week rehabilitation program in a rehabilitation centre. The program was a standard one, including testing, lectures, discussions, and guided physical activity, and was not modified to support technology usage. The PHS was in use at the rehabilitation centre as well. After the rehabilitation period, the participants continued using the technology at home. At the end of the study, the participants filled in a user experience questionnaire.

The participants used WD actively and recorded, on average, 5.5 self-observations per day. Figure 5 b) presents the usage activity as a function of study weeks and shows that, also in this group, usage activity remained high throughout the study. The most actively used variables were blood pressure (average: 1.7 daily entries), weight (0.9 daily entries), and steps (0.8 daily entries).

Most participants found WD easy to learn to use (76%), and all participants (100%) felt that it was easy to enter information with a mobile phone. The most important variables for the users were blood pressure, which was among the top three most important variables for all participants (100%), weight (88%), and exercise (88%). The feedback graphs were considered useful by 76% of participants. The intervention effect of self-monitoring was reflected in a user comment describing daily weight and blood pressure measurements as a wake-up call.

Based on the high ratings in terms of how easy it was to learn to use WD in both studies, the perceived simplicity of WD in the first study, and the ease of making entries in the second study, it can be concluded that WD was easy to adopt and easy to use. The perceived value of WD was also high, which was reflected in the results of the first study, where most participants felt that WD was useful, motivated them to observe their eating and increase physical activity, and helped them in weight management. The perceived usefulness of feedback, especially in the second study, also reflects value. The high and sustained usage of WD in both studies shows that WD is applicable for long-term self-monitoring among the target user group. These results confirm that WD is an acceptable application and applicable for long-term self-monitoring.

The results of these user studies were used in the development of version 2.0. For example, calendar integration was redesigned according to user feedback on the drawbacks of shared views, and a more informative summary view was created. The goal setting functionality was also redesigned, graphs were enhanced with a set of new features, and browsing and modifying old entries were facilitated by creating list views for variables. Usage was further expedited by providing shortcuts to the main functionalities from the main view.

4.2.2 Validation of self-observed data

In Publication II, the self-observation data recorded in the first study of Publication I is examined in terms of the validity of self-reported weight data and the usefulness of the self-observed data for weight management.

The validity of self-reported weights was studied by comparing weight measures entered in WD at the beginning and end of the three-month study period with the pre- and post-study measurements performed at the start-up and closing sessions. Behavioural patterns related to weight management were examined and compared between participants who succeeded in weight loss (weight losers) and those who did not (non-losers) by studying physical activity and eating-related self-observations and the weekly rhythm of weight.

Table 3 presents the measured and self-reported pre- and post-study weights and their correlations. A reasonable agreement between self-reported and post-study weights is illustrated by a Bland-Altman plot in Figure 6. However, there are several reasons for the significant differences in the measures in some cases. For example, the self-reported weight measures were calculated as averages of several measurements, whereas the measured weights were single measurements at the beginning and end of the study. There was also a timing difference between the measures, because participants were weighed before and after the study, whereas WD self-reported weights were from within the study period, from the first and last weeks of the study. The time of day, clothing, and scales were also different when the participants measured themselves at home compared to the official measurement.

Table 3. Pre- and post-study weights and weight changes. Mean values (SD) are shown for the twenty-two participants for whom all the weight measures could be determined.

	Measured	**WD**	**Correlation**
Pre-study weight (kg)	87.0 (13)	84.5 (13.5)*	0.99*
Post-study weight (kg)	84.3 (12)	83.1 (13.1)*	0.99*
Weight change	-2.6 (3.0)	-1.4 (2.6)*	0.80*

* $P < 0.05$

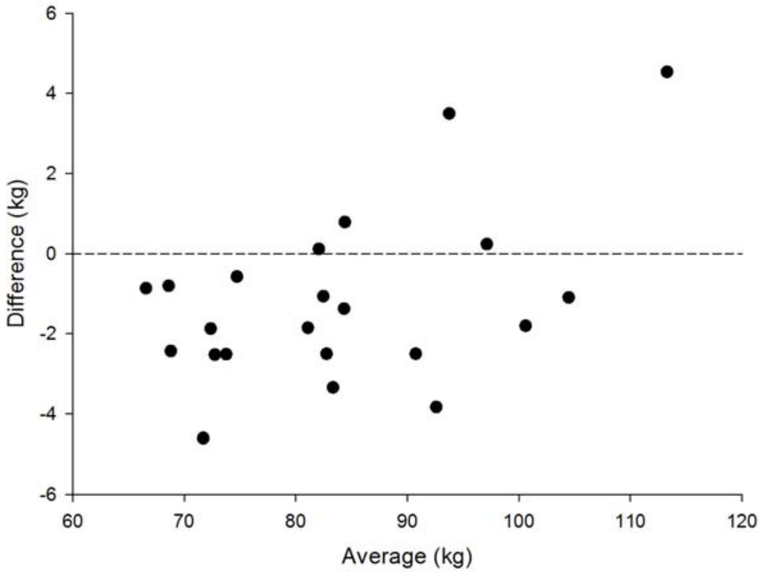

Figure 6. Comparison of measured and self-reported post-study weight values. The abscissa shows the average of these values and the ordinate shows the difference between the two values.

The relationship between exercise and weight was studied by examining the whole study period as well as every month of the study separately. The weekly duration of exercise and the amount of exercise during the first month of the study correlated with weight loss ($r = -0.44$, $p < 0.05$ and $r = -0.57$, $p < 0.05$; respectively). Weight losers exercised more (132 min; range: 16-365 min per week) during the first month of the study than non-losers (65 min, range: 0–205 min).

Changes in diet were studied by calculating the differences in diet measures between the first and the last month of the study. Table 4 presents changes in diet for weight losers and non-losers and the correlation of diet and weight changes. Healthy changes in diet were found to be associated with weight loss; the decreases in the proportion of heavy meals, heavy foods in general, and meals as well as increases in light snacks correlated positively with weight loss.

Table 4. Changes in eating habits and correlation with weight change. Values are percentage changes (SD) in food types from the first month to the third month of the study for weight-losers and non-losers. *: $p < 0.05$, ns: $p \geq 0.05$.

	Weight losers (n = 12)	**Non-losers (n = 13)**	**Correlation with weight change**
% heavy meals	-12.0 (10.0)	-4.0 (8.0)	0.75*
% light meals	14.0 (10.0)	7.9 (10.0)	ns
% heavy snacks	-10.0 (15.0)	-2.0 (9.4)	ns
% light snacks	7.8 (16.0)	-1.9 (9.2)	-0.64*
% heavy foods	-21.0 (22.0)	-5.9 (15.0)	0.61*
% meals	2.0 (11.0)	3.9 (7.8)	0.45*

Figure 7 presents averaged weight changes for weight losers and non-losers during the study period. The patterns of weight changes indicate that Christmas was a risky period for weight management in both groups, which experienced similar weight gain. The groups divided only after New Year.

The weekly weight rhythm presents deviations of weight from the weekly average. The average rhythms of weight losers and non-losers were calculated and compared, as presented in Figure 8. The rhythms of the groups were found to be different; the effect of interaction between group and weekday was significant ($F(1,6) = 2.92$, $p < 0.05$). Weight-losers had a clear weekly rhythm with increasing weight during weekends and decreasing weight during weekdays. Non-losers did not have a clear rhythm.

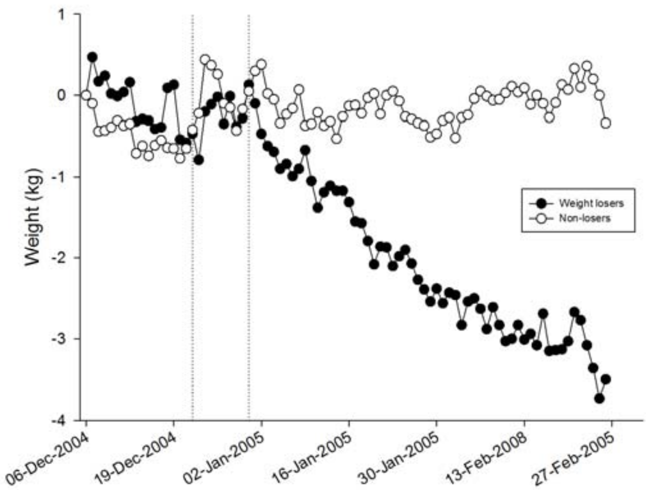

Figure 7. Weight changes in the groups during the study period.

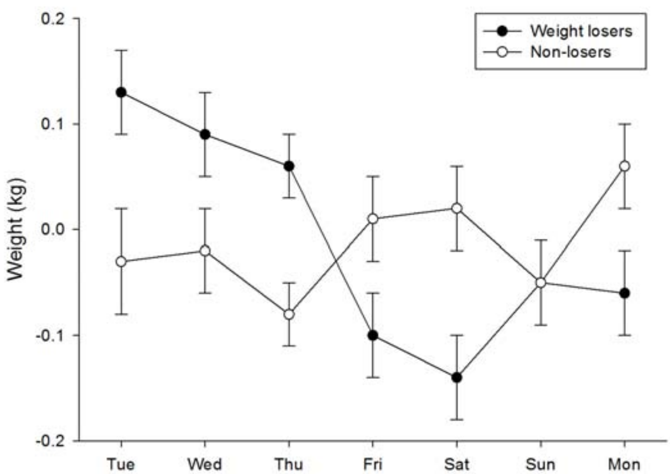

Figure 8. The weekly weight rhythms of weight losers and non-losers.

The results on the validity of weight showed a reasonable agreement between self-reported and measured weight values. Weight change calculated based on self-observations was more conservative than that based on pre- and post-study measurements. Using weight averages based on long-term self-observed data may be a more reliable method to determine weight changes than single measurements, which are prone to errors due to changes in timing, clothing, and the fluid balance of the body.

The self-observations recorded with WD, though very simple, were found to be capable of revealing behavioural patterns in eating and physical activity typically associated with weight loss. Self-observations, even if inaccurate but regular, reveal personal changes in behaviour.

The examination of group-wise weight changes during the study period and weekly rhythms of weight suggests that a compensation mechanism related to the risky periods may be important for weight management. Both groups gained weight during risky periods, such as holidays and weekends, but successful participants exhibited a stronger control mechanism to restore their weight afterwards.

These types of analyses allow generating more personalised and in-depth feedback to the user, potentially pointing out the personal patterns and pitfalls of weight management.

4.3 Evaluation in self-management

Publication III presents the design of a PHS for supporting an occupational health promotion intervention. WD version 2.5 was included in the PHS along with other mobile, Internet, and monitoring technologies. The concept, including the intervention and the PHS, was studied in a one-year randomised controlled trial. Publication IV presents results on the applicability of WD for supporting self-management through user acceptance, adoption rate, and usage patterns in a context where the users had an opportunity to freely choose the technologies they would use.

A PHS consisting of an Internet portal, mobile applications, and monitoring devices was designed to support a face-to-face group health promotion intervention program targeting multiple health risks and behaviours, namely weight management, physical activity, sleep, stress, healthy eating, smoking, and alcohol consumption. The purpose of the PHS was to provide personalised support for self-management between intervention meetings and after the intervention to help make and maintain behavioural changes. The subjects were allowed to freely choose, try out, and stop using any of the technologies in order to find the right tools for themselves. Figure 9 presents the PHS, the components of which are described in the following section.

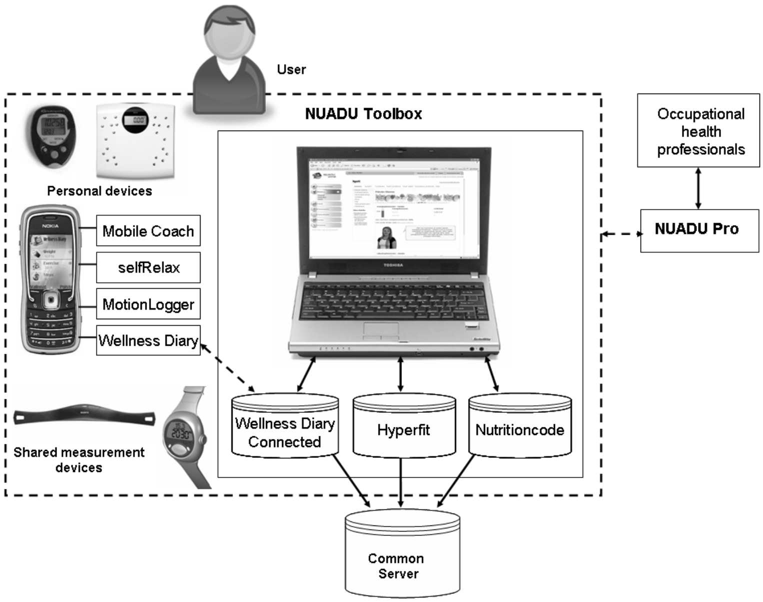

Figure 9. The personal health system used for supporting a health promotion intervention.

The Internet portal integrated three web-based well-being management services, contained information on health-related issues, and enabled communication between study participants and occupational health professionals. The integrated services were:

- Wellness Diary Connected (WDC; Nokia Corp., Helsinki, Finland): a web-based counterpart of WD, providing the same functionalities.
- Hyperfit (Tuulia International, Helsinki, Finland): a service for detailed recording and feedback on nutrition, physical activity, and energy balance, also containing information on nutrition, appraisals of personal nutrition, and goal setting.
- Nutritioncode (Tuulia International): a service for automatic nutrition content analysis of grocery purchases. The information on purchases is transferred to the service by swiping a reward card at the checkout of a grocery store.

Three mobile phone applications were provided for the users to support daily self-management:

- WD version 2.5 featuring two-way synchronisation of data between WD and WDC.

- Mobile Coach (Firstbeat Technologies, Jyväskylä, Finland): an interactive exercise training application, which creates a training program based on the user's background data and goals, and adapts the program to actualised exercises entered to the program by the user.
- selfRelax (Relaxline, Mantes La Jolie, France): an audio-based relaxation application that allows the user to create personalised relaxation programs for different purposes, of different durations, and utilising different relaxation methods.

MotionLogger (VTT, Tampere, Finland) was a research application intended for automatic activity logging and did not provide any information to the user.

The PHS also included simple personal devices to support daily self-observations, namely a scale (Seca 804; Seca, Hamburg, Germany) and a pedometer (Omron Walking Style II; Omron, Kyoto, Japan). In addition, the concept included intermittent measurements for enabling in-depth analysis and professional feedback on well-being. A heart rate belt (Memory Belt, Suunto, Vantaa, Finland) was provided for users to continuously monitor their heart rate for a few days. A professional then analysed the data and created a feedback report for the user with the help of Firstbeat HEALTH software (Firstbeat Technologies). The report contained information on, e.g., stress, recovery and physical activity. A wrist-worn activity monitor, the Vivago Personal Wellness Manager (Vivago, Helsinki, Finland), was envisioned to be used in the concept for monitoring sleep and activity patterns, but due to technical reasons it was not included in the RCT.

Three hundred and fifty-four subjects were recruited for the study based on a health screening questionnaire sent to the employees of the city of Espoo, Finland. The subjects were randomised into three groups (intervention, intervention with technology support, and control). All groups participated in the baseline and end measurements, and filled in health-related questionnaires before the study, after six months, and at the end of the study. Both intervention groups participated in an intervention program during the first eight weeks of the study. In addition, the second intervention group (the "technology group") was supported by the PHS, which was provided for their use for one year from the baseline measurement until the end measurement. The other intervention group received traditional support from occupational healthcare as needed. Publications III and IV concentrate on the technology group, whose demographics are presented in Table 5.

Table 5. Demographics of technology group subjects.

Number of subjects	118
Gender (male/female)	35/83
Age (SD; range)	45 (7; 30–55)
BMI	28 (4.5; 20–41)

The intervention program consisted of five face-to-face meetings lasting an hour and a half to two hours. The meetings were organized bi-weekly in groups of seven to twelve subjects. The intervention was designed based on Acceptance and Commitment therapy and problem solving methods, and it also included elements of the Transtheoretical model [Hayes et al. 2003, Prochaska & Norcross 2001]. The goal of the intervention was to promote health and well-being and endorse individuals as the best experts of their own health. Thus, the subjects were allowed to personally choose the health risks they wished to address, the lifestyle changes to make, and the technologies they wanted to use. The technologies were provided to the subjects in connection to the baseline measurement, but each application was presented more thoroughly in connection to the intervention meeting whose issues the technology addressed. For example, WD was introduced in the first intervention meeting, which taught the subjects self-monitoring.

Publication IV presents results on the user experiences, acceptance and usage activity of the three mobile applications in the PHS. The results are presented for the intervention phase of the study, lasting from the baseline measurement until the last intervention meeting, the average duration of which was two and a half months. The duration of this period varied between subjects due to the ramp-up time of the study, which introduced variable waiting periods between the baseline measurement and the first intervention meeting.

Results from the questionnaires, interviews and application log files are reported. The response rate in the first user experience questionnaire was 74% and in the second, 51%. Twenty subjects were interviewed shortly after the last intervention meeting. Mobile application usage log files were collected during the last intervention meetings, where 58% of phones were reached.

WD was perceived easy to use by 60%, Mobile Coach by 41%, and selfRelax by 66% of respondents. Two-thirds (67%) of respondents agreed that WD contained appropriate functions for them; the corresponding figures were 47% for Mobile Coach and 43% for selfRelax. WD was perceived useful by subjects who had many different health-related goals. WD was reported to contain appropriate functions by a majority of the respondents whose goals were related to weight management (78% of respondents), exercise (65%), stress management (71%), and sleep (79%). WD motivated 59% of respondents to maintain or enhance their well-being, whereas Mobile Coach motivated 41% and selfRelax 26% of respondents. The intention to continue using the application was highest for WD with 57% of respondents agreeing to the statement, compared to 41% for Mobile Coach and 38% for selfRelax.

Based on usage log files, 94% subjects had made entries to WD, 62% had entered an exercise to Mobile Coach, and 83% had listened to at least one relaxation program with selfRelax. The most commonly used variables in WD were weight, which was used by 85% of WD users; steps, used by 80% of users; and exercise, used by 77% of users. Table 6 presents usage patterns during the study period, divided into segments defined by the baseline measurement and the five intervention meetings. WD was actively taken into use already between the baseline measurement and the first intervention meeting. WD was more thoroughly introduced in the first intervention meeting, which further increased the number of users. This effect was observed for other mobile technologies as well. During the following weeks, the usage of WD declined somewhat, but 53% of participants were still using WD at the time of the last intervention meeting. The adoption rates of other mobile applications were considerably lower. The respondents reported very similar changes in usage patterns as the participants of the first study of Publication I. They reported that after a while, their usage habits had become more practical. For example, they reported that they had decreased the number of variables to monitor and that they had started to make several entries at a time instead of just one.

The free text note fields included in WD input forms were used by 65% of subjects. Notes were most actively made on exercise (36% of subjects), steps (35%), sleep (30%), and eating (28%). Most notes contained more detailed information related to the entry, such as the foods that the users had eaten, the description of their physical activity, and reasons for poor sleep. Sometimes the note field was used to describe the location or social context of activities, and sometimes for explaining reasons for not exercising on a particular day.

Table 6. Usage activity of mobile applications during the study period as the percentage of application users out of all subjects whose log data was obtained for analysis. The horizontal line indicates the intervention meeting where the application was presented (E.g. IM1 = first intervention meeting).

Usage interval	**Wellness Diary, %**	**Mobile Coach, %**	**SelfRelax, %**
Baseline – IM1	65	9	30
IM1 – IM2	73	11	12
IM2 – IM3	62	15	6
IM3 – IM4	58	21	3
IM4 – IM5	53	18	12

The main motivational features of WD were the large number of health-related variables it offered, being easy to approach, and its ability to provide feedback on the long-term progress of different aspects of well-being. The graphs were considered to provide valuable information. The main drawbacks were monotonous data entry and the lack of support for cyclic use, i.e., using the application for a while, taking a break and then continuing use. The barriers of use affecting all mobile applications were the small mobile phone keypad and screen, especially the small fonts on the screen, and forgetting to use the applications due to a hectic lifestyle or holidays.

When interpreting the results, it is important to note that the subjects were randomised into groups without taking into account their preference regarding the type of self-management support, i.e., whether they were willing to use technologies. Thus, there may have been subjects who did not want to use technology at all. WD was perceived as easy to use by 60% of respondents, making it the second easiest mobile application to use after selfRelax (66%). The results on ease of use, usefulness, and the fact that WD was considered to include appropriate functions by two-thirds of respondents with different well-being goals show that WD was a well-accepted and useful tool for supporting self-management in a variety well-being issues.

4.4 Future directions

The aim of publication V was to summarise the lessons learned from the studies involving WD to date, to identify the main weaknesses of WD, and to propose ways to improve the concept. Table 7 presents a summary of the studies.

In most studies, WD was used in connection with a face-to-face health promotion intervention program or another type of professional support. One study [Ahtinen et al. 2008] as well as the comments retrieved from discussion forums were used to assess the experience of independent users. Most studies concerned well-being management of mainly healthy individuals, but one study extended WD to support cardiac rehabilitation.

Table 7. Summary of studies with WD. The WD column indicates whether WD was used alone or as a part of a PHS. N denotes the number of participants in the study.

Purpose	**WD**	**Population**	**N**	**Duration**
Weight management; Publication I	Alone	Working-age, healthy	30	12 wk
Occupational rehabilitation; Publication I	PHS	Working-age, stress problems	17	12 wk
Occupational health promotion; Publications III and IV	PHS	Working-age, multiple risks	118	12 mo
Psychophysiological well-being [Happonen et al. 2009b]	PHS	Working-age, stress/depression	37	10-14 wk
Cardiac rehabilitation [Sarela et al. 2009]	PHS	Cardiac patients, in Australia	80	7 mo
Well-being management [Ahtinen et al. 2008]	Alone	Working age, in Finland and India	16	2 wk

WD was found especially appropriate for supporting usage models which included an intervention; this was observed in various different intervention programs. Participants who received some kind of professional support often took WD into long-term use and perceived it more positively than independent users, who were more critical of the application. Intervention participants probably got their initial motivation to adopt WD by participating in the intervention program and getting support from experts. Most of the improvement needs were related to motivational issues, such as engagement, interactivity, and support. These improvements would benefit the intervention users and independent users alike.

Personalisation was considered important in order to match the application to the needs of different interventions, disease management programs, or personal needs, such as self-management needs and cultural and individual preferences. Ready-made profiles consisting of a set of pre-selected variables and suitable targets could be used to enhance personalisation. For example, profiles could be generated for weight management, exercise, or cardiac rehabilitation.

Self-monitoring is required in order to enable users' subsequent self-evaluation [Rokke & Rehm 2001, Kanfer 1970]. Regular self-monitoring over several weeks is usually required for learning and behaviour change. The challenge is to motivate users to start self-monitoring and then continue for the first week or two when changes are not yet visible in the feedback. The adoption of WD could be facilitated by a learning mode, information on the benefits of self-monitoring, and quizzes on healthy behaviours and health, which would provide immediate feedback to the user during early use. Facilitating the entry of self-observations would probably enhance compliance in all phases of use. Prompts and alarms could serve to remind the user to self-monitor. Utilising different input modalities (e.g., voice, tactile, photos) and retrieving data automatically from external devices are also viable alternatives, or rather amendments, to manual entry.

Feedback is a key method of supporting self-assessment in WD. It has also been found to be crucial for maintaining motivation. In many studies, users have expressed their wish to get automatic interpretation, predictions, or expert feedback on their data. Thus feedback that more clearly illustrates the effects of behavioural choices on health and the relationships between behavioural variables would be valuable. Decision-support algorithms could be used to provide expert-level interpretation of the data. New motivational modes of feedback consisting of advanced analysis of self-observation data combined with decision-support instructions were envisioned and are presented in Figure 10.

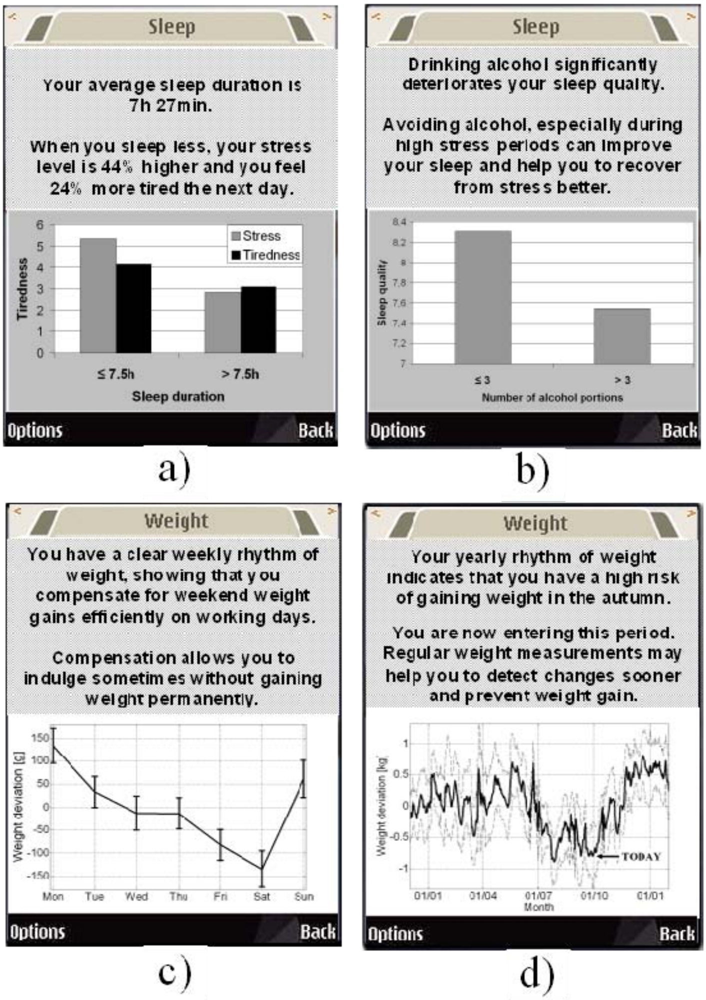

Figure 10. Examples of advanced feedback and analysis, demonstrated with the data of a case subject: a) feedback on the effect of short sleep on stress and tiredness, b) illustrating the well-known effect of alcohol consumption on sleep quality, c) positive feedback based on the weekly rhythm of weight, and d) a warning that a high-risk period is approaching based on the user's yearly rhythm of weight.

For many users, feedback has acted as a reward and as a motivator to continue self-monitoring. This means that feedback has provided users with a basis for internal self-reinforcement, i.e., they have self-assessed their progress based on the feedback and if positive, they have celebrated their success and been motivated to continue. However, more explicit rewards could be included in WD to provide users with the feeling that the application also acknowledges their success.

Novel usage models to support the use of WD were also presented. As WD has been found to be best suited for situations where support is available, usage models where such support is cost-efficiently available should be considered. The web-based version of WD, WDC, has been used to facilitate mentoring in cardiac rehabilitation by allowing both the patient and the mentor to access patient data via the WDC service and to discuss the progress remotely. Occupational healthcare and employee health promotion programs were seen as another promising option for utilising WD. However, these models are not optimal in terms of supporting healthy users. For them, integration within different, e.g., web-based services providing motivational features, such as social support, competition, and self-betting could be a feasible option.

5. Discussion

5.1 Accomplishment of objectives

The objective of this thesis was to gain new knowledge on mobile applications for supporting health management and self-monitoring. To achieve this objective, a personal mobile phone application was designed, validated and evaluated in several studies involving working-age adults from different backgrounds and with various well-being goals.

WD was designed based on Kanfer's self-management model to support self-monitoring, self-assessment, and self-reinforcement [Kanfer 1970]. The development process consisted of two major versions (1.0 and 2.0) and two minor versions (1.5 and 2.5) and was driven by user needs identified in the studies.

The user acceptance of WD can be examined based on the dimensions of TAMM, which are perceived ease of adoption, ease of use, value, and trust [Kaasinen 2005]. Ease of adoption, ease of use, and value were verified in Publications I and IV. In Publication I, about 90% of participants in the first study and 76% in the second study reported that it was easy to learn to use WD. In Publication IV, ease of adoption was expressed by the fact that 65% of participants took WD into use at the beginning of the study with very little guidance. Perceived ease of use of WD was high in all studies. In the first study of Publication I, about 90% of participants perceived WD as a simple application and in the second study, 100% of participants reported that it was easy to make entries with a mobile phone. In Publication IV, WD was perceived as easy to use by 60% of respondents, making it the second most easy-to-use mobile application of the PHS. Perceived value of WD was related to the value of WD in self-management. In the first study of Publication I, more than 70% of participants reported that WD was useful, motivated them to observe their eating and be more physically active, and helped them in weight management. The weight management results of this study were also encouraging; about half of participants lost weight and the rest approximately maintained their baseline weight despite the fact that the study period included Christmas, a known high-risk period for weight management. In Publication IV, two-thirds of respondents reported that WD contained appropriate functions for them and more than half felt that WD motivated them to maintain or enhance their well-being. Furthermore, WD was perceived as useful by participants with goals related to different aspects of well-being, including weight management, exercise, sleep, and stress; it can thus be concluded that WD is applicable for supporting many different health management goals

Although the fourth component of acceptance, trust, was not explicitly studied in the publications of this thesis, the participants did not seem to have problems trusting WD to store their health-related data. Indications of this are the high overall acceptance and usage rates of the application as well as the very few negative user comments related to privacy or trust issues. On the other hand, many participants commented that they did not perceive their self-observations, e.g. weight, physical activity, or sleep, as particularly sensitive information.

WD data were validated for correctness and usefulness in weight management in Publication II. Self-observed weight measures were found to be reasonably similar to those measured. Self-observed data were found to indicate behavioural changes in eating and physical activity, which were consistent with weight changes. A weekly rhythm of weight was observed, similar to that noted by other researchers [Tuomisto et al. 2006, Lappalainen et al. 2005] and the difference between the rhythms of successful and unsuccessful weight losers was shown. These results suggest that self-observed data recorded with WD are reasonably reliable and can be used for studying changes and patterns in weight and weight-related behaviours and providing valuable feedback to the user.

The applicability of WD in long-term self-monitoring was verified by its active and sustained usage observed in three studies. In Publication I, there were only two drop-outs in the first study and none in the second study. Both groups used WD actively for three months, and recorded on average more than five entries per day. In Publication IV, WD was the most actively used mobile application; more than half of the subjects, from whom mobile logs were retrieved, used WD during the intervention phase of the trial. Furthermore, 64% of participants of the first study of Publication I and 57% of respondents in Publication IV wanted to continue using WD in the future, after about three months of use.

The purpose of WD feedback was to enable users to efficiently self-assess their well-being status and progress in terms of their personal goals. Another aim was for feedback to serve as a trigger for self-reinforcement [Rokke & Rehm 2001, Kanfer 1970]. In Publication I, feedback was perceived as useful by a bit less than 60% of the participants of the first study and by 76% in the second study. In Publication IV, feedback was identified as the most important motivational element of WD, and the subjects appreciated the information on long-term progress provided by the feedback graphs.

The studies presented in this thesis – along with three other studies performed with WD – revealed several points for improvement, especially related to motivating usage in different phases of self-management. Considerable improvements were made during the development process from version 1.0 to 2.0. Concepts to further facilitate self-monitoring, improve feedback and data interpretation, and provide supportive and engaging usage models were presented in Publication V. These features are yet to be implemented or validated, but they can be expected to increase the value of WD.

5.2 Impact of the research in its field

The first health management applications for portable devices were developed in the eighties [Burnett et al. 1985]. In recent years, the focus has shifted to mobile phones, as their technical capabilities have rapidly developed and they are available to everyone. This section analyses WD in relation to the applications presented in the literature review. The methods used for self-monitoring and feedback, usage activity, and study settings are compared. Table 8 summarises comparable field studies from the literature review.

WD was designed to support behaviour change and self-management through the cycle of self-monitoring, self-evaluation and self-reinforcement. As behaviour change is a long-term process, supporting regular self-monitoring routines was considered important. The recording of self-observations was designed to be fast and simple in order to enable daily self-monitoring, support momentary usage and facilitate usage on the limited mobile user interface. The design choice was proven successful based on the high self-monitoring activity achieved in the studies. For example, in both studies of Publication I, more than five daily self-observation entries were recorded with WD throughout the three-month study periods without significant declines in usage activity. Furthermore, these studies provided no support for increasing adherence. A similar choice of simplified self-monitoring was made by Gasser et al. [Gasser et al. 2006], who used a point-based monitoring for physical activity and vegetable/fruit intake. In their four-week study, participants made four to five entries a day with the mobile phone application. On the other hand, many developers aimed for accurate monitoring, usually to provide reliable feedback on energy balance or comprehensive data on behaviours [Burnett et al. 1992, Burnett et al. 1985, Agras et al. 1990, Taylor et al. 1991, Lee et al. 2006, Atienza et al. 2008, King et al. 2008]. Although adherence to self-monitoring in these systems was often high at the beginning, notable declines were seen during the study periods, especially when there was no continuous support [Agras et al. 1990, Taylor et al. 1991, Atienza et al. 2008].

WD provides feedback for supporting the self-evaluation of performance. Feedback in WD is presented as graphs with respect to personal targets and simple statistics. This type of feedback also supports the self-reinforcement phase of the self-management cycle, but does not externalise it as praise or rewards. The users perceived the graphical long-term feedback as one of the most important aspects of WD. This finding led to a decision to increase the viewing options in the graphs of WD version 2.0, such as time scales ranging from one week to five years and new browsing options. Feedback with respect to personal goals was emphasized in most of the reviewed applications as well. Many applications provided only short-term feedback related to the current day [Burnett et al. 1985, Lee et al. 2006, Tsai et al. 2007, Gasser et al. 2006] or the current week [Consolvo et al. 2006, Anderson et al. 2007, King et al. 2008]. Longer term feedback was present in only two programs: Agras et al. [Agras et al. 1990] provided fourteen-day graphical feedback and Consolvo et al. [Consolvo et al. 2008b] provided feedback on goal achievements from the past month. Most programs externalized self-reinforcement by indicating goal attainment or providing praise, which the users found motivating [Consolvo et al. 2008a, Burnett et al. 1985, Consolvo et al. 2006, Tsai et al. 2007, Gasser et al. 2006]. Externalized reinforcement seems to act as an important motivator both for the application use and for healthy lifestyles, and therefore should be included in mobile well-being management applications when feasible.

Table 8. A summary of field studies presented in the literature review. Study duration refers to the time the participants had the technology at their disposal.

Focus	**Participants in the study conditions**	**Study duration**	**Adherence**
Weight management [Burnett et al.1985]	1) 6 Computer therapy (CT); 2) 6 controls	8 wk	-
Weight management [Agras et al. 1990]	1) 30 CT; 2) 30 CT+group; 3) 30 behaviour therapy & pen and paper	12 wk	1) 100+% => 29%; 2) 100+% => 70%; 3) 100+% => 29%,
Weight management [Taylor et al. 1991]	1) 28 CT; 2) 27 diet+CT	12 wk	Usage days/week: 1) 6.4 => 3.6; 2) 4.1 => 3.2
Weight management [Burnett et al. 1992]	1) 6 CT 4 d/wk; 2) 10 CT 7 d/wk; 3) 7 CT 4 d/wk+group	12 wk	2.9 times/day
Weight management [Lee et al. 2006]	6 PmEB	1 wk	2–4 times/day
Weight management [Tsai et al. 2007]	1) 5 pen and paper; 2) 5 PmEB+1 prompt; 3) 5 PmEB+3 prompts	4 wk	Usage times/day: [Lee et al. 2006, Tsai et al. 2007]1) 5.5; 2) 6; 3) 3
Healthy nutrition [Atienza et al. 2008]	1) 20 PDA; 2) 16 controls	8 wk	75% => 40%
Physical activity [King et al. 2008]	1) 19 PDA; 2) 18 controls	8 wk	68%
Healthy nutrition and physical activity [Gasser et al. 2006]	1) 10 mobile; 2) 10 mobile + team; 3) 10 web; 4) 10 web + team	4 wk	Entries per day: 1) 4.05; 2) 4.63; 3) 4.76; 4) 3.81
Physical activity [Consolvo et al. 2006]	1) 8 Houston + sharing; 2) 5 Houston personal mode	3 wk	-
Physical activity [Consolvo et al. 2008b]	12 UbiFit Garden	3 wk	-
Physical activity [Consolvo et al. 2008a]	1) 10 UbiFit Garden; 2) 9 no device; 3) 9 no display	12 wk	-
Physical activity [Anderson et al. 2007]	9 Shakra	10 d	-

WD has been involved in several studies, three of which were presented in detail in this thesis. An additional three were briefly described in Publication V. In addition, the usability of WD version 2.0 was evaluated in a small user evaluation [Ahtinen et al. 2007], and the data recorded with WD have been examined in two studies [Pärkkä et al. 2009, Mattila et al. 2007]. More than three hundred participants have been involved in these studies to date. These numbers are paralleled in the literature review only by Burnett et al. [Burnett et al. 1992, Burnett et al. 1985, Agras et al. 1990, Taylor et al. 1991]. The durations of the studies in this thesis, ten to twelve weeks, are also comparable to those of the studies presented in Table 8.

This thesis focused on studying the validity, user acceptance and usage of WD to confirm its applicability for long-term self-monitoring and self-management of health. The user experience study was the main focus of several of the studies reviewed [Consolvo et al. 2006, Consolvo et al. 2008b, Anderson et al. 2007, Lee et al. 2006, Tsai et al. 2007]. The applications in all of these studies generally received positive user feedback. The applications were found motivating, and benefits related to increased awareness were reported by all. Problems related to carrying the physical devices, such as a mobile phone and an activity monitoring device, were reported by Consolvo et al. [Consolvo et al. 2006, Consolvo et al. 2008b]. The potentially demotivating issue of not getting proper credit for physical activities, e.g., due to the limitations of automatic monitoring, was also reported in several studies [Consolvo et al. 2006, Consolvo et al. 2008b, Anderson et al. 2007]. Various researchers pointed out the benefits of using a mobile phone for self-monitoring and feedback [Consolvo et al. 2008a, Tsai et al. 2007, Gasser et al. 2006]. WD received high scores in terms of ease of use, ease of adoption, and value, especially with regards to raising awareness of health and helping and motivating users to change behaviours.

Uniquely, WD has been studied in settings where the users have been able to freely choose the technologies they will use from among several alternatives. This has enabled the acceptance and usage of WD to be compared to those of other technologies. WD has been integrated in two PHSs combining Internet, mobile, and monitoring technologies: a PHS for supporting a multifactor health promotion intervention, which was described and studied in Publications III and IV; and a PHS for supporting the management of stress and recovery [Happonen et al. 2009b, Happonen et al. 2009a]. According to the results presented in publication IV, WD was the best-accepted and most actively used mobile application in the PHS. The second PHS has been studied with three different user groups consisting of altogether ninety-four participants [Happonen et al. 2009a, Kaipainen et al. Accepted for publication]. The results of these studies regarding mobile technologies have not yet been published. Preliminary results show that technologies were actively used over the study periods (ten to fourteen weeks). In these studies, the users were more evenly distributed among technologies. SelfRelax relaxation application had the most active user group, followed by WD and Mobile Coach.

Theoretical models have been taken into account in the design of WD both to optimally support self-management tasks as well as to maximise the acceptance of the mobile application. Self-management methods and theories were involved in all the reviewed applications, but principles related to mobile application design were mentioned only by Gasser et al. [Gasser et al. 2006] and Tsai et al. [Tsai et al. 2007].

Kanfer's self-management model was found suitable for mobile phone based self-management. The three phases of the model, self-monitoring, self-assessment and self-reinforcement, can be efficiently supported and facilitated with a mobile application as found in this thesis and also in other studies [Consolvo et al. 2008a, Consolvo et al. 2006, Gasser et al. 2006].

The TAMM model worked well in the design of WD. An important lesson was that the properties of the mobile phone had a great effect on the perceived ease of adoption. For example, too small screen, fonts or keypad acted as barriers to using mobile applications for some participants, as was reported in Publication IV. In addition, having to learn how to use a new phone in addition to the applications may have discouraged use. Thus, it would be optimal for users to be able to use the applications on their own phones. However, this is usually not feasible during the research phase. Porting applications to different software platforms and phone models requires a lot of work and therefore the applications are usually optimised for a small subset of phone models. Another important finding was that the perceived value of WD was related to well-being management, and not the communication value suggested by Kaasinen [Kaasinen 2005]. However, including social support mechanisms, as proposed in publication V, would probably increase the communication value and thereby the value of WD in general.

All studies in this thesis included some type of health-related face-to-face intervention. Clearly introducing the purpose and potential benefits of health management applications to the participants was found to be important in order to support adoption and long-term use. Some individuals understand the benefits of self-monitoring intuitively, but others need guidance. Another implication was that in interventions utilising technologies, the technologies must be integrated in the intervention and presented in the context of different health management tasks. On the other hand, even minimal intervention, as in the first study of Publication I, may be sufficient to motivate individuals for months.

The studies of this thesis produced information on the acceptance and usage of WD with different types of participants who belong to the target group of WD. The positive results on acceptance and usage show that WD is suitable for supporting the management of many different health-related issues. The mobile phone implementation of WD supported usage when it was most convenient for users. However, forgetfulness due to a busy lifestyle or holidays threatened long-term usage. Recovering from these periods was also identified as an area for future development.

5.3 Limitations of the studies

The settings of the studies presented in this thesis were primarily designed to assess user acceptance and use of WD, but did not allow for evaluating the efficacy of WD in health management. Although there were positive health-related results, such as successful weight management, the results cannot be generalised due to the relatively small number of participants and the lack of follow-up periods. However, WD has been involved in two large RCTs (Publications III and IV and [Sarela et al. 2009]) as well as two smaller RCTs [Happonen et al. 2009a], which will allow efficacy to be analysed, but their results were not available at the time this thesis was written.

As is usually the case in health management studies and also in the studies done for this thesis, the participants were volunteers, who are typically more motivated to change their behaviours than the general public. In most of the studies, there has also been intervention or other expert involvement, which probably increased the motivation of the participants. The applicability of WD to totally independent health management is not known beyond a relatively small user study [Ahtinen et al. 2008] and the Internet discussion forum comments of unknown independent users, as presented in Publication V.

5.4 Future research

The ongoing RCTs will allow the health outcomes related to the usage of WD to be analysed, which is an obvious next step to the studies presented in this thesis.

The most important areas for improvement presented in Publication V were related to motivational aspects, such as engagement in different phases of use, interactivity, and support from experts, peers, and the application itself. Different concepts for personalising WD, new modes of data entry and feedback to more efficiently support self-monitoring, self-evaluation, and self-reinforcement were presented. In addition, social support mechanisms would most likely improve the value of WD for its socially-oriented users. These features should be implemented and tested in the future.

Novel service models that utilise WD would also be an interesting topic of research, as mentioned in Publication V. As WD has been shown to be suitable for different intervention settings, incorporating it to services with some form of expert involvement, such as therapy, coaching, or mentoring, is probably feasible. Service models for supporting independent well-being management, through social features and different types of "nudges", such as self-betting, would be especially interesting and useful.

In the future, as compatible wireless sensors and electronic personal health records become available, their utilisation in connection to WD must be studied. In the case of wireless sensors, emphasis must be placed on maximising the effect of self-monitoring, because automatic monitoring may decrease the user's situation awareness and the reactivity effect.

5.5 General discussion

The need for individuals to take more responsibility for their own well-being has long been acknowledged. The studies with WD and related PHSs have shown that many people are willing to take this responsibility and adopt technical tools to help them in the task, as long as the tools are appropriate, easy to use, low maintenance, and provide real help in health management.

Mobile applications – and generally, technologies that can be easily carried around at all times – seem most promising for supporting daily health management. The advantage of mobile health management applications is that the mobile phone is carried because it provides several vital functionalities for people today, such as phone calls, messages, calendar, web browser, etc. Various kinds of personal and private information are already stored in the mobile phone. Therefore, including health-related information into the mix is hardly a stretch. The mobile phone is on hand at all times, providing many opportunities to use the applications and make entries. And as many people rely on their mobile phones to fill their idle moments, a mobile health management application may provide them with a useful pastime. Many studies have shown that when a mobile phone contains a health-related application, the device itself becomes a pervasive reminder of health management. These aspects provide clear advantages over traditional methods of self-monitoring, such as pen and paper or electronic devices dedicated solely to self-monitoring.

Different monitoring devices, such as pedometers, blood pressure meters, and personal scales, can be used to support daily self-monitoring. These devices have also been used in studies related to WD. Although their purpose in the studies has often been to support WD-related self-monitoring, they are also known to motivate people on their own. For example, pedometers are known to motivate physical activity and produce health effects [Clemes & Parker 2009, Tudor-Locke 2002, Bravata et al. 2007]. Furthermore, as these devices are often very simple, easy to take into use, and provide information that is easy to understand, they may provide a starting point for well-being management. On the other hand, an application such as WD may also support the long-term usage of these devices by allowing the results to be stored for long-term follow-up.

It is important to remember that even though self-monitoring is usually perceived as a data gathering operation, it is also a very powerful intervention. The act of monitoring alone may change behaviours by making the individual aware of his/her situation and behaviour, even without feedback. Therefore, in order to support behaviour change, it is more important to prioritise long-term adherence over detailed data. It is, however, important to allow people to record the information they consider relevant. This implies that the design of self-observations must be done carefully and that some freedom should be allowed, as exemplified by the free text note fields in WD.

Providing the user with feedback on his/her entries is crucial. Feedback enhances the effect of self-monitoring by showing progress in terms of well-being and the effect of behaviour changes. Feedback, especially on long-term progress, is also an important motivational feature, which helps to support long-term adherence to self-monitoring. The third phase of the self-management loop, self-reinforcement, could be supported by externalising it as rewards and praise offered by the applications or services.

The analysis of self-observation data may further enhance the usefulness of self-monitoring. Even the simplest self-observations may reveal important aspects of personal well-being, such as the interconnections between behaviours and health and between personal behavioural and physiological rhythms. Providing this type of feedback, e.g. illustrating risky periods for weight management or the lack of compensation mechanism in weight, could help individuals modify their behaviours even more efficiently. However, extracting such phenomena from incomplete data infested with typing errors requires advanced data analysis methods.

6. Conclusions

In this thesis, the design of a mobile phone application for self-management of well-being and health was presented. The application was validated as a self-monitoring tool and evaluated in several different application areas with a large number of users.

The application was found to be easy to use, acceptable, and capable of attracting high usage rates. It was considered apt for supporting different self-management goals. Self-observation data recorded with the application were found to provide valuable insight into weight management-related behaviours.

These findings support the use of mobile health applications based on self-monitoring in health and well-being management.

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Errata

Publication I:

Table I: The weight variable was included in the S2 implementation.

An overly sensitive statistical test was used in tables IV, V, and VIII. The following results are corrected:

- Table IV: The only significant difference between Losers and Others is in the number of weight entries ($p < 0.05$). There is a near significant difference in the number of exercise entries ($p = 0.10$).
- Table V: There are no significant differences in the table between groups or day types. Near significant differences ($p < 0.10$): the participants tended to make less weight entries on weekends and Losers tended to make more entries on weekends than Others.
- Table VIII: Significant differences were found for sleep ($p < 0.01$), stress and weight ($p < 0.05$). Near significant differences were found for blood pressure, steps, and exercise ($p < 0.1$).

In summary, the only significant difference in the entry activity was that successful weight losers made more weight entries than unsuccessful ones. There were no significant differences between weekday and free day entry activity in the first study. In the second study, the participants made more entries to weight, sleep and stress variables on weekdays than on weekends.

Publication IV: There were altogether 16 variables in WD, not 17.

PUBLICATION I

Mobile diary for wellness management – Results on usage and usability in two user studies

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Mobile Diary for Wellness Management—Results on Usage and Usability in Two User Studies

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***Abstract*—The prevalence of lifestyle-related health problems is increasing rapidly. Many of the diseases and health risks could be prevented or alleviated by making changes toward healthier lifestyles. We have developed the Wellness Diary (WD), a concept for personal and mobile wellness management based on Cognitive-Behavioral Therapy (CBT). Two implementations of the concept were made for the Symbian Series 60 (S60) mobile phone platform, and their usability, usage, and acceptance were studied in two 3-month user studies. Study I was related to weight management and study II to general wellness management. In both the studies, the concept and its implementations were well accepted and considered as easy to use and useful in wellness management. The usage rate of the WD was high and sustained at a high level throughout the study. The average number of entries made per day was 5.32 (SD = 2.59, range = 0–14) in study I, and 5.48 (SD = 2.60, range = 0–17) in study II. The results indicate that the WD is well suited for supporting CBT-based wellness management.**

***Index Terms*—Cognitive-behavioral therapy (CBT), mHealth, mobile application, weight management.**

I. Introduction

MODERN lifestyle with the 24/7 society, fast-pace information work, sedentary lifestyle, and fast food culture has contributed to the increase of health risks such as overweight, stress, and sleep problems. These health risks are pervasive in most modern societies and have been associated with various diseases and high costs to healthcare. In Finland, about 20% of adults are obese (body mass index, BMI $\geq$ 30 kg/m^2) and an additional 48% of men and 32% of women are overweight (BMI 25–29.9 $\mathrm{kg/m^2}$) [1]. Similar trends are seen in other European countries [2], the United States of America [3], and the Asian countries [4]. It has been estimated that obesity accounts for 2%–8% of healthcare costs in Europe [2].

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Stress, especially work-related stress, is another significant health risk. Among European employees, 28% suffer from stress-related problems, and an estimated 50%–60% of all lost working days result from stress [5]–[7]. In the USA, 40% of workers consider their work as "very or extremely stressful" [8]. Sleep problems are also increasing in all age groups. About one-third of the Finnish working-age population have symptoms of insomnia, and the percentage has steadily risen from the year 1977 when it was less than 20% [9], [10]. Furthermore, more than half of the over 65-year-olds have one or more chronic sleep complaints [11]. Overweight, stress, and sleep problems have been associated with various diseases such as cardiovascular diseases and type II diabetes mellitus [12]–[14]. These health risks have complex interconnections, for example, stress provokes sleep problems [15], sleep problems increase the risk of overweight [16], and overweight is associated with sleep problems such as sleep apnea [12]. Almost 60% of the disease burden in Europe is accounted for by seven largely lifestyle-related risk factors: high blood pressure (12.8%) and cholesterol (8.7%), smoking (12.3%), alcohol consumption (10.1%), overweight (7.8%), low fruit and vegetable intake (4.4%), and physical inactivity (3.5%) [17].

The current healthcare system does not have the resources to prevent and manage these health risks. Therefore, individual effort is paramount in disease prevention, i.e., managing the risks before they develop into more serious health problems. In theory, for example, weight management is fairly simple. Since the primary cause of overweight is the excess intake of energy in relation to energy expenditure, weight loss may be achieved by balancing food intake and physical activity. However, in practice, it is not so simple; the success rates of long term weight loss maintenance in different studies range from 2% to 20% [18]–[20]. The challenge is that these health risks arise from a mixture of genetic, lifestyle-related, and environmental factors. The genetic and environmental factors are usually beyond our control, but personal factors such as thinking and behavior can be altered.

A commonly applied psychological approach that aims at inducing behavioral changes in order to cope with these kinds of problems is Cognitive-Behavioral Therapy (CBT). CBT consists of a combination of cognitive and behavioral procedures to help the individual to identify and change the problem-maintaining mechanisms. One of the key methods in CBT is self-monitoring. The subjects are taught to observe their actions, emotional reactions, thoughts, and other variables related to health (e.g., weight), and, through these observations, to recognize the maintaining mechanisms and to identify the behavioral lifestyle changes that would alleviate the problem. Self-monitoring is also used for observing the effects of the behavioral changes made during the treatment. For example, in CBT for weight management, the subjects usually write down their food intake and draw a graph of the results of their regular weight measurements [21]. CBT has been successfully applied in the treatment of various behavioral problems, for example, the management of weight, stress, and sleep problems [22]–[24].

The CBT approach can be efficiently supported by (ICT), for example, in recording self-observations and generating feedback based on them [23], [25]. A large number of wellness management applications utilizing ICT, especially the Internet and mobile devices, have recently appeared [23], [26]–[28]. At present, applications based on mobile devices are more feasible than ever-–most people own some sort of mobile terminal and carry it along all the time. Therefore, integrating a wellness management tool into a mobile device enables using it anytime and anywhere. Kaasinen [29] has summarized the design principles for mobile applications. According to her, the implementation should facilitate momentary usage, because many people prefer to use mobile services during the idle moments of life when there's nothing particular to do, for example, while waiting for a friend, commuting, or at the airport. Furthermore, she emphasizes that a mobile service or application should be easy to adopt and its functions easily understood. In addition, the new services should not only fit into the existing usage cultures, but also provide a possibility to extend them. In order to function as a platform for a wellness application, the mobile device needs to be a lightweight and personal device, have reasonable amount of memory and processing power, and a sufficient user interface. Preferably, the device should also have other important functionality to the user than solely wellness management in order to be important enough to be carried along at all times.

We developed the Wellness Diary (WD) concept for personal wellness management based on the philosophy of CBT. The objective of this paper is to describe the WD concept and to present two separate studies conducted with the WD. In the first study, the WD implementation for weight management was studied, and in the second study, an implementation for general wellness management was used. Our main focus in this paper will be on the usage, usability, and acceptance of the concept and its implementations.

II. Wellness Diary

The key features of the WD are mobility, recording of wellness-related self-observations, and objective graphical feedback automatically generated based on the observations. Mobility enables the user to record self-observations and get graphical feedback whenever and wherever needed, making wellness monitoring a pervasive and everyday part of life. The concept aims to support the user's own recognition and decision-making process in managing behavioral problems. Therefore, the feedback provided by the WD is objective and does not contain instructions.

The mobile phone was selected as the platform for the WD due to its inherent mobility, advanced technical features, role in people's lives, and high penetration (e.g., at the end of 2005, 98% of the Finnish population owned a mobile phone [30]). The modern mobile phones have enough processing power and memory for wellness applications. Furthermore, the user interface is well suited for input and visualization of wellness-related variables. The mobile phone is often considered as a personal trusted device, which contains many kinds of private information, such as personal messages and contact information for family and friends. Mobile phones are also carried along most of the time, and therefore, are always at hand, supporting momentary usage and "on-the-spot" observations.

The WD was implemented on the Symbian Series 60 (S60) mobile phone platform as a stand-alone application, running locally in the mobile phone. The local implementation facilitates and expedites the usage of the application, since no time or money is wasted while waiting for a server connection. Thus, local implementation also supports momentary usage [29]. This approach ensures the user's privacy, since no data are transferred to or from the application without the user's consent. For this reason, also the user's trust in the WD may increase. We integrated the WD into the standard S60 calendar. This was done for two reasons. First, we wanted to facilitate the adoption of and learning to use the application [29]. Often, starting to use a new application is laborious and requires a lot of learning, which, in turn, may decrease the motivation. We hypothesized that starting to use a new feature of an application that the user is already familiar with and maybe even using on the daily basis would be easier than starting to use a completely new application. This way, a fit to the existing usage culture is also provided [29]. Second, the WD and the calendar fit well together conceptually. The calendar looks into the future, containing all future appointments and events, whereas the WD concentrates on the past in terms of feedback generated based on continuous self-observations. In this way, the WD extends the usage of the calendar application as a personal life management tool and makes wellness management an integral part of life rather than a separate task.

The user inputs his/her self-observations into variable-specific input forms, which were designed to resemble the standard calendar input forms [see Fig. 1(a)]. All of the input forms contain fields for entering the relevant information concerning the observation as well as time and date fields for time stamping the information. The WD also supports automatic download of data from measurement devices. The WD may be modified according to the user's needs, which means that the user may leave out or take into use variables at any time. The wellness entries are stored into a local database from which they can be retrieved for visualization. The observations can be viewed in a special wellness view, which contains graphical feedback generated based on the entries [see Fig. 1(b)]. The graphs in wellness view are simple and easy to interpret, which enables the user to make conclusions about his/her wellness. The wellness-related entries are shown on the calendar day view along with the normal calendar entries [see Fig. 1(c)], which enables the user to view and modify old entries. The WD is primarily intended to be a personal, independently used application, but it also provides a possibility to send out the data from the application via

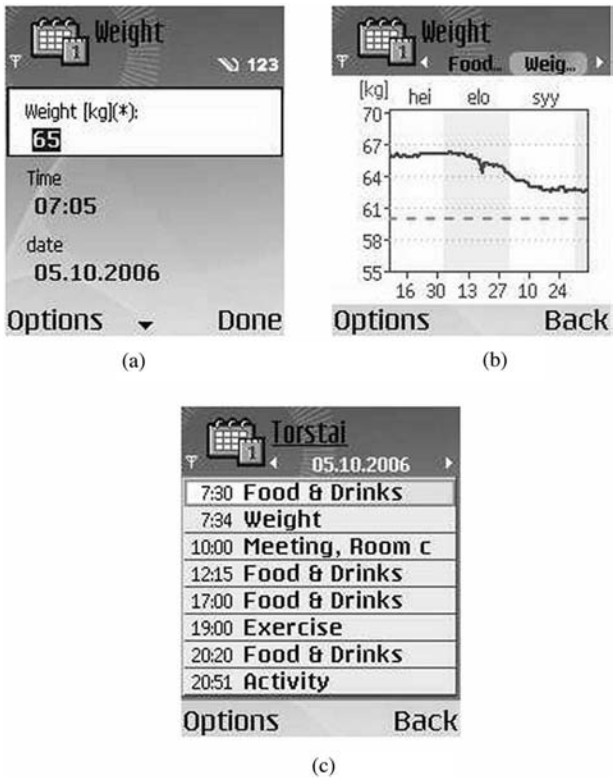

Fig. 1. User interface of the WD. (a) Input form for weight. (b) Weight feedback graph. (c) Combined calendar and WD day view.

multimedia messages or e-mail to a healthcare professional, coach, or whomever the user wishes to send them to.

Two different implementations of the WD concept were made, one for weight management and the other for general wellness management [31]–[33]. The difference between the implementations is the selection of variables offered to the user. The variables and their implementation are presented in Table I. Since time and date fields for time stamping the data are common to all variables, they are omitted in Table I. All input forms have one or more obligatory parameters, which are indicated in the table with asterisks.

The primary goal in selecting the implementations for different variables was that they should support long-term self-monitoring. In many cases, this meant favoring simplicity, i.e., simple input forms with few obligatory fields to fill in. The variable where this is most apparent is the food and drinks variable. The first thought that often comes to mind when considering food diaries is counting calories or keeping a detailed diary with foodstuffs and quantities carefully recorded. However, this approach is often too laborious, and therefore, typically suitable for only a few days' use [34]. We hypothesized that a simpler method would attain higher compliance and still result in learning about one's eating behavior when used over the long term.

The usage, usability, and acceptance of the weight management and general wellness management implementations were studied in two separate studies. In the following two sections, we present the studies and their results.

III. Study I—Weight Management

The objective of study I was to study the usage, usability, and acceptance of the weight management implementation of the WD (see variables in Table I).

A. Materials and Methods

Twenty-nine subjects, 20 males, and nine females (demographics summarized in Table II) volunteered in a 3-month user study. The subjects were recruited through occupational health service (OHS) of a Finnish technology company. The main inclusion criteria were being overweight (BMI > 25 kg/m^2) and having an S60 phone. Exclusion criteria were pregnancy and attendance in other weight management programs simultaneously. All subjects owned an S60 mobile phone and most subjects (25/29) had been using the phone for more than 6 months. Three subjects had been using the phone for more than a month and one subject for less than a month. Seventeen subjects were using the S60 calendar regularly, ten subjects were using it occasionally, and two subjects were not using the calendar at all.

The study procedures consisted of a start-up session in groups of about ten subjects, individual usability interviews at start and at end, and a closing session. The subjects filled in a background questionnaire in the beginning and were asked to attend initial weight and waist circumference measurements organized by the OHS. The start-up session included a 1.5-h lecture about CBT-based weight management with written material given by an expert in psychology and weight management. The CBT lecture was based on the mini-intervention program, and included a summary of behavioral variables that affect eating and weight (e.g., learned hunger and satiety phenomena), instructions on how to maintain weight, and instructions for making self-observations [35], [36]. In the start-up session, WD applications were installed into the subjects' mobile phones and a short usage instructions lecture (∼20–30 min) was given on the WD. All subjects were given an infrared-enabled pedometer (Fitness Monitor, Nokia, Finland), and personal scales were provided to those subjects who did not own one. The subjects were instructed to record daily self-observations during the study in the variables they felt useful. They were suggested to make food and drinks entries after each meal, measure their weight every morning, wear their pedometers daily and download the step counts into the WD, enter exercises after each exercise session, observe their feelings daily, and input health events in case they occurred during the study. They were also asked to send their data to the researchers once a week. After the study, the subjects were invited to a closing session where the results of the study were summarized.

The subjects were interviewed by usability experts after 1 week's use and again after 3 months' use. The usability interviews consisted of a semistructured interview and a feedback questionnaire. The feedback questionnaire contained statements, which the subjects rated using a Likert scale from 1 to 5 (strongly disagree to strongly agree). The first interview focused on early impressions and use routines of the WD, and the second interview concentrated on long-term use experiences. During the study, the subjects could contact a researcher if they

TABLE I
VARIABLES IN WD, THEIR IMPLEMENTATION AND FEEDBACK

Variable	S1 = Study I S2 = Study II	Parameters	Type [unit]	Feedback
Food & Drinks	S1	Food quality *	Selection list: Light snack, Heavy snack, Light meal, Heavy meal	A grid with colored squares presenting eating times and food quality.
		Number of drinks	Numeric	
		Energy	Numeric [kcal]	
		Diet note	Text	
Weight	S1	Weight measure *	Numeric [kg]	Line graph: weight (Fig. 1b)
Steps	S1, S2	Number of steps*	Numeric	Line graph: steps
Exercise	S1, S2	Duration*	Numeric [min]	Sum of weekly exercise duration as stacked bars of exercise sessions. Intensity indicated with color.
		Sport	Selection list with preset sports	
		Intensity	Selection list: Easy, Moderate, Vigorous	
		Distance	Numeric [km]	
		Heart rate	Numeric field [beats/min]	
Feelings	S1	Life satisfaction*	Visual analog scale; VAS [0=poor 10=excellent]	Line graph: feelings ratings
Fat %	S1	Fat% measure*	Numeric [%]	Line graph: fat%
Blood pressure	S2	Systolic blood pressure*	Numeric [mmHg]	Line graphs: systolic, diastolic, pulse
		Diastolic blood pressure*	Numeric [mmHg]	
		Pulse	Numeric [beats/min]	
Stress	S2	Stress	VAS [0=no stress 10=very stressed]	Line graphs: stress, tiredness, irritation, tension
		Tiredness	VAS [0=not tired 10=very tired]	
		Irritation	VAS [0=not irritated 10=very irritated]	
		Tension	VAS [0=not tense 10=very tense]	
Sleep	S2	Fall asleep time	Time	Line graph: sleep duration
		Awakening time	Time	
		Sleep quality	VAS [0=poor quality 10=excellent quality]	
		Awakening date	Date	
Health events: Illnesses	S1, S2	Name of illness	Text	No feedback.
		Note	Text	
Health events: Doctor visits	S1, S2	Reason for visit	Text	No feedback.
		Doctor's name	Text	
		Clinic	Text	
		Diagnosis	Text	
Health events: Treatments	S1, S2	Name of treatment	Text	No feedback.
		Dose	Text	
		Frequency	Text	

The obligatory parameters are indicated with asterisks.

TABLE II
SUMMARY OF STUDY I SUBJECT DEMOGRAPHICS, MEAN (SD, MIN–MAX)

	Men (N = 20)	Women (N = 9)	All (N = 29)
Age [years]	39.3 (8.14, 25–52)	39.8 (8.63, 26–54)	39.4 (8.14, 25–54)
Weight [kg]	94.8 (11.1, 76.0–114)	76.3 (7.93, 68.5–95.0)	89.0 (13.3, 68.5–114)
BMI [kg/m^2]	29.5 (2.24, 25.9–33.6)	27.1 (2.11, 24.8–31.4)	28.8 (2.44, 24.8–33.6)
Waist [cm]	100 (6.79, 86.0–111)	93.3 (9.17, 84.0–111)	98.0 (8.10, 84–111)

had technical or other kind of problems. The researcher could also contact the subjects if they failed to send their data. However, the researcher did not comment on the contents of the data unless there was reason to suspect technical problems.

The statistical tests were performed with the Statistical Package for Social Sciences (SPSS version 14.0, SPSS Inc., Chicago, IL). The Wilcoxon signed ranks test and the Mann–Whitney test were used for statistical testing using the alpha level of 0.05.

B. Results

Two subjects, one female and one male, dropped out in the beginning of the study. The female subject's primary motivation to participate in the study was monitoring and increasing everyday activity with the help of the pedometer. Two of her pedometers broke in a short period of time, and, as a consequence, she lost her motivation to continue the study. The male subject hurt his leg in mid-December. He got sick leave and could not exercise. He also changed phone model to one that was not compatible with the WD shortly after this.

The results are presented for the remaining 27 subjects. We were interested in studying the usage of the application by those subjects who were able to lose weight and those who were not. Thus, the results of the study are presented in three groups: all subjects (ALL, $N = 27$), those who lost weight (LOSERS, $N = 12$), and others (OTHERS, $N = 13$). The ALL subjects group contains more subjects than the other two combined, because it was not possible to determine weight change for two subjects due to insufficient amount of weight entries. The weight change was determined based on the first and last seven days that the

TABLE III
SUMMARY OF WEIGHT CHANGES IN THE LOSERS AND OTHERS GROUPS

	LOSERS (N = 12)	OTHERS (N = 13)
Gender (Male/Female)	8 / 4	9 / 4
Days between first and last Weight entry mean (SD, min–max)	79.7 (5.24, 66–83)	76.5 (9.46, 53–83)
WD start weight [kg] mean (SD, min–max)	88.6 (13.7, 67.1–105)	82.1 (12.1, 70.0–113)
WD end weight [kg] mean (SD, min–max)	85.7 (13.0, 66.1–104)	82.3 (12.7, 69.4–116)
Weight change [kg] mean (SD, min–max)	-2.94** (2.73,-10.9–-1.00)	+0.193 (0.865, -0.700–+2.11)
Weight change % mean (SD, min–max)	-3.22 (2.78,-11.4–-1.10)	+0.150 (0.997, -0.901–+1.86)

Significant changes are denoted with asterisks (**$p < 0.01$).

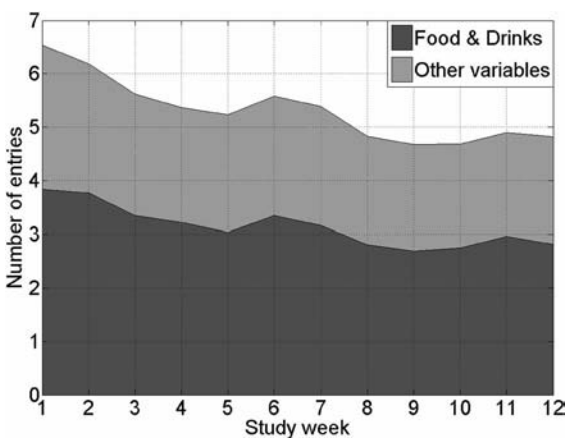

Fig. 2. Average daily number of entries during the study weeks.

TABLE IV
AVERAGE NUMBER OF DAILY ENTRIES AND THE TOTAL NUMBER OF ENTRIES, MEAN (SD, MIN–MAX)

	LOSERS (N = 12)	OTHERS (N = 13)	ALL (N=27)
All entries / day	5.78 (2.55, 0–14)	5.24 ** (2.48, 0–13)	5.32 (2.59, 0–14)
Food & Drinks	3.41 (1.82, 0–10)	3.05 ** (1.70, 0–11)	3.15 (1.79, 0–11)
Weight	0.907 (0.298, 0–2)	0.734 ** (0.448, 0–2)	0.769 (0.427, 0–2)
Steps	0.746 (0.428, 0–2)	0.806 ** (0.400, 0–2)	0.762 (0.429, 0–2)
Exercise	0.379 (0.665, 0–4)	0.203 ** (0.450, 0–2)	0.268 (0.555, 0–4)
Feelings	0.266 (0.447, 0–2)	0.271 (0.447, 0–2)	0.253 (0.438, 0–2)
Total number of entries	471 (152, 189–772)	435 (164, 137–638)	434 (164, 137–772)

Significant differences between the LOSERS and OTHERS groups are denoted with asterisks (**: $p < 0.01$).

subject was using the WD. It was also required that these 7-d periods contained at least two valid weight entries, and that there were at least 30 d containing at least ten valid measurements between the 7-d periods at the start and at the end. The subjects who had lost 1% or more of their initial weight were assigned to the LOSERS group, and the others (fulfilling the aforementioned requirements) were assigned to the OTHERS group. A summary of weight changes in the LOSERS and OTHERS groups is presented in Table III.

The average number of daily entries in the course of the 12 weeks of the study is presented in Fig. 2. The portion of food and drinks entries of all entries is separated in the figure because several entries per day were made to that variable. Table IV presents the entry activity in all the three groups. We do not present fat% and health events separately in this table, because very few entries were made to them. However, they are included in the total number of entries and all entries/day.

The LOSERS group made more entries altogether and in most variables: weight, exercise, and food and drinks. The OTHERS group made more entries to steps.

The number of entries on weekdays and free days are presented in Table V for different groups. Free days include weekends, Christmas time, and some weekday holidays. We tested differences between weekdays and free days in all groups (significant differences denoted with asterisks) and between LOSERS and OTHERS, for example, LOSERS weekday vs. OTHERS weekday (significant differences denoted by plus signs).

The average daily number of entries was significantly higher on weekdays than that on free days in all groups. More entries were made on weekdays in all variables except exercise. In the ALL group, the difference was statistically significant in food and drinks, weight, and steps. In other groups, the results were similar with the exception that there was no significant difference in food and drinks entries in the OTHERS group. The LOSERS made more entries than the OTHERS on weekdays in all variables except steps and feelings. The LOSERS also made more entries than the OTHERS on free days in all variables except steps and feelings. The OTHERS made more entries than the LOSERS to the steps variable on free days.

All the 29 subjects were interviewed after 1 week of WD use. All remaining subjects as well as one dropout participated in the second interview, and thus, 28 subjects were interviewed after 3 months' use. The results of the feedback questionnaires are presented as the percentages of subjects agreeing or strongly agreeing to the statements (first interview, second interview). There were some additional questions in the second interview as compared with the first interview. Therefore, some results are available only for the second interview.

The subjects found the WD as an easy-to-learn (93%, 89%), simple (86%, 93%), and useful application (90%, 79%). The subjects felt that the WD sat well as a part of the calendar application (62%, 61%). About two-thirds of the subjects (66%, 68%) felt that the WD did not complicate their regular calendar usage. Visual feedback was considered as adequate by (59%, 57%) of the subjects. At the end, 79% of the subjects would have liked to have some predictions made based on the data, and 79% wanted to further analyze the data with a PC. At the end, 54% wished they could have had an expert comment on the feedback generated by the WD, and 43% thought that using the WD in a group would have further motivated them. The WD

TABLE V
DAILY NUMBER OF ENTRIES IN DIFFERENT GROUPS ON WEEKDAYS AND FREE DAYS

	LOSERS (N = 12) mean (SD)		OTHERS (N = 13) mean (SD)		ALL (N = 27) mean (SD)	
Variable	Weekday	Free day	Weekday	Free day	Weekday	Free day
All entries / day	6.00 (2.42)	5.50 (2.68) **	5.42 (2.34) +	5.01 (2.63) *++	5.49 (2.49)	5.11 (2.70) **
Food & Drinks	3.56 (1.75)	3.23 (1.75) **	3.12 (1.64) +	2.96 (1.77) ++	3.24 (1.74)	3.04 (1.84) *
Weight	0.947 (0.233)	0.857 (0.357) **	0.779 (0.427) ++	0.678 (0.468) **++	0.807 (0.403)	0.722 (0.451) **
Steps	0.783 (0.417)	0.701 (0.458) **	0.848 (0.364)	0.755 (0.435) **++	0.800 (0.404)	0.714 (0.455) **
Exercise	0.350 (0.601)	0.416 (0.737)	0.194 (0.440) ++	0.214 (0.463) ++	0.250 (0.514)	0.290 (0.602)
Feelings	0.285 (0.460)	0.241 (0.428)	0.289 (0.457)	0.249 (0.433)	0.269 (0.449)	0.233 (0.423)

Significant differences between weekdays and free days (*: $p < 0.05$, **: $p < 0.01$) and between groups (+: $p < 0.05$, ++: $p < 0.01$) are indicated.

motivated the subjects to observe their eating (86%, 71%) and to be more active physically (66%, 71%). The subjects considered weight, steps, and exercise as the most important variables in the application; weight was considered as important or very important by (93%, 96%) of the subjects, steps by (86%, 82%) of the subjects, and exercise by (86%, 86%) of the subjects. Monitoring one's food and drinks intake was considered as important or very important (79%, 54%). The subjects were also asked how often they expected to make different entries in their future use of the WD. The subjects expected to record their weight daily (79%, 86%), input their steps weekly (66%, 86%), input exercise information daily (48%, 64%), and monitor food and drinks intake several times a day (72%, 50%).

In the beginning, 83% of the subjects believed (40% strongly) that the WD would help them in weight management. At the end, 79% said that the WD actually helped them in weight management, with 54% of subjects strongly agreeing to the statement. The average grade, on a scale from 1 to 10, given to the implementation of CBT ideas into the WD was 7.25. At the end, 64% of the subjects wanted to continue to use the WD.

The comments obtained with the semistructured interview are presented in the following. In the first interview, after 1 week's use, most subjects had already shifted from learning phase to routine use, but the feedback graphs were not yet very clear to them. At the end, the subjects had learned to interpret the feedback and identify trends in their observations—they had also found that daily inputs, especially in weight, are better than weekly entries because they produce more feedback. The graphical feedback was well liked and considered as useful not only in observing one's behavior, but also the very act of making entries into the WD was found as an effective intervention. Especially in monitoring food and drinks intake, making entries made some of the subjects reflect on their food and drinks choices and choose the ones with less energy.

The subjects appreciated the simplicity and the low-maintenance approach of the CBT philosophy, and that the WD acknowledged and supported the user's own responsibility in making weight management decisions. Most subjects also liked the personal and private aspect of the weight management approach, but some subjects would have liked to have a peer group to discuss and compare their results with. At the end of the study, the subjects considered improved self-observation as the main benefit of the WD. The subjects also recognized that the same approach could be used with pen and paper, but the WD's benefit was that it can be more easily carried along, and it automatically generates feedback graphs based on the observations. Toward the end of the study, the subjects learned to adapt their usage habits and stopped using the variables they considered as less useful to them personally.

C. Discussion and Conclusion for Study I

The subjects in study I were relatively young and technically oriented. They were users of S60 phones prior to the study, which may have further facilitated the use of the WD. On the other hand, such a subject group could also be more critical about this type of application than a random person from the street.

The WD was considered as a simple and easy-to-use application, and was perceived as a useful weight management tool by most subjects. This was also reflected in the promising weight management results of the group. The CBT-based philosophy of the WD was considered as a benefit and the subjects felt that the CBT ideas were well integrated into the application. Also, the calendar integration was welcomed by these already accustomed users of the S60 calendar, which suggests that the integration was done in a successful way. A couple of subjects felt that the WD complicated their regular calendar use, mostly due to wellness-related entries that appeared in the calendar day view along with the regular entries and crowded the day view [see Fig. 1(c)]. The possibility to separate calendar and wellness views was considered as an important development need.

The usage rate of the application was high and did not significantly decrease during the study, which shows that the WD is suitable for daily use over long periods of time. During the study, the subjects adapted their usage according to their personal needs. For example, the importance of weight measurements increased during the study and the subjects were more prone to monitor their weight daily. The importance and expected input frequency of food and drinks decreased most dramatically during the study. The reason for this, according to the subjects' comments, is that in the beginning, when they were learning to observe their own behavior, monitoring food and drinks intake was considered as important. Later, when the subjects learned to observe their behavior better in their daily lives, they felt that their need to input every meal decreased. It must be noted, that merely based on the data, we cannot conclude whether the decreased number of food and drinks entries is due to the subject making less entries or actually eating less. In this study, based on the subjects' comments, it is more probable that the subjects started to make fewer entries after having learned to monitor their eating. However, as depicted in Fig. 2, the subjects made,

TABLE VI
STUDY II SUBJECTS' BACKGROUND INFORMATION

Subject	Gender	Age	Profession	BBI
04	Female	60	Assistant	48
05	Male	57	Planning engineer	54
06	Female	52	Senior research scientist	50
07	Female	60	Chief engineer	60
08	Female	53	Chief librarian	53
09	Female	58	Service center director	38
12	Female	40	Office secretary	48
13	Male	58	Laboratory engineer	33
14	Female	50	Practical nurse	43
15	Female	58	Departmental secretary	26
16	Female	48	Service secretary	72
17	Female	54	Cleaner	48
18	Female	51	Sales ledger clerk	70
19	Female	57	Area sales manager	58
20	Female	62	Trustee secretary	43
21	Male	54	Cable worker	54
22	Female	54	Departmental secretary	39

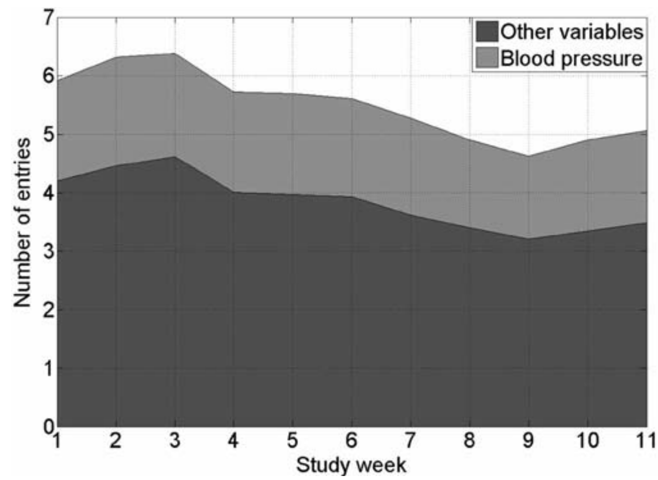

Fig. 3. Average daily number of entries during the study weeks.

on average, more than three food and drinks entries every day to the WD throughout the study. Based on this result, we argue that this simple approach to diet monitoring has paid off. Burdening the subjects with a detailed food diary would most likely have resulted in a low number of entries in this variable simple approach, we made the subjects think about their eating at least three times a day every day for 3 months.

IV. STUDY II—GENERAL WELLNESS MANAGEMENT

Study II was a part of a larger wellness monitoring study, where the WD was one of the applications the subjects were using. We will only concentrate on the WD usage, usability, and acceptance results. From the WD point of view, the objective of study II was to study a different implementation of the concept (see variables in Table I) in a more demanding subject group.

A. Materials and Methods

Seventeen subjects, three males and 14 females (mean age 54.5 years, range 40–62, SD 5.4), participated in the study. The subjects were volunteers who were participating in a work-related rehabilitation program and who had an elevated burnout score ($\geq$25) according to the Bergen Burnout Indicator (BBI-15) [37]. Due to the heterogeneity of the subject group, the demographics of the subjects are presented individually in Table VI. None of the subjects had used an S60 phone before, and one subject did not own any kind of mobile phone.

The subjects were provided with S60 mobile phones (Nokia 6670, Nokia, Helsinki, Finland), pedometers (Walking Style II, Omron, Kyoto, Japan), and blood pressure meters (705IT, Omron, Kyoto, Japan). Also, personal scales were provided to those subjects who did not own one. During the study, the subjects were also using a variety of other devices, including: a heart rate monitor, a wrist-worn activity monitor, a pressure sensitive sheet under the mattress, a sensor box monitoring environmental variables such as temperature and lighting, and a laptop computer, which gathered the data from these devices and relayed them to the researchers (except the WD data, which were sent directly via Multimedia Messaging Service [MMS] or e-mail).

The study procedure started with a researcher installing the study equipment into the subjects' homes and teaching them to use each device. The subjects were instructed to measure their blood pressure twice a day, in the morning and in the evening, measure their weight every morning, and wear the pedometers every day, and enter the results in the WD. They were advised to make exercise entries after each exercise session, and enter self-assessments about their sleep duration, sleep quality, and stress into the WD. The subjects annotated each day as working, sick day, holiday, or rehabilitation. After having used the equipment at home for 1–2 weeks, the equipment was moved to a rehabilitation center where the subjects participated in an intervention for 1–2 weeks. After the intervention, the equipment was moved back to the subjects' homes, where the monitoring continued for another 2 months. At the end, the subjects filled in a usability questionnaire regarding all of the equipment, containing several questions about the WD. The study was ended with an individual feedback given to the subjects based on their measurements.

B. Results

The results will be presented for the whole group. The usage rate as a function of study weeks is presented in Fig. 3. Blood pressure is separated because the subjects were instructed to observe it more than once a day. The average usage time of the WD, in this group, was 10.7 weeks (SD 1.72, range = 5–13). Therefore, Fig. 3 is presented for the first 11 weeks of the study when most subjects were using the WD. The average daily number of entries in different categories is presented in Table VII. The number of entries made on weekdays and on free days (weekend, holiday, sick day, etc.) are presented in Table VIII. Health events variable is not presented separately due to the small number of entries.

TABLE VII
AVERAGE NUMBER OF DAILY ENTRIES AND THE TOTAL NUMBER OF ENTRIES, MEAN (SD, MIN–MAX)

	Number of entries
All entries / day	5.48 (2.60, 0–17)
Blood pressure	1.65 (0.758, 0–5)
Weight	0.923 (0.637, 0–4)
Steps	0.790 (0.456, 0–3)
Exercise	0.482 (0.764, 0–4)
Sleep	0.798 (0.434, 0–3)
Stress	0.746 (0.501, 0–4)
Total number of entries	414 (111, 101–525)

TABLE VIII
DAILY NUMBER OF ENTRIES ON WEEKDAYS AND ON FREE DAYS

Variable	Weekday entries mean (SD)	Free day entries mean (SD)
All entries / day	6.14 (1.97)	5.19 (2.80) **
Blood pressure	1.87 (0.521)	1.55 (0.829) **
Weight	1.12 (0.543)	0.813 (0.661) **
Steps	0.871 (0.381)	0.753 (0.477) **
Exercise	0.388 (0.663)	0.567 (0.833) **
Sleep	0.912 (0.331)	0.741 (0.469) **
Stress	0.840 (0.447)	0.703 (0.520) **

Significant differences between the day types are presented with asterisks (**: $p < 0.01$).

The subjects made significantly more entries on weekdays than on free days. More entries were made on free days than weekdays only in the exercise variable.

The usability questionnaire results are presented as the percentage of subjects agreeing or strongly agreeing to the statements presented in the questionnaire. Most subjects found it easy to learn to use the WD (76%) as well as making entries into it (88%). All subjects (100%) considered using the mobile phone for entering information as easy, and 71% of the subjects found it easy to send data from the application. The subject who did not own a mobile phone prior to the study used the WD with the help of her husband in the beginning. During the rehabilitation, she recorded her self-observations by using pen and paper. She learned to use the WD after the rehabilitation.

Feedback graphs were considered as useful by 76% of the subjects. Blood pressure, weight, and exercise were considered as the most important variables; blood pressure was important or very important for all subjects (100%), weight and exercise for 88% of the subjects. One subject described daily weight and blood pressure measurements as "a wake-up call." Based on the subjects' comments, improvements may be needed in the assessments of stress (stress, tiredness, irritation, and tension)—the subjects either did not understand what they were supposed to assess or the assessments were not personally relevant to them.

C. Discussion and Conclusion for Study II

The subjects in study II were predominantly female, older, and less technically skilled than the subjects in study I. However, the results in terms of usage and usability were surprisingly similar in these two studies. Study II subjects actually made more entries to the WD than study I subjects. Also, the usage rate was maintained at a high level throughout the study very similarly as in study I. With no previous experience in using S60 phones or phone calendars, the subjects found neither the phone nor the WD application difficult to use.

The fact that study II was a part of a larger study may have somewhat affected the subjects' behavior and increased their motivation. However, in the light of the positive responses to the usability questionnaire and the high and sustained usage of the WD, we may conclude that WD was well accepted by this subject group. Thus, the results indicate that the WD application is suitable for people of different ages and backgrounds, and not only the technically oriented young people.

V. DISCUSSION

The prevalence of various lifestyle-related health risks is on the rise. They contribute to the risk of several chronic diseases, which lead to incapacity, premature death, and high costs to society. The most straightforward way to decrease these costs is to prevent the diseases or delay their outbreak by improving the lifestyles of those at risk. However, the healthcare system is already struggling to cope with those already ill and does not have the resources to take the preventative action required to manage the risks. Therefore, individuals need to take more responsibility for their own health and wellness. The question is: how to motivate people to take care of themselves and how to help them in the task?

We developed the WD concept for personal and mobile wellness management, and implemented it on the S60 mobile phone platform. Two different implementations, WD for weight management and WD for general wellness management, were studied in two 3-month studies, study I and study II, respectively. The subject groups in the studies were rather different. Subjects in study I were relatively young, mostly male subjects, who worked in a technology company and were already experienced S60 mobile phone and calendar users. Study II subjects were older, mostly female, and not very accustomed to using modern technology, especially "smart" phones. Despite the differences between the groups, the results were very similar in terms of usage rates and usability responses. Both the groups used the WD actively and sustained high usage throughout the study. In study I, also weight management results were studied. Typically, the amount of weight loss is 8%–10% during 4–6 months of weekly group therapy (including 16–24 sessions) [38]. In this study, about half of the subjects lost, on average, 3.2% of their weight during 3 months after only one lecture combined with the use of the WD. This is a reasonably good result taken into account that this study was done over the Christmas holidays, which often result in an increase in weight. It must also be noted that most subjects in study I were only overweight and not obese (average BMI 28.8 kg/m^2), and therefore, very large weight losses could not be expected. Both the groups gave positive feedback on the usability of the WD; they regarded the WD as an easy-to-use and useful application.

The ICT has been widely applied in various health-related interventions. The Internet has been the most popular medium for eHealth applications. Although there is still a limited number of randomized controlled trials in the field, there is some evidence that computerization and computer-tailoring may improve the effects of health interventions and education as compared to the conventional approach [39], [40]. Kirsch and Lewis [39] reviewed nine studies concerning Internet-based health interventions targeting, for example, weight management, recurrent headaches, asthma, panic disorder, and back pain. The interventions consisted of some of the following components: educational material (e.g., videos and guides), bulletin boards, electronic encyclopedias, contact to professional via e-mail or telephone, weekly behavioral diaries, and feedback (via e-mail or telephone). Most of the studies reported significant improvements in knowledge, self-efficacy, and self-care management. However, little evidence of behavior change has been found.

Tate *et al.* [26] found that the intervention group that filled in behavioral diaries about their weight, calorie, and fat intake, and exercise and received emailed behavioral lessons and feedback, lost significantly more weight than those who only had access to a Web site with links to weight loss resources. Web site login frequency correlated significantly with weight loss in both the groups. Similar result was obtained in our study I where the LOSERS group made more entries to the WD than the OTHERS group.

Key elements in many ICT-based wellness programs are recording of self-observations and getting feedback based on them. Often, it is the act of making self-observations that is the key to learning about one's behavior and changing it [41], [42]. This was also found in study I, where monitoring their food and drinks intake made the subjects more aware of their eating than the feedback they were given. Some subjects commented that they actually left out some of their evening snacks because they did not want to report them to the WD. The role of feedback is to help maintain the motivation by showing the long-term progress in the observed variables.

Another related question that often arises is that of automated data entry. Since the technology is already available, why should we not record measurement results automatically? As mentioned earlier, self-observation is paramount in inducing learning and behavioral change. Automatic data entry may decrease the user's situation awareness and the usefulness of the information [41]. When entering data manually, the individual needs to remember the measurement result or the assessment until the entry is made. In study I, there was semiautomatic data transfer from the pedometer to the mobile phone via an infrared link. Other variables were entered manually. The subjects were asked whether they would have preferred automatic transfer of their daily weight measurements from their personal scales to the WD, but they rejected this idea. Even if automated transfer would not require anything from the user and even if the price of such scales would be low, manual input was still the preferred choice. However, automating the entry of some variables may considerably facilitate the use of a wellness tool. When to automate data entry and when to stick to manual entry is a question yet to be answered.

It has been established that self-observation, and especially, continuous self-observation is a key element in successful weight-loss program [43], [44]. But, what is the required detail level? We are often tempted to measure everything just because we can. This is often a very laborious approach for the user, and may, in fact, decrease compliance, as has been found in the case of traditional pen and paper nutrition diaries [34]. We argue that it is more important to make self-monitoring as easy as possible, while still maintaining the user's situation awareness. This approach promotes long-term usage, which supports better learning to recognize the behaviors that maintain the health problems.

The Internet may be used for delivering advanced wellness management programs, rich in content and functions. However, the weaknesses of Internet-based tools are often poor accessibility and the lack of assimilation into the user's daily life. The need to have a computer and Internet connection to access the wellness Web sites makes wellness management a separate task, which needs to be allocated a time slot rather than an integral part of life. And certainly, continuous "on-the-spot" self-monitoring and momentary usage are not optimally supported by Internet-based applications. Since the emergence and development of personal mobile terminals, the interest toward providing health management applications for the nomadic user has increased. Especially personal digital assistants (PDA) and "smart" mobile phones offer exciting possibilities for providing wellness management tools, which can be used independent of time and location. In the recent years, numerous health and wellness applications utilizing mobile technologies have emerged. In their review of mobile eHealth interventions for obesity, Tufano and Karras [28] concluded that the future platform for self-monitoring is a Web-enabled "smart" mobile phone or a wireless PDA. Mobile terminals have become an important part of our everyday lives, and they are already providing us several services, for example, phone calls, text and multimedia messages, cameras, music, calendar, the Internet, and even measurement sensors. Therefore, extending life management further and adding also wellness management into the picture seem like a natural next step.

Many of the new wellness concepts and applications concentrate on nutrition and exercise monitoring [45]–[50]. In a recent study by Consolvo *et al.* [45], a mobile application for encouraging physical activity was developed. The application consisted of a commercial pedometer and a mobile phone fitness diary for recording the step counts from the pedometer. The application enabled both personal and private use as well as sharing step count information with a group of friends. In a 3-week study, the subjects who shared their results and received social support were more likely to meet their step goals than those who used the application in the personal mode. Social support was found to be the most important motivator also in a study by Toscos *et al*. [46] who developed a mobile tool for motivating teenage girls to exercise. Some of study I subjects would have liked to use the WD in a group or have an expert comment on the results. However, no one solution is perfect for all people. In our study I, there were also many subjects who appreciated the private and personal approach. Therefore, it is clearly beneficial to offer the users different usage possibilities, both private and shared, as was done by Consolvo *et al*.

Lee *et al*. [47] developed a mobile application for monitoring energy balance, PmEB. The application enables entering nutrition intake and expenditure with the help of a detailed nutrition and exercise database stored in the mobile phone. In a small, 1-week user study with six users, the users were given a mobile phone with the PmEB application and a pedometer. They were instructed to incorporate the application into their daily lives and to use it whenever appropriate. The average usage rate of the application during the 1-week study was two–four times a day. The subjects also commented that the PmEB application helped them to change their nutrition and physical activity habits. In both of our studies, the subjects interacted with the WD, on average, more than five times a day for 3 months. In study I, most subjects felt that the WD helped them to observe their eating and be physically more active.

One of the challenges in developing ICT-assisted wellness tools is to make them acceptable to very different user groups and to provide a feel of a personal tool. This may be done by targeting the application to a certain user group as was done by Toscos *et al*. and Brown *et al*. [46], [48]. Also, the provision of different usage modes helps, as in the application by Consolvo *et al*. [45]. Simplicity and ease of use are always important. The results of our two studies imply that the WD, as a concept, is adaptable for different purposes and different user groups. The WD was easily adopted by both study I and study II subjects, who were of rather different ages and backgrounds. This indicates that the WD is not only suitable for technically skilled young people, but also for older people with less technical knowledge.

VI. Conclusion

The WD is a concept for personal and mobile wellness management. The WD offers its user a self-monitoring tool, which is embedded in an already familiar life and time management application, the calendar. The WD enables entering wellness-related self-assessments and measurement results. It automatically generates objective graphical feedback based on the measurements and does not give instructions, thus supporting the user's own responsibility in making wellness management decisions. Thanks to its stand-alone, local implementation in the mobile phone, the WD can be used anywhere and anytime, and it especially supports momentary use during the idle moments of life.

In the two studies presented in this paper, the WD was well accepted and actively used by two rather different user groups. The results indicate that the WD is well suited for supporting CBT-based wellness management. In the future versions of the WD, we target to improve the user interface, feedback, and personalization possibilities of the application.

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PUBLICATION II

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Use of a mobile phone diary for observing weight management and related behaviours

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Summary

We studied self-observations related to weight management recorded with a Wellness Diary application on a mobile phone. The data were recorded by 27 participants in a 12-week study, which included a short weight management lecture followed by independent usage of the Wellness Diary. We studied the validity of self-observed weight, and behavioural changes and weight patterns related to weight management success. Self-observed weight data tended to underestimate pre- and poststudy measurements, but there were high correlations between the measures ($r \geq 0.80$). The amount of physical activity correlated significantly with weight loss ($r = 0.44$) as did different measures representing healthy changes in dietary behaviours ($r \geq 0.45$). Weight changes and the weekly rhythms of weight indicated a strong tendency to compensate for high-risk periods among successful weight-losers compared to unsuccessful ones. These preliminary results suggest that the mobile phone diary is a valid tool for observing weight management and related behaviours.

Introduction

Obesity is a serious and rapidly spreading health risk. In the countries of the WHO European Region, 26–68% of adults are overweight (body mass index; BMI ≥ 25 kg/m^2) and 6–27% of them are obese (BMI ≥ 30 kg/m^2).[1] Obesity is a significant risk factor for many diseases, including type II diabetes, cardiovascular diseases, and certain types of cancer.[2]

Weight loss requires permanent changes in lifestyles, especially eating and exercise. This is difficult for most people and only about 20% of those who lose weight succeed in long-term weight loss maintenance.[3] Regaining weight is common, and many people return to their pretreatment weight during follow-up.[4] The inability to comply with diet and exercise recommendations seems to be the main cause for regaining the weight.

Behaviour is affected by a complex set of factors, many of which are psychological. Thus, psychological approaches such as cognitive-behaviour therapy (CBT) have been applied in weight management treatments. A central element in these treatments is self-monitoring, i.e. participants observe and record their own behaviour, identify the factors that affect their behaviours or maintain the problems, make changes in their daily habits and monitor the effects of the changes.[5] Regular self-monitoring has many advantages, such as increasing self-knowledge and providing valuable information on the effects of interventions. Self-monitoring may also have an impact on the efficacy of treatments, for example, daily self-weighing has been associated with a decreased risk of regaining weight.[6] In the long term, self-monitoring of weight may also delay weight regain and promote weight management during the holiday season when the risk of weight gain is high.[7–9]

Self-monitoring data may also reveal individual physiological and behavioural factors explaining weight changes, and thus provide more precise tools for solving weight problems. In a case study by Lappalainen *et al.*[7] a female participant recorded her weight regularly for ten years. The weight data indicated that she mainly gained weight during August, September and late December. In addition, a weekly rhythm was identified in which the subject's weight increased during the weekends and decreased during weekdays. In another study, 14 healthy, middle-aged men recorded self-observations for periods of 50–79 days.[10] Their body weight showed a clear weekly rhythm with the lowest weight on Thursdays and Fridays; weight then rose over the weekend and peaked on Mondays. Accordingly, people have been reported to have a weekly rhythm in nutrition involving greater energy intake and larger meals during weekends.[11] However, little is known about the way in which these rhythms relate to success in weight management.

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Detecting these patterns requires regular and reliable self-monitoring over the long term. However, such data are seldom available, since long-term recording is laborious and compliance is often low. The reliability of self-reports has also been questioned, since people tend to underestimate their weight and energy intake, and overestimate their physical activity.[12–14]

ICT (Information and Communication Technology) applications have the potential to facilitate and motivate daily long-term self-observations, and may thus improve compliance with the self-observation regimen. Mobile applications seem especially promising because they are already available to most people; they can be seamlessly integrated into people's everyday lives; and they can provide timely persuasion, personalized to the users' preferences and even context. The computing power of current mobile phones allows for data processing and for the generation of automatic feedback and interpretation. Electronic data format enables real-time in-depth feedback, illustrating changes, patterns and interconnections among health variables. Wireless connectivity facilitates data sharing with professionals and peers, enabling consultation and support features, even over long distances.[15]

In the present study, we used data from an earlier study,[16] and examined the validity of self-observed weight measures as well as behavioural patterns in those successful and unsuccessful in weight loss.

Methods

The Wellness Diary (WD) is a tool for recording simple self-observations and viewing graphical feedback on a mobile phone screen (Figure 1). It was designed to support CBT and other counselling. It has been described in detail elsewhere.[16] Self-observations are entered manually on forms resembling standard Symbian Series 60 calendar forms (Figure 1a). The WD also provides an option to collect step count data wirelessly from an infrared-enabled pedometer. The self-observations can be visualized as line or bar graphs (Figure 1b). The WD also enables data transfer via email and multimedia message to other people such as weight management experts, doctors and peers. To maintain user control and data security, data transfer must be initiated by the user.

We have studied four variables related to weight management: weight, steps, exercise, and food and drinks. The input forms of these entries included only a few obligatory variables. The weight and steps entries each contained one obligatory variable, the weight measurement result and the pedometer step count. The exercise entry included the duration of exercise and title of sport (selected from a list) as obligatory variables, and distance, intensity and average heart rate as optional variables. The food and drinks entry contained the meal type (selected from a list: light snack, heavy snack, light meal, heavy meal) as the obligatory variable and the number of drinks and energy in kilocalories as optional variables.

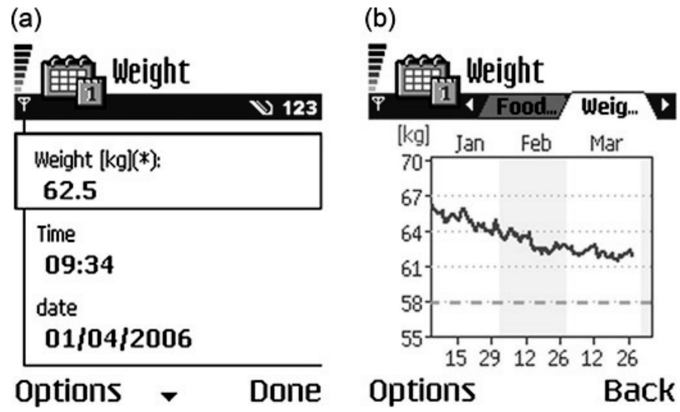

Figure 1 User interface of the Wellness Diary: (a) weight input form, (b) weight feedback graph

Participants and study procedures

Thirty volunteers enrolled in the study,[16] but one male subject dropped out for unknown reasons before the study began. Twenty males and nine females (age 29 years, range: 25–54; BMI 28.8 kg/m^2, range: 24.7–32.1) participated in a 12-week study investigating the usage, usability and acceptance of WD. One male and one female subject dropped out during the study for reasons not related to WD,[16] leaving a total of 27 participants who completed the study.

We used the same *post hoc* division as in a previous study to examine the differences between those who were successful and unsuccessful in weight loss. The division was made based on weight entries recorded in the WD. The 12 (8 male) subjects who lost more than 1% of their body weight are referred to as 'Weight-losers', and those 13 (9 male) who lost less are referred to as 'Non-losers'. There were no significant differences in the initial BMI of the groups. The average BMI of the Weight-losers was 28.7 kg/m^2 (SD 2.8) vs. the Non-losers whose average was 28.4 kg/m^2 (SD 2.2).

The study began with a start-up session, which was held in groups of about ten subjects, and included a prestudy measurement of weight and waist circumference and a background questionnaire; a 1.5-hour lecture on CBT-based weight management with written material (mini-intervention[17]); and the installation of the WD on the subjects' mobile phones with a short user tutorial. Usability interviews were conducted twice, one week after the start-up session and at the end of the study. A closing session was organized after the study, including a summary of the results of the study and poststudy weight and waist circumference measurements. The participants not present were invited to visit the occupational health nurse later for the measurements.

The participants were encouraged to record daily self-observations with WD, in as many categories as they considered feasible. For example, they were recommended to weigh themselves every morning; wear the pedometer daily and transfer the data to WD regularly; record their exercises; and make food and drinks entries after every meal. They were also asked to send their data to the researchers once a week by email or multimedia message. If participants failed to send in their data, they were reminded by a researcher, but no comments related to the quantity or content of the data were made.

Ethics committee approval for the study was not required. The participants provided informed consent and the data were handled confidentially.

Statistics

The study data were analyzed using Matlab version R2006b (Mathworks, Inc., Natick, MA, USA) and the Statistical Package for Social Sciences (SPSS version 14.0, SPSS Inc., Chicago, IL, USA). The Mann-Whitney U test, Wilcoxon signed ranks test and two-way analysis of variance were used for statistical testing.

Results

Validity of self-observed weight

Pre- and poststudy weights measured by the occupational health nurse were compared with self-reported weights entered in the WD. Twenty-two participants participated in both measurements and all of them had enough WD entries to determine pre- and poststudy weights. The average weight of the first WD usage week was used as the WD prestudy weight and the average of the last usage week as the WD poststudy weight, provided that there were at least two valid weight entries during both weeks. The measured weights as well as the WD self-observed pre- and poststudy weights and weight changes are shown in Table 1. Self-observed weights tended to underestimate pre- and poststudy weights, but the measurements were strongly correlated.

Patterns and rhythms in weight and behaviour

Behaviours related to weight management and periodical patterns in weight were studied based on self-observation data. First, weight changes in the Weight-losers and Non-losers were studied over the entire study period. Second, self-observations related to physical activity and eating behaviour were studied. Finally, a weekly rhythm of weight was analysed.

The average normalized weights for both Weight-losers and Non-losers over the study period are shown in Figure 2. The groups behaved relatively similarly until Christmas. Both groups gained weight during Christmas, but Weight-losers continued losing weight while Non-losers approximately maintained their Christmas time weight. Many participants had another holiday period at the end of February (coinciding with winter holidays at schools), which resulted in a small weight increase in both groups.

Physical activity and eating behaviours and their changes over the study period were studied by analysing the contents of steps, exercise, and food and drinks entries. Change measures were determined by comparing self-observations recorded in December (6–31 December) to those recorded in February (1–27 February). There was a significant correlation between weight change and the weekly duration of exercise ($r = -0.44$, $P < 0.05$) as well as the amount of exercise in December ($r = -0.57$, $P < 0.05$). The weekly exercise duration in December differed between the groups ($P < 0.05$); the median duration of exercise was 132 min (range: 16–365 min) vs. 65 min (range: 0–205 min) per week for Weight-losers and Non-losers (respectively). No other significant differences or correlations were observed in physical activity.

Decreases in the proportions of heavy meals, heavy foods and meals correlated positively with weight loss, as did increases in light snacks (Table 2). In this regard, there were no significant differences between Weight-losers and Non-losers, but Weight-losers tended to decrease their proportion of heavy meals ($P = 0.059$) and heavy foods ($P = 0.091$) more (Table 2).

The weekly rhythm of weight presents daily deviations from the weekly average and was calculated by synchronized averaging as follows. The weight data of each participant were organized into weeks from Tuesday to

Table 1 Pre- and poststudy weights and weight changes. Mean values (SD) are shown for the 22 participants for whom all the weight measures could be determined

	Measured	Wellness Diary	Correlation
Prestudy weight (kg)	87.0 (13)	84.5 (13.5)*	0.99*
Poststudy weight (kg)	84.3 (12)	83.1 (13.1)*	0.99*
Weight change (kg)	−2.6 (3.0)	−1.4 (2.6)*	0.80*

*$P < 0.05$

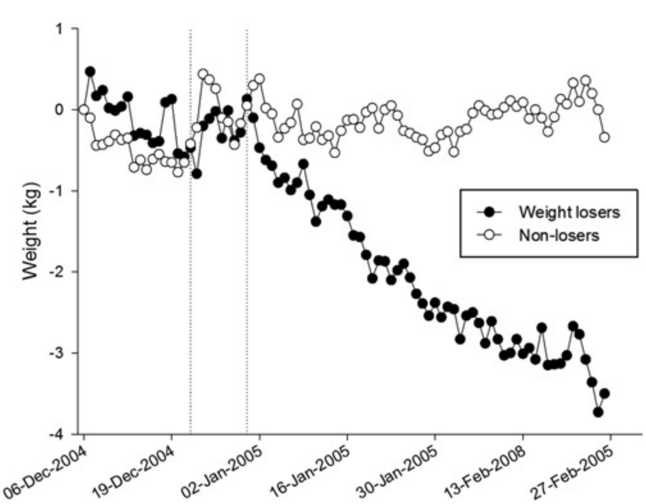

Figure 2 Average normalized weight for Weight-losers (closed symbols) and Non-losers (open symbols). The Christmas and New Year period is indicated with vertical broken lines

Table 2 Changes in eating habits and their correlation to weight change. Values shown are percentage changes (SD) in food and drink entries for Weight-losers and Non-losers from December to February

	Weight-losers (n = 12)	Non-losers (n = 13)	Correlation with weight change
% heavy meals	−12.0 (10.0)	−4.0 (8.0)	0.75*
% light meals	14.0 (10.0)	7.9 (10.0)	ns
% heavy snacks	−10.0 (15.0)	−2.0 (9.4)	ns
% light snacks	7.8 (16.0)	−1.9 (9.2)	−0.64*
% heavy foods	−21.0 (22.0)	−5.9 (15.0)	0.61*
% meals	2.0 (11.0)	3.9 (7.8)	0.45*

*$P < 0.05$
ns, $P \geq 0.05$

Monday, and each week's data were normalized by subtracting the average of that week from the values. The weekday values were then averaged to obtain a single value for each day of the week, thus creating the weekly weight rhythm of a participant. A female participant (Non-loser) was excluded from the analysis due to an insufficient number of weight entries. Christmas time (from 24 December to 2 January) was removed in order to study the normal weekly rhythm. Weeks with less than four entries were also excluded. Group rhythms (Figure 3) were calculated by averaging individual weekly rhythms within the groups, and two-way analysis of variance was performed to study the effects of group and weekday on the weight rhythm. The effect of interaction between group and weekday ($F = 2.9$, $P < 0.05$) was significant, indicating a difference in the weekly rhythms of the groups.

Discussion

Self-observation data recorded with the WD mobile application were studied using data gathered by 27 participants over a 12-week period. The objective was to study the validity of self-observed weight data, and changes in behaviour and weight among those successful and unsuccessful in weight loss.

The correlations between pre- and poststudy weights measured by the nurse and determined from WD self-observations were high ($r \geq 0.80$), providing some evidence of the validity of self-observed weight. There was also reasonable agreement between the measured and self-determined values at the end of the study (see Figure 4).[18] However, the self-observed weights and the weight changes were generally lower than the measured ones. The differences were probably due to the different scales used; the timing difference between the methods (WD-based measures were based on self-observations entered during the study, whereas pre- and poststudy weights were measured before and after the study); the fact that pre- and poststudy measurements were done only once; and the time of day of the measurements (WD weights were mostly measured at home in the morning, whereas the pre- and poststudy weights were measured in the daytime with full clothing). However, the differences between the methods were consistent, indicating that self-observations made with the WD were a reliable, yet slightly conservative method for determining weight change.

We were able to detect behavioural factors consistent with weight loss results. We found that a higher amount of self-reported weekly exercise, decreases in heavy meals, heavy foods and meals, and increases in light snacks correlated positively with weight loss. This indicates that WD self-observations were accurate enough to be used, for example, for creating more informative and personally meaningful feedback to illustrate the cause-and-effect relationship between behaviour and weight.

The weekly rhythm of weight, with weight increasing during weekends and decreasing during weekdays, has been previously reported. We found that Weight-losers had a

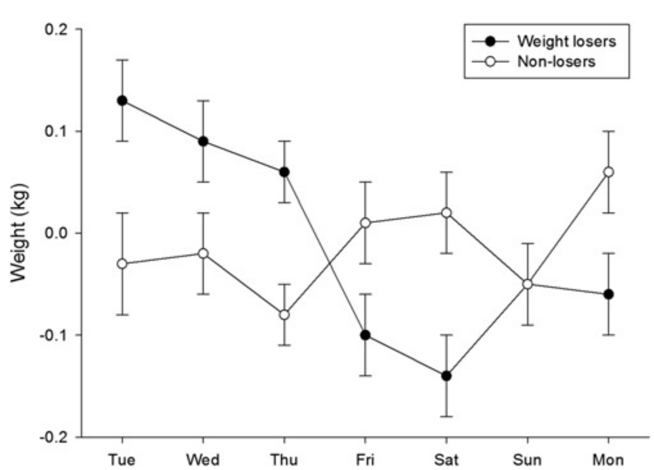

Figure 3 Weekly rhythm of weight: average (line) and standard error of mean (vertical bars) for Weight-losers and Non-losers

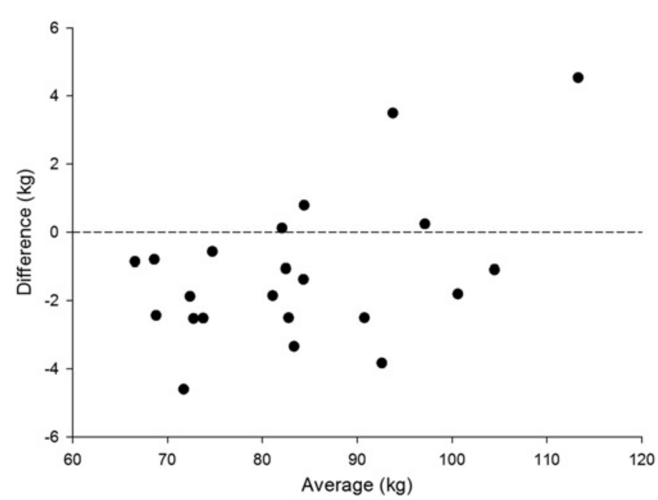

Figure 4 Comparison of poststudy weight values and those self-reported. The abscissa shows the average of the two values, and the ordinate shows the difference between the two values[18]

strong weekly rhythm of weight, closely resembling the rhythms in earlier studies, while Non-losers lacked such a clear rhythm. This suggests that successful weight management may be associated with weekly weight rhythms. Thus, a strong control mechanism to restore weight balance after certain risk periods, such as weekends or holidays, may be important for successful weight management. The comparison between the weight changes of Weight-losers and Non-losers, especially over Christmas, supports this hypothesis. Hence, it seems that successful weight management may not be characterized by the lack of weight gain periods and variability, but rather by the person's ability to compensate for the periods of excess caloric intake during daily life. These findings are in accordance with observations made by Jordan *et al.*[19] who found that successful weight maintainers restricted their calorie intake for a couple of days after eating large amounts of food. They also planned their food intake beforehand, saving calories for holidays and other pleasant events.

The present study had some limitations. Most important, it was based on a non-controlled, short-term study, primarily designed to research the usage patterns and usability of the WD on a small sample of participants. The participants were motivated and relatively well-educated volunteers. Thus, the data may be biased in comparison with more general weight management groups and longer follow-up, and the observations on behavioural patterns should be considered as preliminary. Although the results are consistent with some earlier observations as discussed above, their validation calls for larger and longer studies designed specifically to study their existence and correlation to success in weight management.

Our findings emphasize the importance of regular long-term self-monitoring in weight management. Mobile devices and applications have been suggested to facilitate self-monitoring and their validity has been discussed.[20,21] In the present study, the self-observations recorded with the WD were found to be valid, and capable of revealing changes in behaviour and weight. If weekly weight rhythms and immediate regulatory behaviours are critical for weight maintenance, continuous self-monitoring of weight or of other behaviours associated with weight is required in order to detect changes in a timely manner. There are data indicating that weighing oneself daily is associated with a reduced risk of regaining weight, and delayed weight regain.[6–9] In many weight management programmes, participants are recommended to weigh themselves only once a week but these findings suggest that more frequent monitoring may be beneficial.

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PUBLICATION III

Nuadu Concept for Personal Management of Lifestyle Related Health Risks

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Nuadu Concept for Personal Management of Lifestyle Related Health Risks

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***Abstract*—Majority of the health risks and diseases in the modern world are related to lifestyles, e.g., overweight, unhealthy diet, physical inactivity, sleep deprivation, and stress. Behavioral change towards healthy lifestyles is the key to the prevention and management of these risks, but early and efficient interventions are scarcely available. We present the Nuadu Concept, an ICT (Information and Communication Technologies) assisted wellness toolbox for the management of multiple, behavior-originated health risks. The concept is based on psychological models, which provide methods and motivation for behavior change. The individual is considered as the best expert of his/her own wellness. Thus, the Nuadu Concept provides a variety of personal wellness technologies and services, among which the user may freely choose the best tools for him/herself. We believe this approach has the potential to provide efficient, acceptable, available, and affordable wellness management support for a significant number of people.**

I. Introduction

LIFESTYLE related health risks, such as overweight, unhealthy diet, physical inactivity, stress, and sleep problems are prevalent in most modern societies. They result in deteriorated quality of life, diseases, lost productivity and absenteeism from work, and early retirements. Health risks also tend to cluster, i.e., having one increases the risk of others [1]. One could prevent most cases of chronic diseases, such as strokes, cardiovascular diseases and type II diabetes, and add years and quality to one's life by healthy lifestyles [2], [3]. However, changing lifestyles and especially maintaining the changes is challenging, e.g., only about 20% of people succeed in long-term weight loss maintenance [4].

The healthcare system does not have sufficient resources for primary prevention of illnesses and early lifestyle interventions, which leaves the citizens responsible for their own health and wellness until a disease is diagnosed. And ultimately, it is always the individual him/herself who makes the final decisions on his/her health and lifestyles. It is important to empower citizens and reinforce their self-efficacy, because people with high self-efficacy are more likely to succeed in health management [5]. Also *long-term* support for behavior change is needed, because new behaviors require persistent practice to become permanent.

Traditional health promotion interventions typically focus on a single health risk factor, such as overweight or smoking. They may be performed as individual consultations or in small groups lead by healthcare professionals. Intervention programs tend to be short-term and not provide support for change maintenance, which usually leads to compromised long-term results [6]. They have also been criticized for not reaching those who would need them the most; it is often the "worried well" who are the most eager to participate [7].

Modern psychological theories provide knowledge which could be used when solving problems associated with lifestyle changes. The Transtheoretical Model (TTM) [8] describes the process of behavior change as six stages: *pre-contemplation, contemplation, preparation, action, maintenance, and termination*. In each stage, there are different approaches to optimally facilitate advancing to the next stage [9]. The cognitive-behavioral methods such as the Cognitive-Behavior Therapy (CBT) [10] provide several tools that could support behavioral changes. In CBT, the individual identifies the factors that cause or maintain problematic lifestyles, and makes small changes to them. Self-observations of health related behaviors and feedback based on these observations are important tools in CBT. The beauty of these theories is their applicability to most behavior-originated health risks. Recently, new CBT based approaches have been presented. Interventions, such as the Acceptance and Commitment Therapy (ACT) [11], assist in planning lifestyle changes and boost motivation. One of the key concepts of ACT is the value analysis, in which the individual determines what constitutes "good life" for him/her and what actions promote it. This turns the focus from negative to positive, i.e., to striving towards better life instead of trying to avoid diseases looming far in the future.

Modern Information and Communication Technologies (ICT) are frequently suggested for supporting personal wellness management. Most people in the western world have access to PCs and the Internet, and own a mobile phone. Thus, ICT based solutions can be provided to a large number of citizens at an affordable cost by using these generic platforms. ICT also provides a possibility for continuous long-term support in a personalized manner. PCs and mobile phones are usually considered as personal and

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trusted devices, which may lower the threshold of using ICT based services, e.g., compared to face-to-face interventions requiring physical presence. ICT has already been utilized in wellness management, and the results are promising. For example, some computerized CBT methods have proven to be as effective as therapist-lead treatments in treating mild depression and anxiety [12].

In [13], we presented the Nuadu Concept for health promotion in the occupational healthcare context. In this paper, we provide a deeper discussion of the concept and present its actual implementation.

II. NUADU CONCEPT

A. Concept Design

The goal of the Nuadu Concept is to forgo the short-term, single-risk-factor interventions and one-size-fits-all thinking. Since health risks tend to cluster, they should also be managed together, in synchrony. Long-term support is required because behavior changes are slow and relapses are more the rule than the exception. Hence, we developed an ICT toolbox for managing multiple lifestyle related factors: weight, physical activity, nutrition, stress, sleep, smoking, and alcohol consumption. The concept is primarily designed for personal and independent use by the individual, who is endorsed as the best expert and only authorized decision-maker of his/her wellness. Thus, the user is free to choose the behaviors to change and tools to use.

The design is based on the application of psychological theories and intervention strategies for behavioral change management, namely TTM, ACT, and CBT. The concept was designed to support different stages of change; provide different levels of self-observation and feedback tools from simple to detailed; and enable long-term use that fits into the users' everyday lives. Flexibility for needs changing over time was also considered as important.

We chose to utilize a set of personal wellness technologies: web services, mobile applications, and measurement devices. Web services are suitable for long sessions and detailed analysis, but are not always available conveniently and for free. Mobile terminals are usually carried along, making mobile applications suitable for daily use in situations where lifestyle choices are made. This also supports fast momentary usage during the idle moments of life. Mobile applications are optimal for short sessions of only a few minutes, but have to be fairly simple to enable efficient use. Measurement devices provide detailed and objective information on the health and behavior of an individual and support self-observations in the daily life. The integration of these tools is called the Nuadu Concept.

Integration can be implemented on several levels, i.e., from just gathering technologies together to integrating services and data seamlessly with a common look and feel. Very light integration is fast to perform but the result may look like a collection of technologies without a common goal. Seamless integration, on the other hand, looks like one service to the user, but also requires a lot of work, prohibiting fast inclusion of new technologies and services, and complicating maintenance and updates. This is the case especially when different technology providers are in charge of developing different tools in the concept. We chose an integration that promotes easy usage of all services and technologies and ties them together conceptually, but is simple enough to enable integration and maintenance of different technologies with a moderate amount of work.

B. Nuadu Concept Implementation

Fig. 1 presents the implementation of the Nuadu Concept and its three main components: services and technologies for personal use by individual users (Nuadu Toolbox); services for health professionals (Nuadu Pro); and a common data repository (Common Server).

Nuadu Toolbox consists of a web based Nuadu Portal with integrated wellness services; a mobile phone with wellness applications; and measurement devices. Nuadu Portal is a framework for integration of different wellness services, which run independently on their own servers. For them, it provides a layer of basic services and content, e.g., service orchestration; user account management and single sign-on; user's guides for all technologies; health related information; and means for contacting a health professional. The integrated services are: Wellness Diary Connected (Nokia, Helsinki, Finland), Hyperfit and Nutritioncode (Tuulia International, Helsinki, Finland). *Wellness Diary Connected (WDC)* is a diary for CBT based self-observations on wellness related parameters, such as weight, physical activity, sleep, and stress. The observations are simple and fast to enter, with only few obligatory parameters to fill in. Automatic graphical feedback is generated based on the entries. *Hyperfit* [14] is a detailed food and exercise diary, mainly intended for managing weight and nutrition. Foodstuffs and daily physical activities are entered to the service, which generates elaborate feedback on the nutritional content of the diet and energy balance. Hyperfit also contains questionnaires related to nutrition and physical activity, which may help the user to detect problematic behaviors. A light version of Hyperfit, for access on a mobile phone browser, is also available. *Nutritioncode* [15] is a service for analyzing the nutritional content of groceries. The cashier at a grocery store automatically transfers the grocery information to the Nutritioncode web service by reading a bar code on the user's reward card. The contents of foods are analyzed on the server and detailed feedback is created. The service is available in Finland in a chain of grocery stores.

The mobile applications in Nuadu Toolbox are: Wellness Diary (Nokia, Helsinki, Finland), Mobile Coach (Firstbeat Technologies, Jyväskylä, Finland), selfRelax (Relaxline, Mantes La Jolie, France), and MotionLogger (VTT, Tampere, Finland). *Wellness Diary (WD)* is a mobile version of WDC implemented on Symbian Series 60 mobile phone

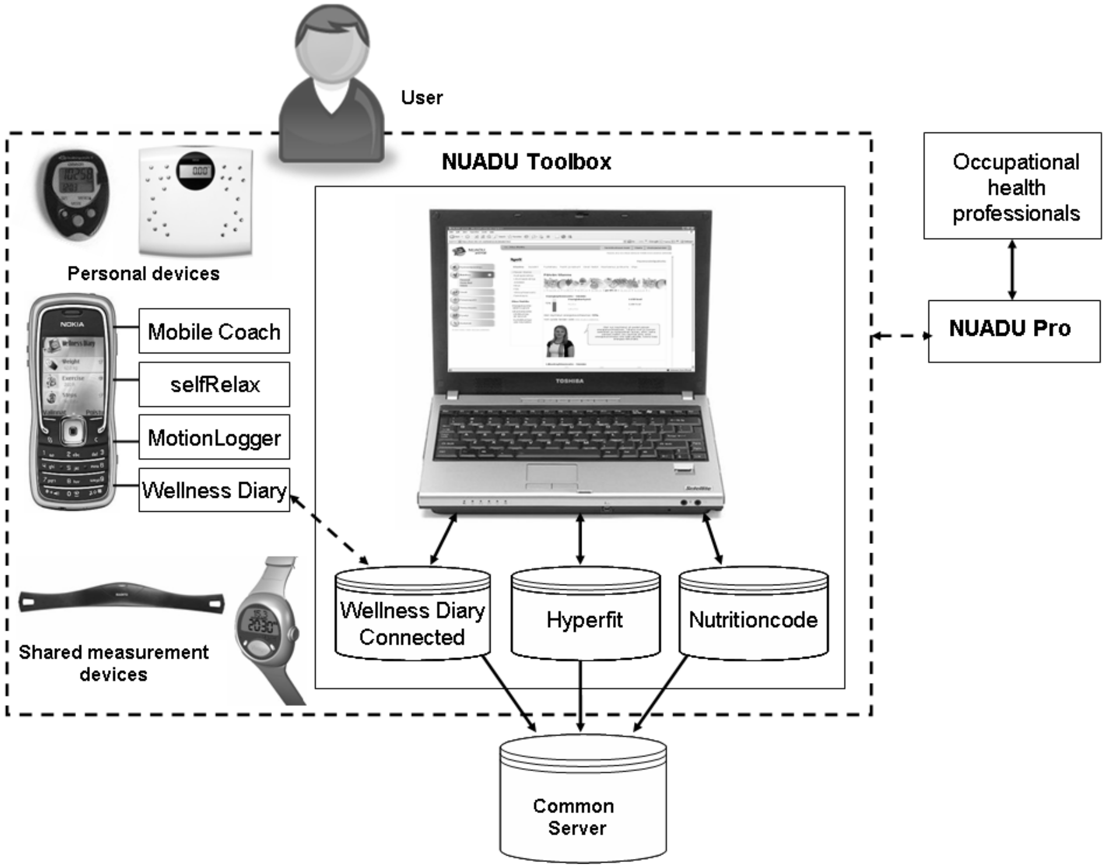

Fig. 1 Nuadu Concept

platform [16], [17]. WD is a stand-alone application, functioning locally in the mobile phone. It contains the same features as WDC and, in addition, enables synchronization of self-observations between WD and WDC via mobile data connection. WD is intended for frequent, even daily self-observations and feedback. *Mobile Coach* [18] is a personal fitness coach implemented on the J2ME mobile Java platform. It automatically generates a training program based on the user's personal information and goals. The user inputs his/her performed exercises to the application by entering the duration of exercise and one of the following: self-assessed intensity, distance, average heart rate, or training effect obtained from a heart rate monitor. The application analyzes the effectiveness of the exercise and updates the program accordingly. Since training information may be entered in different ways, the application does not require heart rate measurement during exercise, hence supporting flexible use as a part of daily life. *selfRelax* [19] is a mobile relaxation assistant based on personalized relaxation programs. The user chooses the purpose and duration of relaxation, and may set also other personal preferences, such as position, background sounds, and relaxation techniques. The personalized program can then be listened to from the mobile phone. selfRelax is implemented on the J2ME mobile Java platform. *MotionLogger* is an application for tracking the movements of the mobile phone, and thus indirectly its user's, using a built-in accelerometer. The application was developed for Nokia 5500 Sport mobile phone and implemented on Symbian Series 60 platform. The application and its data are intended strictly for research purposes and there is no feedback for the user. However, the user may control the application, i.e., stop or restart logging.

The measurement devices in the Nuadu Concept are divided into two categories: personal and shared sensors. Personal sensors include a weight scale and a pedometer, whose purpose is to support daily self-observations on weight and physical activity, correspondingly. The data from these devices can be manually input to WD, WDC or Hyperfit. Shared sensors include a heart rate belt (Memory Belt; Suunto, Vantaa, Finland) and a wrist actigraph (IST Vivago Personal Wellness Manager, PWM; IST International Security Technology, Helsinki, Finland). The heart rate belt is used for measuring heart rate variability, which is analyzed using the *Firstbeat Pro* software [20] for identifying periods of physical exercise, stress, and recovery during daily life. *IST Vivago PWM* and *Vivago Pro* analysis software are used for monitoring daily activities, especially the duration and quality of sleep [21], [22]. Shared sensors can be borrowed from a health professional, used for an agreed period of time, e.g., a week, and then returned. The professional downloads the data, analyses them, creates feedback reports, and posts them to the user's Nuadu Portal. These periodical reports provide the user with objective baseline or follow-up data related to his/her wellness, e.g., stress and recovery, and the quality and quantity of sleep and physical activity. This information helps the user to plan behavioral changes to improve these factors and to follow-up the effects of the changes.

Nuadu Pro was designed to enable professional involvement in wellness management. It may be used by, e.g., a nurse or a personal trainer. Nuadu Pro consists of shared sensor analysis software and a web service for managing users and exchanging messages, feedback reports and other material with the users.

Common Server [23] acts as the data repository and integrating element for all data in Nuadu Portal. The data from the portal and integrated wellness services' servers are transferred to Common Server. The data are stored according to Nuadu ontologies, which describe the terminology and relationships in the personal health domain. Common Server includes privacy control, which allows the information to be safely shared for research purposes.

C. Usage Scenarios

Examples of using the Nuadu Toolbox for different health problems are presented by the following two scenarios.

Anna's goal is to lose weight. First, she wants a clear view on the causes of her weight problem, so she starts using Hyperfit in Nuadu Portal. She fills in food and physical activity questionnaires and then decides to keep a detailed food and exercise diary. After two weeks, she has lost some weight and stops using Hyperfit because she feels that she now knows how to balance her nutrition and physical activity – and anyway, she can always go back. She decides to continue by monitoring her weight regularly with WD in order to prevent weight regain. She also wants to improve her physical fitness and starts using Mobile Coach, which generates a training plan for her.

Peter has felt a lot of stress lately and has not slept well. He borrows a heart rate belt and IST Vivago PWM from his occupational health nurse, and wears them for a week. He returns the devices, and in a couple of days, feedback reports appear in his Nuadu Portal. He learns that he does not sleep enough nor recover from his stress very well. He finds information on stress management and sleep hygiene in Nuadu Portal and decides to try out small changes in his habits. He uses WD for monitoring his daily stress feelings and sleep duration and quality. He also uses selfRelax for relaxing a couple of times a week. After a month, he feels better and according to his WD feedback graph his stress level has decreased. He borrows the shared sensors again to get a follow-up report on his situation.

III. Discussion

The Nuadu Concept is a wellness toolbox consisting of a set of technologies and services for health management. The toolbox approach was chosen in order to provide wellness tools for the management of multiple health risks; for different individual needs; in different usage situations; and for different stages of behavior change process. The user is free to choose the lifestyle changes and the tools that best fit his/her personal needs and preferences at any given time.

The Nuadu Concept is currently studied in a randomized controlled trial (RCT) with 360 City of Espoo employees in Finland. The subjects are divided into three groups of 120 subjects: intervention, intervention and technology, and control group [13]. The intervention groups participate in five 1.5-hour group sessions based on ACT, CBT, and problem-solving. The intervention methods are suitable for treating most behavioral problems, which allows the participants to focus on the problem they consider the most important for themselves. This approach also eliminates the need for separate interventions for every health problem. In addition, the first intervention group receives traditional support and the second group is given the Nuadu Toolbox for health management. All study groups receive a health questionnaire at baseline, 6 months and 12 months and participate in fitness and laboratory tests at the beginning and end of the 12-month follow-up time. The goal of the trial is to study the effect of ICT on the impact of the intervention.

We believe there will be a significant sub-group of subjects who will get additional and more sustained benefit from ICT support. This sub-group may include some individuals who would drop out from traditional interventions or not participate in them at all. Although an RCT is the golden standard in validating health related methods, its suitability for ICT related research is somewhat questionable. In an RCT, the subjects are randomized into using technologies, whereas in the real life, they would be allowed to choose. This may have a negative effect on the results, but may also provide an opportunity to study how the tools are perceived by the general population, including those who would not choose ICT support voluntarily.

The implementation presented in this paper is only one possible solution and the first iteration of the concept. The concept would enable including many other technologies and services. For example, the light integration chosen for Nuadu Portal allows fast integration of virtually any wellness related web service. The web services maintain their own look and feel and remain independent of each other. Sharing some data between them could facilitate their use, e.g., in the case of self-observations common to several services (e.g., weight). The mobile applications are mostly stand-alone, which enables fast and free usage since no server connection is needed. WD has an option for data synchronization with the server, which could be an advantage also for other applications for data back-ups and more elaborate feedback.

Psychological models of behavior change have been considered in the design of the Nuadu Concept and the selection of technologies. For example, WD has been designed on the basis of CBT. Also Mobile Coach's and Hyperfit's self-observations and feedback support CBT. In addition, Hyperfit has features that support TTM, namely wellness questionnaires and information to support the early stages of behavior change, and goal setting for the planning stage. ACT based value analysis is performed at the intervention, but it could also be included it in the technologies. Peer support, e.g., discussion forums and data sharing, and more advanced feedback were planned but, due to resource and schedule restraints, not realized in this implementation. They would support more independent use of the system, desirable for many users. They would also enable free formation of peer groups and even provide a support group for those who do not have it otherwise.

The design and implementation process of the Nuadu Concept was challenging due to high ambitions and tight schedules. We learned that ample time for testing the components and the integrated system should be reserved. The testing should be performed with real users and in the target environment, which is seldom optimal, e.g., there are old web browser versions and the users may not update their browsers or computers. The professionals supporting users may also be unaccustomed to using technological tools. Involving them at an early stage is important in order to reduce the anxiety related to using new methods, but also for gaining a fresh view for the design process.

IV. Conclusions

The Nuadu Concept was developed by integrating wellness management technologies and services, with a basis on psychological theories of behavior change. We believe that the toolbox approach enables more people to find personally relevant and acceptable tools for managing their health problems than only one fixed service would. This hypothesis will be tested in the ongoing RCT.

We consider the individual as the best expert of his/her own wellness and as the only person who can make health related decisions. Thus, the individual may freely choose the lifestyle changes to implement and the tools to use.

The concept also enables the inclusion of other services and technologies, in addition to those presented in this paper. This provides a new distribution channel for service and technology providers. The psychological basis of the concept provides understanding on the processes of behavior change, which we consider vital in supporting people in making lifestyle changes.

Acknowledgment

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PUBLICATION IV

User experiences of mobile wellness applications in health promotion. User study of Wellness Diary, Mobile Coach and SelfRelax

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User Experiences of Mobile Wellness Applications in Health Promotion

User Study of Wellness Diary, Mobile Coach and SelfRelax

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***Abstract*—An ever-increasing number of people are affected by lifestyle-related health risks, such as overweight, physical inactivity and stress. An ongoing Nuadu trial studies the user acceptance and effectiveness of technologies in supporting the wellness management of working-age citizens. The technologies consist of different Web, mobile and wearable solutions. In this paper, we present the user experience results of three mobile wellness applications: the Wellness Diary, Mobile Coach and SelfRelax. We studied their usefulness, perceived usability, usage habits and motivational factors gathered during the first phase of the trial. The data were collected with user experience questionnaires and interviews, as well as actual usage logs from mobile applications. The findings indicate that the usage habits change during the usage period of more than two months towards more practical ways of use. The results also point out several aspects to be considered when developing future wellness applications for long-term use. These are, e.g. adaptability, versatility, guidance and usability.**

Keywords-wellness; health risk management; mobile application; user experience; motivation

I. Introduction

It is common for working age citizens to suffer from lifestyle-related health problems causing absences from work and loss of productivity. Those in turn bring about high expenses to the society. In addition to the personal perspective and experiences, the society-level impacts produce incentives for supporting preventive approaches in healthcare in contrast to treatment only. With the current societal healthcare resources, there is no possibility to support everyone individually, which makes the role of self-motivation essential. Wellness management, consisting of different types of tasks, such as weight management, physical activity increase, healthy diet and stress level reduction, is usually a long-term process, and in many cases the concrete results are only visible after a long time. The key issue in wellness management is to achieve permanent changes to habits and lifestyle.

For most people changing their habits, and especially maintaining the changes, is a challenging long-term process requiring a lot of personal motivation. Many theories from psychology describe the various aspects of the process of behavioral change. Among the most interesting and widely utilized are the Transtheoretical Model (TTM) [1] and Cognitive Behavior Therapy (CBT) [2]. TTM describes the process of behavior change in terms of six stages of change: *pre-contemplation*, *contemplation*, *preparation*, *action*, *maintenance* and *termination*. Different approaches are required in each stage in order to optimally support advancing to the next. CBT, in turn, provides various tools for supporting the making and maintaining of behavior changes, such as self-observation and feedback.

Wellness technologies aim to help, support and motivate persons in their wellness management and improvement. This becomes true only if they are designed well, taking into account several usefulness and usability factors. Good user experience is a sum of several different aspects, e.g. the product should respond to user needs, provide a solid and easy-to-learn user interface, and offer pleasant experiences in general [3]. The existing work in the domain of wellness technologies is already quite extensive. Several types of wellness technologies have been designed and launched, e.g. heart rate monitors, step counters, fitness games, health portals and communities, and several research organizations are working in the domain, e.g. [4], [5], [6]. Technological devices and applications, especially mobile ones, may act as powerful persuaders because they can be kept along all the time, allowing timely appropriate persuasions, e.g. in the form of prompts [7]. The disadvantages of mobile devices are certainly the insufficient input and output capabilities. Wellness applications can have a positive impact on wellness, e.g. increase the level of physical activity [8], [5], [9]. However, earlier studies focus on relatively short-term user experiences, i.e. some weeks, and consequently, the existing knowledge lacks aspects of long-term user experiences with wellness applications.

Designing wellness applications for long-term usage is challenging, as they must include successful persuasive elements. Fogg [7] discusses many possibilities to inspire people in the areas of wellness with the help of technological tools. One way to persuade is by an interactive approach between the user and application by providing timely and contextually appropriate feedback and guidance. Motivational theories reveal other factors, which can help in persuasion. Many theories focus on the motivation towards learning, but elements from these can be utilized in application design as well. For example, Malone & Lepper [10] distinguish the following factors that promote intrinsic motivation: curiosity, control, fantasy, competition, cooperation and recognition. Some of these elements have already been utilized in wellness application design, e.g. the fantasy factor has been used in fitness games like the Nintendo WiiFit, and competition in the applications for social sharing of wellness activities, e.g. Shakra [9] and Houston [11].

The Nuadu trial [12] is an ongoing randomized, controlled trial in Finland. It focuses on wellness management and the management of multiple health risks (overweight, physical inactivity, stress, sleep, etc.). The one-year trial started in the beginning of 2008 and will end by summer 2009. A total of 360 participants, each of them having at least two health risks, and willingness for life-style related changes, are involved in the trial. They have been divided into three groups: *technology group, traditional intervention group and control group*. All groups participate in the baseline and end measurements consisting of questionnaires, laboratory tests and physiological measurements, and fill in health-related questionnaires at 6 months. The participants in the technology and traditional intervention groups were invited in 5 group-based intervention sessions. In addition, technology group participants have a possibility to use different kinds of wellness technologies throughout the trial, i.e. they have been provided with a toolkit from which they can select the technologies that best suit their individual needs. The toolkit consists of seven wellness technologies, including wearable, mobile and Web-based solutions [12]. The language of the toolkit is Finnish. The participants of the technology group were provided with mobile phones (a choice between Nokia 5500 and Nokia E50) to be used as their personal phone during the trial. The applications were pre-installed on the phones. The applications were introduced briefly to the participants during the baseline measurement session and in more detail in the intervention sessions so that one or two technologies were presented in each intervention session. The technology group participants were also provided with a pedometer (Omron Walking Style II) and weighing scale (Seca 804). The participants in the traditional intervention group receive traditional support after the intervention, i.e. they have an access to occupational health professionals when needed, and are encouraged to self-observe their health and behavior using paper diaries. The intervention designs are based on theories of behavior change, namely the Cognitive Behavior therapy (CBT) and the Transtheoretical model (TTM) [2], [1].

In the Nuadu trial, we have had a unique opportunity to study the user experiences of wellness technologies during a long time period, with a large amount of participants, who all are potential users for the wellness technologies in our focus, and with a set of different kinds of solutions. This paper focuses on one specific topic split from the large research framework: user experiences of mobile applications within the first phase of the trial, i.e. from the baseline measurement to the last intervention meeting. The research questions of this study were formulated as follows:

- How do the users perceive the applications and their usage?
- How do the usage habits change during the study period?
- What elements of the applications does this target group perceive as motivating in wellness management, and what are the perceived barriers of use?
- What can be learned from the findings for future design of wellness applications, especially for supporting long-term motivation in wellness management?

II. Research Setting

A. Participant Profile

The participants of our study consisted of 119 (35 males and 84 females) persons, the so called *technology group* of the Nuadu trial.

The participants were employed by the city of Espoo, in Southern Finland. The average age of the participants was 45 years (range: 31-56 years). Out of the participants, 8 had vocational education or had been trained at work, 66 had vocational or polytechnic education and 45 had a Masters level or higher university degree.

The habits of using technologies in general were studied in a baseline questionnaire prior to the trial. Calling and text messaging on mobile phones were used daily, and one fourth of the participants also used the calendar on a daily basis. Over a fifth of them used the camera on mobile phone at least weekly. The mobile internet connection, music player and multimedia messages were used seldom or never. These results are in line with, e.g. [13] and indicate that the participants were ordinary mobile phone users. Approximately 90% of the respondents kept their mobile phones with them during physical activities. The main reasons for keeping the mobile phone along when exercising were: “to be available” and “for safety reasons”.

The participants had some experience in the use of wellness technologies prior to the trial. About one third of the respondents had a heart rate monitor (HRM) available prior to the study, but only 3% of them used it actively. A step counter was a slightly more familiar device than the HRM for the participants. Forty-one percent of them had a step counter available prior to the study, and 11% were using it actively.

The self-proclaimed most important and challenging personal wellness topics in the beginning of the study were the following: a figure of 79% of them wanted to increase their exercise activity and fitness level, 66% focused on weight control and eating habits, 38% had goals related to sleep quality and duration, and 31% had stress-related concerns.

The initial attitudes towards the benefits of mobile wellness devices in providing motivation for a healthy lifestyle were quite positive among the participants. A majority (81%) of the participants either agreed or strongly agreed with the statement

"I believe that mobile wellness devices and applications can motivate me towards a healthy lifestyle". On the contrary, only 50% believed that Web-based wellness services can provide the same motivation.

B. Mobile Applications

We focused on the mobile solutions of the technology toolkit: the Wellness Diary [14], Mobile Coach [15] and SelfRelax [16]. All of them are mobile, stand-alone applications for wellness management and they run on S60 software platform smartphones. However, they differ from each other in several ways, especially in their primary focus, the effort needed by the user to use them, the amount of interactivity and adaptability, and the forms of feedback received by the user.

The Wellness Diary (WD) [17] is a mobile journaling tool for a wide variety of wellness-related self-observation parameters (altogether 17 parameters), such as weight, exercise, steps, eating, stress level, sleep duration and quality, and tobacco and alcohol consumption (Fig. 1). From these parameters the user can select the most suitable ones for her and personalize the application main view accordingly. The entries are made to the application manually on the input forms, preferably on a daily basis, and the application provides graphical feedback of the progress. Every input form on WD contains a free note field where the users can add their own notes. In earlier user studies with WD, the application has been found to be an easy-to-use tool for journaling wellness-related activities. However, the perceived value of the application has been relatively low in short-term use, as making manual entries requires some effort [18] and the feedback graphs are not considered motivating due to the lack of history data [19].

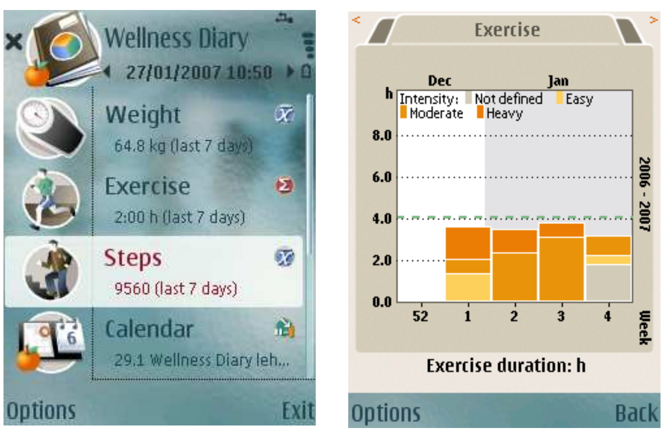

Figure 1. Screenshots of the Wellness Diary: the main view and feedback graph of exercise.

The Mobile Coach (MC) is a mobile application for supporting physical activities (Fig. 2). It automatically generates training plans based on personal goals, including recommendations of the duration and intensity of each training session, and adapts the training program based on the exercises actually performed. The user inputs the performed exercises as the duration of exercise and at least one intensity measure: self-assessed intensity, distance, average heart rate or measured training effect from a heart rate monitor. MC also provides graphical feedback of the workouts compared to the plan.

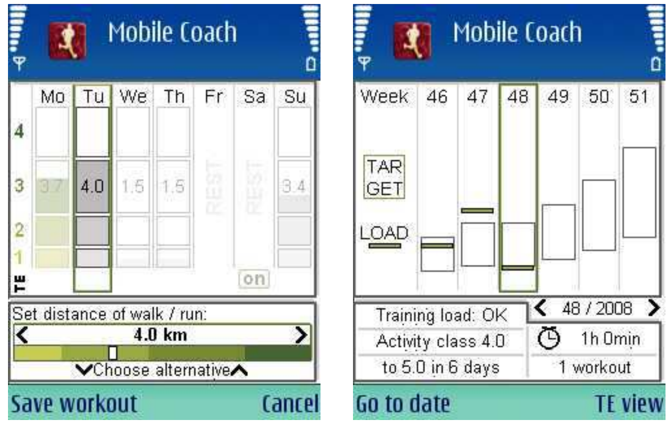

Figure 2. Screenshots of the Mobile Coach: the view for entering the conducted exercise and the exercise summary of the week.

The SelfRelax (SR) is a mobile relaxation assistant based on personalized relaxation programs (Fig. 3). The user chooses the purpose (sleep, stress, migraine, other pain, or general relaxation) and duration (3, 5, 7, 10, 15, 20 or 30 min) of relaxation, and may also set other personal preferences, such as position, background sounds, and relaxation techniques. The personalized program can be listened on the mobile phone.

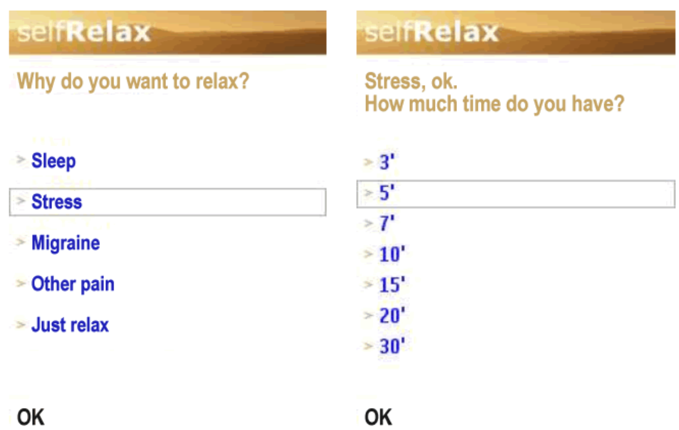

Figure 3. Screenshots of the SelfRelax: selection of the program and setting the duration of the relaxation session.

C. Data Collection and Analysis Methods

We collected user experience data in three different ways by utilizing the benefits of mixed-methods research [20]: online questionnaires, telephone interviews and application usage log files. The number of participants varied between different data sets due to the response rates of the questionnaires and limited number of interviewees.

The duration of the study period varied from participant to participant due to the ramp-up time of the trial, with the average duration being 73 days (range: 57–116). The variance is due to the waiting period between the baseline measurement and first intervention meeting, the length of which was, on average, 17 days (range: 1–60). The time period from the first intervention meeting to the last meeting was 8 weeks.

The log files were used to get an objective view of the usage frequency of the applications. Log files were manually downloaded from the participants' mobile phones during the fifth intervention meeting. Fifty-eight percent of the mobile phones were reached (i.e. the participants were present at the meeting and had remembered to bring their phones along). To normalize the usage time in the analysis of logs, we analyzed the data in intervals defined by baseline measurement and intervention meetings, i.e. from baseline measurement to first intervention meeting, from the first meeting to the second, and so on.

We launched online questionnaires in three phases: prior to the study (baseline questionnaire), at the time of the initial, independent use of the technologies (pre intervention questionnaire), and finally, soon after the intervention meetings had ended (post intervention questionnaire). Responding to the surveys was voluntary and anonymous. An URL link to the survey was sent to all technology group participants by email. The baseline questionnaire focused on technology use frequency and habits prior to the study (mobile phone, PC and wellness technologies), participants' wellness concerns, and initial opinions and attitudes towards the abilities of the wellness technology in wellness management. We got 95 respondents to the baseline questionnaire. The pre and post intervention questionnaires were identical, and they concerned the use of wellness technologies included in the trial. Their focus was to follow up the users' perceptions of technologies in the independent use after a short introduction (pre intervention questionnaire) and after proper introduction to each application (post intervention questionnaire). We had questions about the frequency of use, and opinions related to the usability, usefulness, motivational factors and the willingness to continue the use. Most questions were statements (e.g. "Application includes appropriate functions for me" or "I'm going to use the application in the future") with a 5-point Likert scale including the following options: disagree, slightly disagree, neutral, slightly agree and agree. For the pre intervention questionnaire we got 87 respondents. A figure of 51 of them stated that they had used WD, 36 had used MC, and 43 had used SR. 60 respondents responded to the post intervention questionnaire. In this phase all of them had used WD and only a few respondents had not used other applications.

TABLE I. THE AMOUNT OF PARTICIPANTS OR RESPONDENTS FOR DIFFERENT DATA COLLECTION METHODS.

	Pre intervention questionnaire	Post intervention questionnaire	Logs	Interviews
N	87	60	66	20

The semi-structured telephone interviews were arranged in the end of the study period of this paper, i.e. after the last intervention meeting. The interviews were arranged for 20 voluntary participants to get a more in-depth view and insight into the user experiences. The interviews covered subjective opinions and feelings evoked by the technologies. More specifically, the questions dealt with the perceived most and least important wellness technologies and the motivations and reasons of use, as well as the barriers of use for them. We also included questions of the experiences related to the start-up phase and the long-term use of technologies. Each interview took about 25 minutes.

The questionnaires included both quantitative (multiple choice) and qualitative (open-ended) questions, so they generated both types of data. The quantitative data was transferred from the online questionnaire tool to spreadsheets for examination. The log data was treated in the same way. The interview questions were mainly qualitative in nature. The qualitative data from the interviews, questionnaires, and free notes in log files was analyzed by using the content analysis method, i.e. the data was categorized under themes and subthemes that were generated either based on the research questions or occurrence among the data.

III. RESULTS

This section describes the main findings of the study. The findings are divided under the following themes: ease-of-use, usage habits and their changes, usefulness, motivating factors and barriers of use. The citations provided are authentic comments of the participants from open-ended responses of the questionnaires, or from the interview data. Figures 4 and 5 provide an overview of the post intervention questionnaire responses to four statements concerning usability, functions, motivation and future use of the applications.

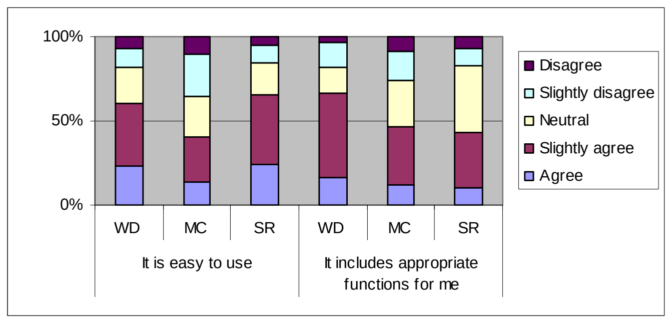

Figure 4. Post intervention questionnaire responses to the statements concerning perveived usability and appropriate functions of the applications. N for WD=60, MC=59 and SR=58.

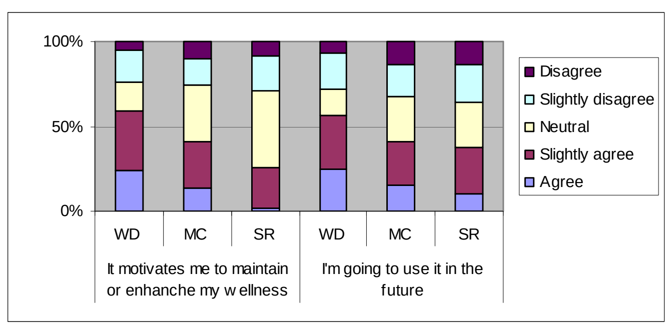

Figure 5. Post intervention questionnaire responses to the statements concerning the motivational role and future use of the applications. N for WD=60, MC=59 and SR=58.

A. *Ease-of-Use*

According to the interview responses generally concerning all three applications, the opinion was that their usage was quite easy to learn (17/20). The interviewees said that once the usage became a routine, the applications were easy to use. Four out of twenty stated that they would have needed more instructions in the beginning. However, there were differences in the perceived usability between the applications. Based on the questionnaire results (Fig. 4), WD and SR were considered clearly easier to use than MC. Moreover, the interviewees mentioned some difficulties in the use of MC:

"It was difficult to assess own level of progress… The communication between me and MC didn't work somehow. I didn't' learn to set daily programs either." (female, 47)

Many participants stated that having the application along all the time on phone was a benefit, i.e. it was simple to make the entries:

"WD is handy as it is in a mobile phone. I just mark daily exercises, steps and weight because it is always with me." (female, 51)

B. *Usage Habits and Their Changes*

Wellness Diary. The log data shows that ninety-four percent of the participants made wellness-related entries to Wellness Diary. The median number of usage days was 20.5 (range: 1–79) and the number of entries was 76 (range: 1–677). Out of the 17 possible parameters in WD, the participants made at least one entry to a median number of 6 parameters (range: 1-12). The most used wellness parameters in WD were weight, steps and exercise. 85% of participants made weight entries, 80% made steps entries, and 77% made exercise entries. Other parameters had smaller, but often very active user groups.

TABLE II. CHANGES OF USAGE ACTIVITY OF THE APPLICATIONS DURING THE STUDY PERIOD. THE HORIZONTAL LINE INDICATES THE TIME WHEN THE APPLICATION WAS PRESENTED TO THE PARTICIPANTS (E.G, IM1=FIRST INTERVENTION MEETING).

Usage interval	Wellness Diary	Mobile Coach	SelfRelax
Baseline – IM1	65%	9%	30%
IM1 – IM2	73%	11%	12%
IM2 – IM3	62%	15%	6%
IM3 – IM4	58%	21%	3%
IM4 – IM5	53%	18%	12%

Table II shows the how the usage activity of the applications changed during the study period. 65% of the participants used WD during the independent usage (between baseline measurement and first intervention meeting). After the first intervention meeting, where WD was presented, the percentage increased to 73% and declined slightly during the intervention program, being 53% at the time of the last intervention session. The interviewees commented that their usage activity declined mainly because with time their usage habits changed towards more practical:

"In the beginning I entered exercises, steps, etc. to WD, but then decided to enter only the most essential ones. I have left unnecessary parameters out. In the beginning there was more curiosity, but now the usage has changed to more practical – I just use what I need." (male, 34)

"Quite soon it became clear what parameters I would start following up." (female, 36)

Many interviewees reported that they started making multiple entries at a time, while they in the beginning made each entry separately.

Every self-observation input form on WD contained a free note field where the users could add their own comments. Sixty-five percent of participants made at least one note to WD and the median number of notes was 7 (range: 1-346). Most actively notes were used in exercise (36% of participants), steps (35%), sleep (30%), and eating (28%). Most notes contained more detailed information related to the entry, e.g. foodstuffs in eating, description of activity in exercise or steps, or reasons for poor sleep. Sometimes, the social context or location of activities was reported. In exercise and steps, the note field was also used to explain the lack of activity or poor results.

Mobile Coach. Sixty-two percent of participants made an entry to MC at least once, and the median number of entries was 3 (range: 1-40). One fourth of MC users used it actively making at least one entry/week and a median number of 22.5 entries (range: 13-40). The users of MC commented that it required a learning period, as it was more complicated than the other applications. However, when they got used to using it, the usage became regular, like the following quote reveals:

"As I got used to the use of MC the usage became daily." (male, 34)

The logs reveal that only 9% of the participants took MC into use initially (Table II). However, the percentage of the participants who used MC increased over time and after the third intervention meeting, where it was presented, it was 21%. When the interventions ended it was still 18%.

According to the interviewees, the usage activity of MC remained high among them because it had features that kept the usage motivation high, i.e. updated exercise programs. The participants reported that they used MC for entering exercises, viewing exercise- and rest-related suggestions and conducted exercises (durations, heart rates):

"From MC I view what exercises it has recommended for me. If I cannot do it during the same day, I will do it during the week, however." (female, 44)

"I have exercised and had resting days according to MC's suggestions. That has felt really good." (female, 51)

SelfRelax. Eighty-three percent of participants listened at least one relaxation session. The median number of usage times was 4 (range: 1-25). Fifty-one percent of SR users used it at least 5 times. A total of 304 relaxation sessions were listened on SR. The most used program duration was 3 minutes (54% of sessions) and the second most used was 5 minutes (19%). The most typical relaxation session was sleep (43% of sessions), the second was stress (25%), and the third was general relaxation (24%). Moreover, the open-ended questions on the questionnaires revealed that many participants preferred the sleep relaxation, i.e. using the relaxation programs at home in the evening before going to sleep. Sometimes they also used SR at the workplace, as the following comments state:

"A couple of times when I have had very difficult customers I have taken 3 minutes just to sit and relax." (female, 43)

"We have tried it out at workplace as a group. We have had relaxation sessions in the beginning of the day and it got good feedback." (female, 48)

The usage activity of SR (Table II) declined during the study period. It was independently taken into usage by 30% of the participants, but in the end of the study period the percentage was 12.

C. Usefulness

This section discusses the perceived usefulness of the applications (from post intervention questionnaire) compared to the self-proclaimed most important and challenging wellness concerns (from the baseline questionnaire).

Out of the participants who named weight control as their main goal, 78% stated that WD included appropriate functions for them. Sixty-five percent of the participants who had named exercise and fitness as their main target stated that WD included appropriate functions for them. Seventy-one percent of the participants who had named stress as their primary target stated that WD included appropriate functions for them. Out of those who named sleeping as their main target, 70% said that WD included appropriate functions.

Out of those who set exercise activity and fitness level as their primary target 43% stated that MC included appropriate functions for them.

Out of the respondents, who named stress control as their primary goal, 36% said that SR included appropriate functions for them. Out of the participants who named sleep quantity and quality as their primary target, 45% considered that SR contained appropriate functions for them.

D. Motivating Factors on Applications

According to the post intervention questionnaire results (Fig. 5), WD seemed to be the most motivating mobile application in the trial. According to 9/20 interviewees, an important motivational factor in WD was its ability to provide information on the long-term progress of different aspects of wellness, e.g. steps and weight. One participant commented that when having a wellness-related target, for example decreasing weight, WD shows that something is really happening before the concrete results are visible in the body. Even though the weight changes up and down during weeks, WD shows that the trend still remains towards the right direction. The graphs provided were considered to give valuable information as the following quotes state:

"I like to view progress and declines on the graph for a long-term period." (female, 51)

"The diagrams motivate me to try to keep the exercise level high." (male, 51)

Even though WD was considered motivating due to its ability to show long-term progress, some participants commented that it would suit a cyclic than continuous use better – use it for a while, then have a break, and then use it again for a while to compare the current values to the previous ones.

According to the post intervention questionnaire (Fig. 5), MC had a motivational role in wellness for a great amount of participants. According to the interview results, the participants perceived MC as a personal trainer. It allowed them to see what exercises they should do next. The participants liked the feature that planned the exercises for them. The adaptability of the application was a key point - the participants enjoyed seeing how their physical condition improved with time, and how the application raised the requirements as a result. In addition, the participants appreciated the feature that MC re-planned the week if they wanted to have a break on a certain day. The personal approach of the application and the adaptability were the reasons that kept the participants using and following the training programs. It was commented that the ready-made training programs and coaching are motivating factors towards exercising more.

"MC plans everything and the user doesn't need to think of the duration or intensity. The application does it for you. You just need to arrange time to do the things that it suggests." (male, 34)

"With MC I have exercised notably more than before and in a more versatile way." (female, 51)

According to the post intervention questionnaire data (Fig. 5), SR did not receive as high rates as the other applications for its perceived motivational capability. The interview data reveals that some participants used SR for quick relaxation in a successful way. A few participants described how they switched SR on sometimes when going to bed, and that it helped in falling asleep. They stated that by using it they were able to relax immediately. Another participant commented that SR was so good that it should be compulsory in every mobile phone. One participant had tried SR in an innovative way:

"And at the workplace, nursery, I have tried it with kids and they turned silent with the help of that." (female, 46)

E. Barriers of Use

The main reason for declines in the usage of wellness applications was being in a hurry. When the participants felt very busy, they did not give attention to the usage of the applications. Another situation when the applications were not usually used was during holidays. Some participants also commented that they had enough technical gadgets in their lives even without wellness applications, and expressed their tiredness in using them:

"I study besides working and that's why I need to deal with devices all the time. That's why the use of mobile has been quite minimal." (female, 43)

The mobile device as a platform caused usability-related problems to the target user group. They gave critique towards the font size, which was considered too small, and the size of the buttons of the mobile phone:

“I don’t use much mobile applications because I cannot read the text properly and do not own reading glasses yet.” (female, 47)

“The keys are so small.” (female, 53)

MC was perceived as too complicated to use by several participants. Some participants stated that they could not, for example, asses the intensity level of the exercise, which was asked by MC. The main issue on MC, however, seemed to be that it was considered to be an application for real exercisers. Participants felt that they should exercise more and do it more intensively to get benefit from the use of MC, and that it did not support everyday activity that they were mainly doing:

“I don’t need MC: it doesn’t regard everyday exercise which I mainly do. Maybe it would be useful if I would exercise more.” (male, 51)

“I would like to get stretching instructions, versatile exercise tips, and instructions from the headset, etc. instead of just abstract intensity and time.” (female, 34)

Regarding SR, some participants commented that it did not feel appropriate because it was considered monotonous or artificial:

”SR is a quite good application, but it is too monotonous. I like to meditate so SR is not enough for me.” (female, 48)

“SR is quite artificial. I have tried it for a few times, but it doesn’t feel so meaningful that I would bother using it more.” (female, 46)

Some participants also said that they easily forgot to use SR, and in the appropriate situations, e.g. when sitting on the bus, the outside noise made the relaxation inconvenient.

IV. Discussion

We have presented a user study of three different kinds of mobile wellness applications. In general, the applications in focus got a positive response among the participants. In the beginning, many participants seemed to try out different functionalities due to curiosity and because they were looking for the most suitable solutions for themselves. In the end of the period, the usage habits and personal goals had shaped towards more practical and needs related usage of the applications, and active user groups had sprang up for each application. Understanding the purpose of the applications and perceiving them as personally relevant may have increased the usage rate in all applications. Table III summarizes the pros and cons of each application and indicates what their key elements as motivators were.

TABLE III. Summary of the main findings per application.

	Wellness Diary	**Mobile Coach**	**SelfRelax**
Ease-of-use	Intuitive, easy	Required learning period	Intuitive
Usefulness	All applications had active user groups		
Motivating factors	Variety of wellness parameters, easy to approach, information on long-term progress, graphs	Updated and adaptable exercise programs, increased requirements, suggestions, coaching	Help in falling asleep and relaxation
Barriers of use	Mobile phone keypad and screen, hectic situations of life		
	Monotonous data entry, does not support cyclic use	Too complicated initially, application for real exercisers, difficult to assess exercise intensity, does not support all forms of exercise	Monotonous, artificial, does not motivate much, easily forgotten, not convenient to use e.g. in bus

The positive design solutions in the Wellness Diary seemed to be clearly its perceived ease-of-use and low threshold to start using. The functionalities and purpose of the application were understandable for the general public. It also supported many different kinds of use cases as it included a great variety of wellness parameters. The main motivating factor on it was the graphs that provided long-term information about the progress. Wellness Diary can be perceived as supporting the challenge factor from the theory of the intrinsic motivation [10] as it displays the progress towards the goals. The free form notes were used quite actively, which indicates the need of recording qualitative experiences in addition to quantitative data. However, the problem of WD was that making entries became monotonous in the long run. Participants wanted to use it in the cyclic way, i.e. the application should be adaptive for intended breaks during the use, and support easy restart after the break. As such, WD does not include persuasive elements but the usage of it depends on the user’s intrinsic motivation towards her wellness goals. By adding some persuasiveness to WD its role could be changed from a simple diary tool to the personal motivator. Timely and contextually appropriate prompts and notifications could be one way to add persuasiveness [7]. Explicit recognition [10] of achieving the targets or sub targets would probably work in this kind of an application. Elements to add curiosity or playfulness could also be utilized in the future design, although it depends on the target user group whether those would be wanted or accepted. One possibility to increase curiosity would be to update new elements and features on the application as the time goes by.

On the other hand, while being more challenging to understand and learn, Mobile Coach provided solutions that the participants perceived motivating and persuading. Those included the adaptable training programs and goals, and other forms of coaching. This kind of adapting approach can be more interesting than a static approach in the long term use. Out of the factors of intrinsic motivation [10], MC currently utilizes curiosity, challenge and control. Possibilities for the future design of MC could include adding social features to the application and thus support co-operation and competition as motivational factors. However, the designers should consider how to fix the main barrier of use, i.e. usability problems.

SelfRelax was perceived as intuitive to use, and there were participants who considered it beneficial. It helped them in falling asleep and relaxing. The considerations for the future design of SR relate to its potential usage locations and provided variations. First of all, it was not convenient to use the application in situations such as sitting on the bus because of the background noise. Another problem related to perceived monotonousness and artificiality. More natural and versatile ways for relaxing could be utilized in the future designs.

The strength of the study was that a large number of participants who were ordinary people and not e.g. technologically oriented, were studied for a long-term period in the randomized, controlled trial. The data collection methods generated a lot of complementary data. The main limitation of the study was the great variation of the usage periods among the participants due to the ramp-up time of the trial. As future work, we will analyze the user experiences during the entire trial duration. We will also analyze the usage of the Web service in the toolkit in relation to the mobile applications. In addition, we will study the user experiences with relation to the background information of the participants, such as gender and age.

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PUBLICATION V

Empowering citizens for well-being and chronic disease management with Wellness Diary

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Empowering Citizens for Well-being and Chronic Disease Management With Wellness Diary

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***Abstract*—Chronic conditions closely related to lifestyles are the major cause of disability and death in the developed world. Behavior change is the key to managing well-being and preventing and managing chronic diseases. Wellness diary (WD) is a mobile application designed to support citizens in learning about their behavior, and both making and maintaining behavior changes. WD has been found acceptable, useful, and suitable for long-term use as a part of an intervention. When used independently, however, it does not seem to have enough engaging and motivating features to support adoption and long-term commitment. The main improvement needs identified based on a review of WD-related studies were: personalization of the application to individual needs, increasing motivation during early use, maintaining motivation, and aiding in relapse recovery in long-term use. We present concepts to improve the personalization of WD as well as improvements to the feedback and interpretation of the self-observation data. We also present usage models on how this type of mobile application could be utilized.**

***Index Terms*—Cognitive-behavior therapy, mobile application, self-management, self-observation.**

I. Introduction

LIFESTYLE-RELATED chronic diseases are the main cause of disease burden and deaths in the developed world. Cardiovascular disease alone accounts for 23% of the disease burden and 52% of deaths in Europe, while 70–80% of health-care expenses are due to chronic conditions [1]. The costs are mainly incurred from complications due to poor treatment compliance, not from the chronic conditions *per se* [2]. Lifestyles play a major role in the onset and progression of these diseases, and therefore, behavior modification, e.g., smoking cessation and weight loss, is central in the prevention and management of chronic diseases.

In Europe, nearly 60% of the disease burden is associated with seven leading lifestyle-related risk factors, e.g., tobacco, alcohol, overweight, poor nutrition, and physical inactivity [1]. The prevalence of these risks is high, as 28–79% of adults in the World Health Organization European Region are overweight (body mass index; BMI ≥ 25 kg/m^2) [3] and nearly 30% smoke [4]. These risk factors tend to cluster in individuals and interact multiplicatively in causing diseases [1]. This implies that the risk factors also need to be managed together. As the mixture of health risks and comorbidities varies from one individual to another, personalized prevention and management strategies are needed.

Behavior modification is an effective method for the prevention and management of diseases, but only if maintained [5], [6]. Maintenance of lifestyle changes has been found to be challenging, e.g., only 20% of people succeed in long-term weight loss maintenance [7]. Lack of information on healthy lifestyles is one reason for the high prevalence of health risks, but the knowledge-behavior gap is probably an even more significant factor [8]. Psychological theories of behavior change, such as the cognitive-behavioral therapy (CBT) [9], transtheoretical model (TTM) [10], and motivation theories [11], [12] provide an understanding of the process and mechanisms of behavior change and are applicable to most behavioral problems. Thus, methods derived from these theories are suitable for supporting people in the management of their individual mixture of health risks and diseases.

The healthcare system does not have sufficient resources to support long-term and personalized interventions at an early enough stage. Current disease management models do not reach all those who need them, e.g., in hospital-based supervised cardiac rehabilitation, participation rates of only 14–43% are reported [13]. People must be empowered to take responsibility for their own health and well-being, and new models of chronic disease management and rehabilitation need to be devised. Due to the scale of the problem, the support must be inexpensive, available to large numbers of people, and effective for at least a significant portion of them. Optimally, the methods should extend smoothly from the management of well-being and health risks to the prevention and management of chronic diseases, and enable both independent use and collaborative care models.

Mobile devices provide a promising platform for personal health and disease management, and offer advantages over personal computers and the Internet. These devices are available 24/7 and carried along everywhere, acting as pervasive reminders of wellness management. This enables fast and easy usage at the times most convenient to the user, integrating health management into the daily life.

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Fig. 1. WD: main view (left), exercise input form (middle), and exercise diagram (right).

TABLE I
SUMMARY OF STUDIES WITH WD

Purpose	WD	Population	N	Duration
Weight management [15]	Alone	Working-age, healthy	30	12 wk
Occupational rehabilitation [15]	In PHS	Working-age, stress problems	17	12 wk
Occupational health promotion [16],[17]	In PHS	Working-age, multiple risks	118	12 mo
Psychophysiological wellbeing [20]	In PHS	Working-age, stress/depression	37	10-14 wk
Cardiac rehabilitation [19]	In PHS	Cardiac patients, in Australia	80	7 mo
Wellness management [18]	Alone	Working age, in Finland and India	16	2 wk

WD column indicates whether WD was used alone or as a part of a PHS. N denotes the number of subjects that participated in each study.

Wellness Diary (WD) is a mobile application for personal wellness management (see Fig. 1) [14], [15]. WD supports two important mechanisms of CBT: self-observation and feedback. WD enables recording of health and behavior-related self-observations, such as weight, physical activity, sleep, stress, smoking, alcohol consumption, and blood pressure, and automatically generates graphical feedback to the user based on the entries. WD has been and is currently involved in several studies, both as a stand-alone application and as a part of a larger personal health system (PHS) (see Table I) [15]–[20]. WD has been found useful in wellness management and suitable for long-term use, especially when connected to an intervention. However, it seems to have some shortcomings in engaging and motivating users, and thus, does not optimally support independent usage [18].

In this paper, we present concepts for improving WD. We first present findings from earlier studies and analyze their implications to future WD design. We then present design factors derived from psychological theories and propose improvements to the WD concept.

II. WD STUDIES AND IMPLICATIONS

WD has been studied in several different settings, as a sole stand-alone application and as a part of a PHS containing also other technologies, in intervention studies, and with independent volunteers. We present a summary of the key findings and their implications to WD.

A. Intervention Studies

Mattila *et al.* [15] studied WD in two 12-week user studies with adults aged 30 to 60. In the first study, 30 subjects used WD in connection with a weight management intervention and in the second study, 17 subjects used WD as a part of a PHS in an occupational rehabilitation intervention. Both groups found WD easy to learn and use despite the differences in their ages and backgrounds. Both groups used WD actively (>5 entries/day) throughout the study. For the subjects, weight and exercise were in the top three most important variables in both studies. In addition, the steps variable was considered very important in the first study and blood pressure in the second study. The subjects felt that WD helped them manage their weight, be more physically active, and observe their eating behavior. Twelve subjects lost weight (−3 kg, SD: 2.7 kg), and the rest more or less maintained their baseline weight (0.2 kg, SD: 1.0 kg). The subjects appreciated the privacy of the application, but some wished for expert feedback, peer support features, or more advanced analysis on a PC.

WD was included, together with its Web-based counterpart Wellness Diary Connected (WDC), in a PHS consisting of mobile, Web, and measurement technologies [16]. The PHS was used to support a multifactor, face-to-face health risk management intervention in a one-year randomized controlled trial. The subjects were allowed to freely choose which health risks to address (such as overweight, lack of exercise, stress, sleep problems, smoking, or alcohol use), as well as the technologies to be used. According to preliminary user experience results after 2–3 months of use [17], WD was the most actively used mobile application in the PHS, with 53% of the respondents using it at least weekly. 67% of respondents felt that WD included functions that were appropriate for them, 59% felt that it motivated them to maintain or improve their well-being, and 56% intended to keep using it. WD's ability to provide feedback on the long-term progress of the different variables was considered an important motivational factor. Some subjects commented that WD would be more appropriate for cyclic rather than long-term continuous usage. The main barriers to using the applications were forgetfulness and being too busy, and many people stopped using them during holidays.

B. Studies With Independent Users

In a cross-cultural user study, Ahtinen *et al.* [18] used WD in identifying design factors for culturally sensitive wellness applications. The subjects were 16 adults aged 25 to 50 in Finland and India, who used WD for two weeks. WD was used daily by six (out of eight) Finnish and seven (out of eight) Indian subjects. The subjects recorded their self-observations either immediately after each event over the course of the day or only once a day. Exercise was perceived as the most important variable; all the subjects used it. The weight variable was used by 8 subjects, and eating by 11. While WD was generally considered to be easy to use, the subjects were not willing to invest the effort to enter data only for the diagrams in the current version of WD. The subjects felt that WD was "one way," i.e., the effort it requires outweighs the benefits. Both groups wanted feedback

"Thank you nokia. This type of software is exactly what I wanted." –Stephen

"I've been using excel and OfficeSuite on my N73 to track several health parameters. Obviously this Nokia app is a much more elegant way to perform this tracking.... this app is exactly what I've been looking for." –Karen

"I downloaded the application in February, and since then I have lost 14 kgs, thanks guys and Nokia!!!!" –Sven

"I want a bluetooth scale to synch with my phone. Weight and bodyfat percentage. That would rock." –geek

"I've using this product for 3 days now and I think it is nice. But it could be better if there would be a connection to a sports data base and food database. Now you can input how many calories you ate but how do you know how many you ate?" –wouterk

Fig. 2. Some representative examples of comments from Internet discussions [21] related to WD, evidencing success stories of its use totally independently.

on the concrete impact of their efforts. Although many Finnish participants saw the value of long-term self-observations and feedback, they thought they would get bored and stop using the application before reaching that state. The subjects wanted a more interactive, exciting, joyful, and lively approach with more features to keep their usage motivation high. They felt that they would stick with the application if it would prompt them to exercise or provide them with alarms, rewards, analysis, or other such motivational features.

Finns were more eager to set numerical goals in WD, but this was a new way of thinking for the Indian subjects—some of them stated that goals could be beneficial, but would create yet another cause of stress in their lives.

Since its release as a freeware application on the Internet in January 2007, reviews reflecting the views of independent users have been posted on discussion boards (see Fig. 2). The success stories among the reviews suggest that some users have clearly experienced WD as a valuable wellness management tool.

C. Implications From the Studies

These findings suggest that WD works rather well when used in an intervention setting, i.e., when the subjects get attention from experts and are properly introduced to the benefits of self-observations and the usage of WD. The intervention program probably provides the initial motivation and engagement enabling users to reach the "long-term" stage where the benefits of WD become visible. The experiences also suggest that WD provides a good fit for such settings.

Despite several success stories from independent users, WD does not seem to provide optimal support for many of them. The main problem is the lack of sticky features for use in the early phase and for maintaining long-term interest in a setting without external support and motivation. Even when external support is available, it is desirable to have features that engage users, maintain their motivation, aid relapse recovery, and provide more elaborate feedback. Simple personalization of WD to the needs of each specific user group and different modes of self-observation would improve its fit to the wide range of user needs.

Most of the improvement needs were related to motivational issues, such as engagement, support, and interactivity. To identify mechanisms to improve the WD concept and tackle the aforementioned shortcomings, we took a closer look at the psychology of behavioral change and motivation.

III. Design Factors to Support Behavior Change

Behavior change is an active process, requiring long-term commitment and learning in order to achieve the ultimate goal—permanent behavior change. Theories and models of behavior change and motivation provide a sound and evidence-based foundation for supporting self-management.

WD was designed to support CBT, which aims to help individuals to identify and change their problematic behaviors. CBT has been widely applied and found effective in addressing various health problems, e.g., eating disorders, weight management, insomnia, and depression [22]–[24]. WD is a self-monitoring journal, a tool for recording self-observations on behaviors and health, which is a key method in CBT and other behavioral therapies [9], [25]. Self-monitoring, especially when performed on a regular basis, has been found efficient in behavior change and its maintenance [25], [26]. The effect may be increased by mentoring or peer support, because knowing that one's self-observations will be seen by others may steer behavior to the desired direction [25].

A central element in CBT is learning through self-observing, which is based both on the cognitive processes related to self-observing *per se* and on getting feedback connecting the behavior to its consequences. In general, humans are poor at learning from their experiences if the consequences of an action only become clear much later (e.g., neglecting proper diet and exercise causes increased risk of cardiac disease after 20 years) or the feedback is ambiguous or indirect (e.g., that taking antihypertensive medication reduces risk of cardiac disease) [27]. Hence, the response time, clarity, and personal relevance of the feedback are important.

Motivation, self-efficacy, and empowerment have been associated with successful and maintained behavior changes [28]–[30]. Autonomous or intrinsic motivation means doing something for reasons emanating within oneself or because it is inherently enjoyable [11]. Self-efficacy refers to the belief that one is able to achieve desired outcomes by one's own actions [31]. Ahtinen *et al.* [18] summarize the methods of promoting intrinsic motivation, proposed by Malone and Lepper [12], and discuss their implications to wellness applications. Social support (*cooperation, competition, recognition*) can motivate behavior change, and can be naturally implemented using the messaging and data sharing features of the mobile phone. Modeling and encouragement can also increase motivation and boost self-efficacy [31]–[33].

The current version of WD provides feedback on long-term progress, but the sense of *challenge* and *control* [12], [18] could be further increased by, e.g., immediate feedback accentuating changes and the cause-and-effect relationships between behaviors and health. Highlighting the successes may also increase self-efficacy [31]. Prompts, alarms, and rewards attract *attention* and *curiosity*, and could be realized using, e.g., ring tones or vibration, or the wallpaper on the stand-by screen of the mobile phone [34].

Stages of change theories present the process of behavior change as a series of stages. TTM [10] defines six stages of change: *precontemplation*, *contemplation*, *preparation*, *action*, *maintenance*, and *termination*. TTM suggests that different methods are needed to optimally support progression from one stage to the next. Relapse is acknowledged as an inherent part of the change process. Automatically detecting the user's stage and adapting to it might not be feasible, because people seeking to manage multiple health risks might be in several different stages regarding each health risk. However, the existence of different phases should be acknowledged. Currently, WD mainly supports the action phase. To support uptake, a learning mode could be added to educate the user on the usage of WD, and the principles of self-observations and feedback as mechanisms to manage health and wellness; to highlight and demonstrate the benefits of self-observation, and to provide information and quizzes on healthy behaviors and health, such as RealAge [35].

Personal goals may boost commitment to change, as long as they are truly personal and intrinsic [36]. The current version of WD enables setting numerical targets for most of the variables, and checks them against medical recommendations, e.g., to ensure that the weight target does not lead to underweight and is not unrealistic (weight loss more than 10%). It could also be useful to set intermediate goals on the way to the ultimate goal, e.g., it may be demotivating to immediately try to increase physical activity from 0 to 3 h a week.

In the active usage phase, it is challenging to maintain motivation and stay on track during one's busy daily life. In this phase, it is essential to show the impact of behavior changes. Rewards for meeting goals have been found to be motivating [32], [34].

Relapse detection and recovery methods would be important in long-term use. This could be done, e.g., by noticing a significant change in the usage pattern, e.g., no entries for several days for a usually active user, asking the user whether he or she has relapsed, and then, offering recovery options, e.g., starting to monitor something more closely to get back on track, selecting a holiday mode with only infrequent prompts to enter self-observations, or taking a break with a reminder later on.

IV. Concepts to Improve WD

On the basis of the findings from different studies with WD and the methods presented in the previous section, we have designed the following features to improve the WD concept.

A. Profiles, Defaults, and Personalization

Personalization and profiling should be included in WD to enable tailoring of the application to individual self-management needs or personal preferences; the requirements of a specific intervention or disease management program; or different cultural features.

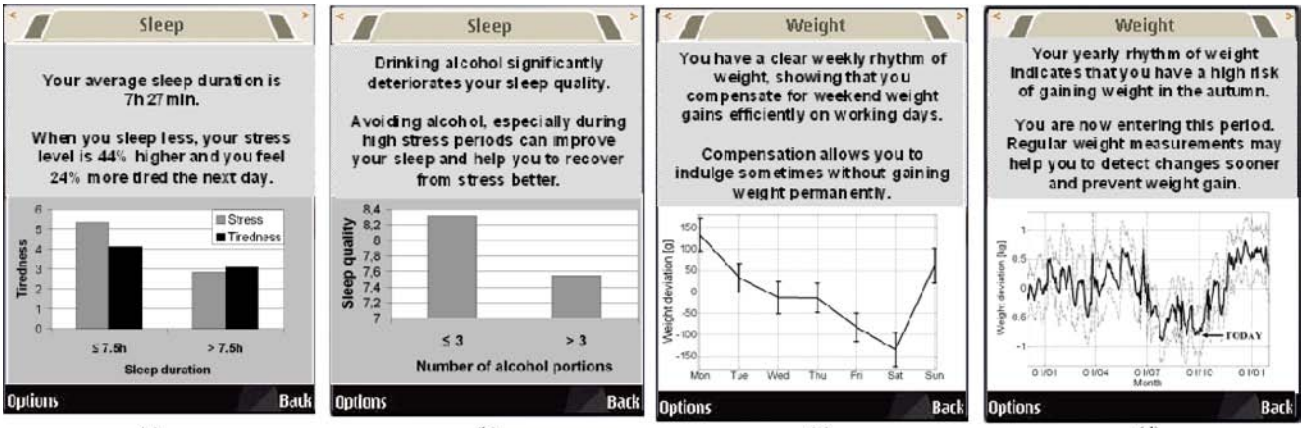
The application should provide a set of predefined user profiles, e.g., for independent users interested primarily in weight loss or exercise, or participants of a cardiac rehabilitation program. These profiles should also be culturally sensitive, e.g., follow the national health guidelines, terminology, and semantics of the target country. New profiles should also be easy to make, e.g., by different service providers or the user communities themselves. The application must be easily modifiable at any time by the user, or if available, his or her mentor or a healthcare expert.

Well thoughtout default settings, both in variable selection and goal setting, may be very influential in changing behaviors [27], and therefore, such profiles should be carefully created for each target group. For example, a weight management application should include variables for monitoring weight, physical activity, and nutrition, and the goals should be based on national nutrition and exercise recommendations. An independent user would be able to select from a range of predefined profiles or use a wizard to help identify his or her optimal profile. In addition, modeling could be leveraged in goal setting. For example, default goals based on statistical data could be used, e.g., how much does an average person of the user's age exercise, as long as these defaults are better than the user's current level. Very easy goals could be set in the beginning, but the challenge level could be ramped up incrementally over time [27]. For participants of a disease-specific program or intervention, goal setting should be based on clinical guidelines (e.g., healthy blood pressure or blood glucose limits) and expert evaluation.

Different self-observation options should be available, ranging from fairly detailed to very simple. For example, in diet monitoring, a detailed mode based on food database with rich feedback might be educational in the beginning. After a couple of weeks, a simpler and faster mode, such as recording the meal rhythm and self-assessed healthiness of diet could be used.

B. Easier Entry, Better Feedback, and Decision Support

Although the manual entry of self-observations is simple to perform, it has been found to be laborious. Automatic transmission may facilitate data entry, especially in the case of data-intensive measurements. Currently, WD supports automatic retrieval of step count data from the Nokia Step Counter application, which utilizes the inbuilt accelerometer of the mobile phone [19], [37]. For external measurement devices, data transmission will become more feasible in the coming years due to the standardization work of Continua Health Alliance [38] and the emergence of suitable monitoring devices that support standard interfaces. However, automatic data transfer must be carefully designed in order to maintain the user's situation awareness and the impact of self-observations [39]. The mobile phone also enables other input modalities, such as voice, photos, and even tactile input based on accelerometers. Photo input is implemented in the current version of WD and this feature is being used in cardiac rehabilitation, where photos taken with the phone's inbuilt camera can be automatically associated with self-observation entries, e.g., in nutrition mentoring [19].



(a) (b) (c) (d)

Fig. 3. Examples of advanced feedback and analysis, illustrating the data of a case subject. (a) Feedback on the effect of short sleep on stress and tiredness. (b) Illustrating the well-known effect of alcohol consumption on sleep quality. (c) Positive feedback based on the weekly rhythm of weight. (d) A warning of an approaching high-risk period based on the yearly rhythm of weight.

As mentioned earlier, feedback is crucial for changing behaviors, learning, and staying motivated [12], [27]. In order to engage a new user, valuable feedback should be provided right from the onset. WD should provide in-depth analyses and reveal aspects of the data that are not visible from the basic time series diagrams. For example, automatic detection and visualization of connections between different variables or patterns in the data, combined with decision support (DS) and clinical guidelines would amplify the value of general health guidelines and make the feedback more personal. As an example, Fig. 3 illustrates the feedback related to the connections of sleep, stress, and alcohol, as well as weekly and yearly weight rhythms based on the data of a male subject who has been using WD for four years. In this example, personal patterns and statistically significant correlations between the variables are visualized and enhanced by context-sensitive guidelines [40]–[43]. As shown in Fig. 3, combining WD with a DS system based on evidence-based clinical data would enhance the feedback by providing rule-based interpretation of the data. The Finnish Medical Society Duodecim has developed a DS system called evidence-based medicine electronic decision support (EBMeDS) [44]. The system combines medical knowledge with individual patient data and provides user-specific reminders, prompts, alerts, and individual guidance [45]. The current scripts are mainly targeted at healthcare delivery and decision making for professionals, but the EBMeDS system also enables the creation of new scripts from any structured data, such as WD data. The EBMeDS system was tested by integrating it with the WDC Web-based service. A single rule was implemented to warn the user about elevated risk for type II diabetes. The warning was given if the user's BMI exceeded 30 kg/m^2, and the user was advised to check his or her blood sugar level from time to time. This proof of concept shows that this technology could be extended to a large variety of conditions, from chronic disease management to health risk management and illness prevention. This type of feedback might be valuable in helping the user identify potential health risks and even detect changes in their chronic diseases by alarming the user when the thresholds for certain risks are exceeded. The future challenge lies with the robust analysis of self-observation data and the creation of evidence-based guidelines for its interpretation, since WD data, consisting of self-observations and simple measurements in uncontrolled conditions, may be sporadic, less reliable, and noisier than data obtained in a clinical setting by professionals.

C. Usage Models

WD is personal and private, which many users appreciate. However, it would be desirable to introduce optional mentoring or peer support features to add value and increase the stickiness of the application. This is supported by the observation that WD seems to work well in connection with an intervention program or mentoring. Considering cost efficiency and scaling to large-spread use, close health professional involvement and personal mentoring is probably feasible only in the case of chronic diseases, where direct savings can be achieved through decreased travel and expert working time. Therefore, new usage and business models supporting minimal, but efficient expert support and health coaching are needed.

Technically, WD already enables wireless transmission and two-way synchronization of data with WDC, which enables mentoring [16], [19]. A mobile phone also offers other social features, such as sharing of personal data, comparing one's results with the peer group's data, and sending messages, as was done in [32], [33]. WDC is a Web-based service for recording personal health records with WD. The parameters supported by the service are largely the same as those in the mobile application [19]. WDC consists of three parts: end user view, professional view, and administrator view. *End user view* consists of several views, such as a customizable dashboard (main view), charts, entry list, goal settings, calendar, images, and messaging. The feedback and motivation methods include traffic light indicators, a simple measure of physical activity, goal setting, and verbal feedback. The feedback is based on simple "hard-coded" rules programmed into the system. As mentioned earlier, a DS system based on clinical guidelines has also been demonstrated with WDC. *Professional view* (ProView) is a separate interface for professional users (e.g., mentors or health coaches). Its functionalities enable user management, intervention support, and research support. ProView allows management of groups, patient monitoring and analysis, news postings, and system-wide messaging with attachments. It enables professionals to make searches on users, create questionnaires, and access the users' data. *Administrator view* (AdminView) is meant for system administrators and is intended for creating and managing user groups and providing Admin and Proview rights.

A typical chronic disease management model based on mentoring and WD is described in [19]. This model uses WD and WDC in a home-based care model for cardiac rehabilitation patients. The patients use WD to collect health and exercise data either through self-observations or by using simple measurement devices such as weight scales. Physical activity is measured with the inbuilt accelerometer in the mobile phone and the Step Counter [37] software. The WD client reads the measured daily steps from the Step Counter. All patient data are collected through the WD mobile client and synchronized with the WDC service a few times a week. A trained mentor can access the patients' data on the WDC service and evaluate their progress and current status in relation to the goals. Every week, the mentor calls each patient, and together they review the progress related to previous goals, discuss opportunities for improvements, and set new personal exercise and lifestyle goals for the next week. The care model is based on weekly themes focusing on different aspects of lifestyle improvements and issues important to cardiac patients. The mentoring sessions are amended with daily motivational short message service messages as well as multimedia and audio material stored in the patients' phones (see Fig. 4). The data sharing routine and personal contact with the mentor, including weekly evaluations of the information, are expected to motivate and encourage the patients to sustainably use WD and WDC. The WDC portal provides objective and relevant data to the mentors in a simplified format, which will help them to quickly address the issues important to each individual patient and understand their personal progress better than they would by merely conducting a telephone interview. This model could be extended to the management of other chronic diseases, where use of active remote mentoring would be potentially cost-efficient.

Guidance, coaching, and mentoring, and even minimal support for self-management may be crucial to the uptake and use of self-management technologies [46]. Therefore, sustainable and cost-efficient services and business models for health risk and wellness management should be developed. Potentially, employee health promotion and occupational healthcare settings may provide an early business model and domain for these applications [16]. In the employee health domain, group interventions and health promotion programs could be combined with technology support to foster maintenance of the intervention effects [16]. Although the evidence for the cost-efficiency of these programs is still uncertain, some employers are already launching such programs as part of their human resources management policies.

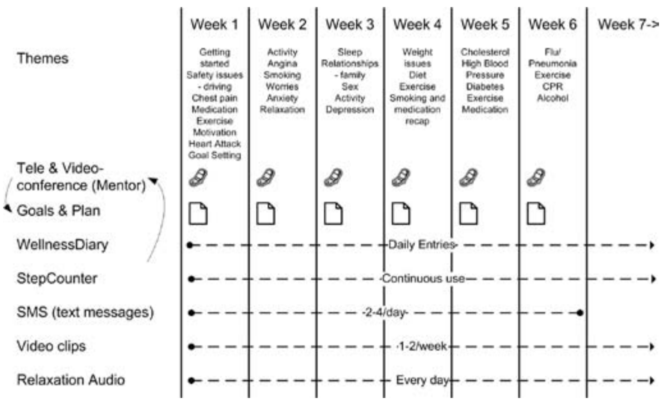


Fig. 4. Home program schedule used in [19], including weekly mentoring and goal review via telephone and daily use of technologies.

Finally, models supporting independent and personal use should be developed. In these models, in contrast to the aforementioned models, the service would be paid mostly by the individuals themselves. Some Web-based services already provide health coaching and feedback, as well as personalized action plans for an initial and/or monthly fee. As mobile phone plans allow straightforward implementation of the payment mechanisms to subscribe to such services, their implementation would be possible with WD. To better support this, WD could include better tools for planning and goal setting, as well as better integrated messaging with health coaches. External motivation can also be provided. For example, the Commitment Savings for Smoking Cessation (CARES) program [27], [47] is based on "self-betting," i.e., voluntary commitment to reaching certain goals by making a monetary "bet". In CARES, participants commit to smoking cessation by making weekly payments to the program. At the end of the program, they are tested for smoking, and if they fail the test, they lose their bet; if they succeed, they get their bet back. This program has reported successful outcomes [47]. Although the study was not strictly scientific, the idea could be extended to concepts such as WD, where weekly payments could be associated with certain health goals and goal monitoring would be embedded in self-monitoring variables.

V. Discussion and Conclusion

WD is a mobile application for personal health and disease management. It has been found easy to use and useful in well-being management, and it has been actively used for several months in intervention studies. In this paper, we presented a summary of findings from earlier studies with different user groups, and proposed new concepts to improve WD to make it more useful, engaging, and motivating for independent and supported users alike. These findings are also relevant to other, especially mobile and wellness applications.

The goal of WD is to enable sustained behavior change and learning through self-observations and feedback. To promote learning and support decision making, it is essential to enhance feedback and analysis of self-observation data, revealing the cause-and-effect relationships between behavior and health. Feedback should be timely and focus primarily on the factors and behaviors that the individual is able to change. DS systems and evidence-based clinical guidelines, developed specifically for self-management of health or chronic illnesses, can further enhance the usefulness of the concept.

Challenges related to different usage phases were encountered in the studies [17], [18]. In the beginning, the lack of motivation and engagement was a major barrier for the usage of WD. Later on, busy everyday life and holidays caused breaks in WD usage. The benefits of WD should be made evident to the user from the very beginning by taking a more interactive approach with the help of, e.g., a learning mode, quizzes, and immediate feedback. Relapses should be recognized early on, and coping mechanisms should be provided. Long-term motivation could also be promoted with social support features, such as data sharing and encouraging messages, as well as simple and pervasive rewards [32]–[34].

Personalization, profiles, and different usage modes for WD would improve its fit to the widely varying needs of the users. Providing preset and easily modifiable profiles for different purposes, e.g., weight management, would facilitate the independent usage of WD. Profiles should also be provided for goal setting, as goals may be culturally sensitive [18]. Currently, WD supports numerical goals set by the user. Although the goals are checked by the application, they are static and do not change over time unless manually modified. More engaging and dynamic options should be developed.

WD has been found to work well with expert support or intervention, and along with WDC, it seems to provide a good fit for intervention and mentoring settings. These features could be further improved with disease or intervention specific profiles and goal setting, as well as flexible modification options for healthcare experts and mentors.

WD is a promising and extendable wellness management concept to support both independent users and individuals participating in an intervention. We believe that the key success factors of WD are its simplicity and mobility, allowing fast and easy usage independent of location and time. These factors should be carefully maintained, whenever possible, when upgrading the concept.

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Design and evaluation of a mobile phone diary for personal health management

Abstract

The increasing prevalence of lifestyle-related health risks coupled with the lack of resources in preventative healthcare calls for novel and cost-efficient methods for supporting citizens in their independent health and well-being management. Behaviour modification is an efficient way of preventing chronic diseases and other lifestyle-related health problems, provided that the healthy behaviours are sustained over the long term. The challenge is to develop efficient methods that support citizens in their health management and empower them to take more responsibility for their health. Psychological methods, such as those based on cognitive-behavioural therapies, provide an understanding of behaviour change as well as efficient methods for supporting it. However, providing preventative face-to-face therapies for health promotion is not economically feasible and does not necessarily offer the long-term support required to establish permanent healthy behaviours.

Lately, information and communication technologies have been harnessed for use in health promotion programs. Mobile phones provide a particularly promising platform for health management applications due to their central role in people's lives as well as their technical capabilities. This thesis presents a mobile phone application for supporting the self-management of health and well-being, targeting working-age citizens. The Wellness Diary (WD) is based on a core method in cognitive-behavioural self-management, self-monitoring. The main aim was to enable the long-term self-management of well-being with the help of a mobile terminal. WD has been evaluated in several studies with different user groups and in different research settings. Three of the evaluations are presented in this thesis. Based on the results, most users found WD to be easy to use and useful. Furthermore, a significant number of users used WD regularly over several months, which shows that WD is capable of enabling long-term self-monitoring.

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Tekijä(t)

Elina Mattila

Nimeke

Hyvinvoinnin hallintaan tarkoitetun matkapuhelinsovelluksen suunnittelu ja arviointi

Tiivistelmä

Elämäntavoista johtuvien terveysriskien lisääntyminen sekä terveydenhuollon resurssien riittämättömyys sairauksien ehkäisyssä ovat johtaneet tarpeeseen kehittää uusia, kustannustehokkaita menetelmiä kansalaisten omaehtoisen hyvinvoinnin hallinnan tukemiseen. Käyttäytymisen muuttaminen on tehokas tapa ehkäistä elämäntapoihin liittyviä kroonisia sairauksia ja terveyshaittoja, edellyttäen että terveelliset elämäntavat ovat pysyviä. Haasteena on kehittää tehokkaita menetelmiä, joilla kansalaisia voitaisiin tukea hallitsemaan omaa hyvinvointiaan paremmin ja ottamaan siitä enemmän vastuuta. Psykologiaan perustuvat menetelmät, esimerkiksi kognitiivisen käyttäytymisterapian menetelmät, antavat tietoa käyttäytymismuutoksesta ja sen tukemiseen soveltuvista keinoista. Perinteisiä, henkilökohtaisiin tapaamisiin perustuvia terveydenedistämisohjelmia ei kustannussyistä voida tarjota kaikille niitä tarvitseville, eivätkä ne välttämättä tarjoa pitkäaikaista tukea, jota tarvitaan terveellisten elämäntapojen vakiinnuttamiseen.

Viime aikoina tieto- ja viestintäteknologioita on alettu hyödyntää terveyden edistämisessä. Matkapuhelimet tarjoavat erityisen lupaavan alustan hyvinvoinninhallintasovelluksille, sillä niiden rooli ihmisten elämässä on keskeinen ja niiden tekniset ominaisuudet kehittyvät jatkuvasti. Tässä väitöskirjassa esitellään työikäisille suunnattu matkapuhelinsovellus hyvinvoinnin hallinnan tukemiseen. Wellness Diary (WD) perustuu itsehavainnointiin, joka on yksi kognitiivisen käyttäytymisterapian ydinmenetelmistä. Tärkein tavoite oli pitkäaikaisen hyvinvoinnin hallinnan mahdollistaminen mobiilin päätelaitteen avulla. WD:tä on arvioitu useissa tutkimuksissa, erilaisilla käyttäjäryhmillä ja erilaisissa tutkimusasetelmissa, joista kolme esitellään tässä väitöskirjassa. Tulosten perusteella suurin osa käyttäjistä koki WD:n helppokäyttöiseksi ja hyödylliseksi. Lisäksi merkittävä osa käytti WD:tä säännöllisesti usean kuukauden ajan, mikä osoittaa, että WD mahdollistaa pitkäaikaisen itsehavainnoinnin.

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