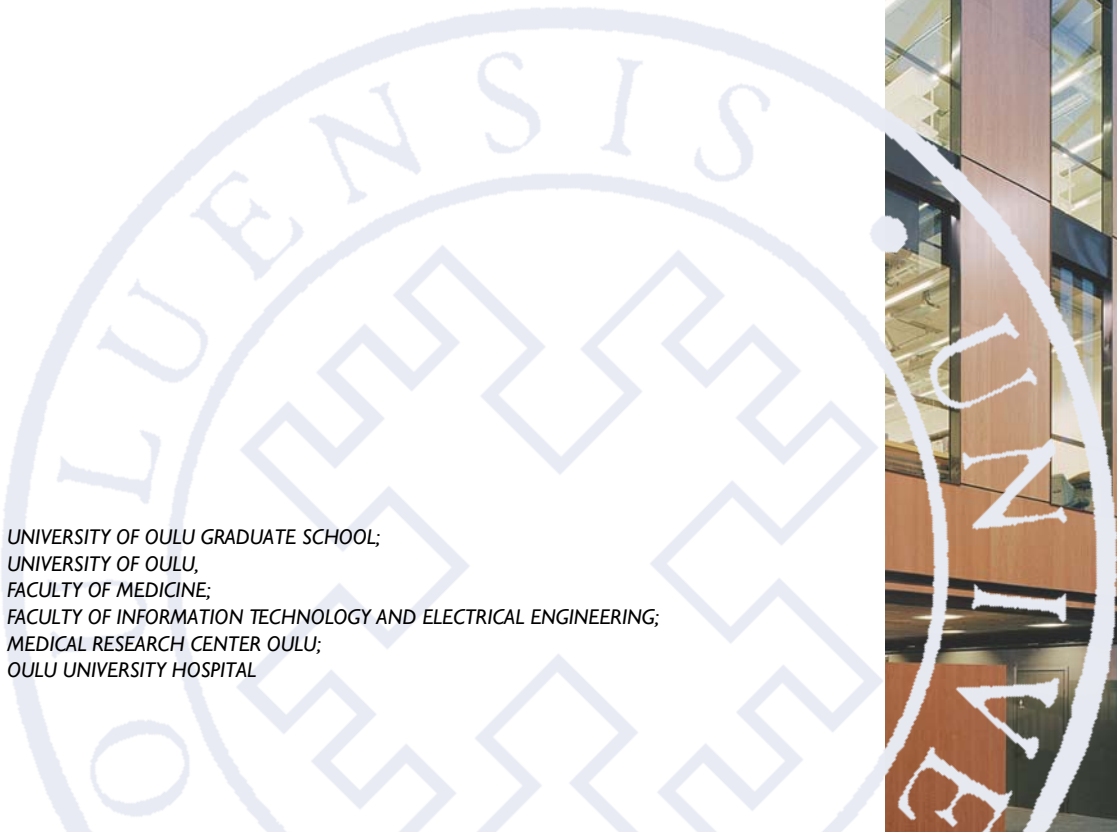


Md Sanaul Haque

PERSUASIVE MHEALTH
BEHAVIOURAL CHANGE
INTERVENTIONS TO
PROMOTE HEALTHY
LIFESTYLE

UNIVERSITY OF OULU GRADUATE SCHOOL;
UNIVERSITY OF OULU,
FACULTY OF MEDICINE;
FACULTY OF INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING;
MEDICAL RESEARCH CENTER OULU;
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MD SANAUl HAQUE

**PERSUASIVE MHEALTH
BEHAVIOURAL CHANGE
INTERVENTIONS TO PROMOTE
HEALTHY LIFESTYLE**

Academic dissertation to be presented with the assent of the Doctoral Training Committee of Health and Biosciences of the University of Oulu for public defence in the Leena Palotie auditorium (101A) of the Faculty of Medicine (Aapistie 5 A), on 29 May 2020, at 12 noon

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Abstract

Promoting a healthy lifestyle has attracted a significant amount of attention in recent years. This is also the case in workplaces, where the focus on wellbeing at work and changes in personal health behaviours has been raised. Technology-enhanced interventions are a possible solution for motivating people towards healthy lifestyle promotion, such as healthy eating and physical activity (PA). Persuasive applications have been proposed as a promising technique for fostering behavioural change and promoting healthy lifestyles. The major limitation of most existing mobile health (mHealth) applications is that they are not grounded in theoretical concepts. On the other hand, value propositions (VPs) might increase the effectiveness of persuasive applications.

This study aimed to develop mHealth behavioural change interventions, that is, persuasive mHealth applications based on psychological theories to promote healthy eating and PA in the workplace. Four VPs were proposed and implemented to enhance the efficacy of the persuasive mHealth application. Elaborated Intrusion (EI) theory was applied to develop a healthy eating application (iCrave) and self-determination theory (SDT) was used to develop a PA application (iGO). iCrave allowed users to track their snack cravings and record whether they chose to eat healthily or unhealthily. iGO allowed users to promote their PA, and to decide whether to select PA after breakfast or lunch. The design of the applications was performed by an iterative User-centered design (UCD) process. The feasibility of the applications was assessed by experimental studies with quantitative and qualitative surveys. The results of the study demonstrate that the design process of the applications was a successful approach and can be used in future persuasive mHealth applications.

Keywords: EI theory, healthy lifestyle, mHealth, persuasive application, SDT, UCD

Haque, Md Sanaul, Suostuttelevat mobiilisovellukset terveellisten elämäntapojen edistämiseen.

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Tiivistelmä

Terveellisten elämäntapojen edistäminen on viime vuosina saanut kasvavaa huomiota. Myös työpaikoilla keskitytään yhä enemmän työhyvinvointiin ja henkilökohtaiseen terveyskäyttäytymiseen. Teknologian avulla tuetut interventiot ovat mahdollisia ratkaisuja motivoida ihmisiä edistämään terveellisiä elämäntapoja, kuten terveellistä ruokailua ja fyysistä aktiivisuutta. Suostuttelevia sovelluksia on ehdotettu lupaavaksi ratkaisuksi käyttäytymisen muutoksen edistämiseksi ja terveellisten elämäntapojen parantamiseksi. Suurin rajoite useimmissa olemassa olevissa terveyteen liittyvissä mobiilisovelluksissa (mHealth) on se, että niillä ei ole teoreettista perustaa. Toisaalta arvoehdotukset voivat lisätä suostuttelevien sovellusten tehokkuutta.

Tämän tutkimuksen tavoitteena oli kehittää käyttäytymisteorioihin perustuvia suostuttelevia mHealth-sovelluksia terveellisen ruokavalion ja fyysisen aktiivisuuden edistämiseksi työpaikoilla. Työssä toteutettiin neljä arvoehdotusta suostuttelevan mHealth-sovelluksen tehokkuuden parantamiseksi. Elaborated Intrusion (EI) -teoriaa sovellettiin terveellistä syömistä edistävän sovelluksen (iCrave) kehittämiseen ja itsemääritysteoriaa fyysistä aktiivisuutta edistävän sovelluksen (iGO) kehittämiseen. iCrave antoi käyttäjille mahdollisuuden seurata heidän välipalatoiveitaan ja valita terveellisiä tai epäterveellisiä vaihtoehtoja. iGO edisti käyttäjän fyysistä aktiivisuutta kannustamalla liikkumaan joko aamiaisen tai lounaan jälkeen. Sovellukset toteutettiin käyttäen iteratiivista käyttäjakeskeistä suunnittelua. Sovellusten toimivuus arvioitiin kokeellisissa tutkimusasetelmissä määrällisillä ja laadullisilla kyselytutkimuksilla. Tutkimuksen tulokset osoittavat, että sovellusten suunnitteluprosessi oli onnistunut lähestymistapa, ja sitä voidaan käyttää tulevaisuuden suostuttelevissa mHealth-sovelluksissa.

Asiasanat: EI-teoria, mHealth, SDT, terveellinen elämäntapa, UCD, vakuuttava sovellus

*Dedicated to the researchers who always struggle to get a
VISA traveling around the world and to the precious
souls who passed away of COVID-19*

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April 2020

Md Sanaul Haque

Abbreviations

App	application
etc.	et cetera
i.e.	id est
e.g.	exempli gratia
BI	behavioural intention
EI	elaborated intrusion
EU	European union
EE	effort expectancy
FC	facilitating conditions
FP	foundational premise
HTA	health technology assessment
HCI	human-computer interaction
ISO	international standard organisation
mHealth	mobile health
PA	physical activity
PBL	point, badges, and leaderboards
PE	performance expectancy
POV	point-of-view
SDT	self-determination theory
SI	social influence
UCD	user-centered design
UB	use behaviour
UK	United Kingdom
UTAUT	unified theory of acceptance and use of technology
VP	value proposition
WHO	world health organisation

Original publications

This thesis is principally grounded on the following original articles, which are referred throughout the text by their Roman numerals (I–VI):

- I Haque, M. S., Arman, A., Kangas, M., Jämsä, T., & Isomursu, M. (2018). Towards value propositions for persuasive health and wellbeing applications. In: Maglaveras N., Chouvarda I., de Carvalho P. (eds) *Precision Medicine Powered by pHealth and Connected Health, ICBHI 2017. IFMBE Proceedings*, 66, 217–221. Springer. https://doi.org/10.1007/978-981-10-7419-6_36
- II Hsu, A., Yang, J., Yilmaz, Y., Haque, M. S., Can, C., & Blandford, A. (2014). Persuasive technology for overcoming food cravings and improving snack choices. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI 2014*, 3403–3412. ACM. <https://doi.org/10.1145/2556288.2557099>
- III Haque, M. S., Jämsä, T., & Kangas, M. (2017). A theory-driven system model to promote physical activity in the working environment with a persuasive and gamified application. In: A. Editor, M. Meder, A. Rapp, T. Plumbaum, and F. Hopfgartner (eds.): *Proceedings of the Data-Driven Gamification Design Workshop, MINDTREK 2017*, 37–44. CEUR.
- IV Haque, M. S., Abdullah, W. M., Rahaman, S., Kangas, M., & Jämsä, T. (2016). Persuasive health and wellbeing application: A theory-driven design in promoting physical activity. *2016 International Conference on Medical Engineering, Health Informatics, and Technology, MEDITEC*, 1–5. IEEE. <https://doi.org/10.1109/MEDITEC.2016.7835369>
- V Haque, M. S., Isomursu, M., Kangas, M., & Jämsä, T. (2018). Measuring the influence of a persuasive application to promote physical activity. In: R. Orji, M. Kaptein, J. Ham, K. Oyibo, J. Nwokeji (eds.): *Proceedings of the Personalization in Persuasive Technology Workshop, Persuasive Technology 2018*, 43–57. CEUR.
- VI Haque, M. S., Kangas, M., & Jämsä, T. (2020). A Persuasive mHealth behavioral change intervention for promoting physical activity in the workplace: feasibility randomized controlled trial. *JMIR Form Res 2020*, 4(5):e15083. JMIR. <https://doi.org/10.2196/15083>.

Contents

Abstract	
Tiivistelmä	
Acknowledgements	9
Abbreviations	13
Original publications	15
Contents	17
1 Introduction	21
1.1 Overview	21
1.2 Research focus	22
1.3 Structure of the thesis.....	23
2 Literature review	27
2.1 Healthy lifestyle	27
2.2 Value propositions in persuasive mHealth applications	28
2.2.1 Value	29
2.2.2 Value co-creation	31
2.2.3 Value propositions	31
2.3 Behavioural change intervention utilising mHealth.....	32
2.3.1 Healthy eating behavioural change intervention	34
2.3.2 Physical activity behavioural change intervention	36
2.4 Game-design elements	37
2.5 User-centered design.....	38
2.6 Unified theory of acceptance and use of technology	39
2.7 Feasibility of mHealth interventions	40
2.8 Gap in research.....	41
3 Objectives of the study	43
4 Research process and conceptual framework	45
4.1 Adopting Peffers' design science research process model	45
4.1.1 Problem identification and motivation	45
4.1.2 Design and development	45
4.1.3 Demonstration	47
4.1.4 Evaluation.....	47
4.1.5 Communication	47
4.2 Conceptual framework.....	48
5 Application design	51
5.1 Identifying key value propositions (I).....	51

5.2	Designing a persuasive mHealth healthy eating application (II).....	53
5.2.1	iCrave application (II)	54
5.2.2	Enhancing rewards of health choices (II)	55
5.3	Designing a persuasive mHealth physical activity application (III-IV)	56
5.3.1	Game-design elements (III)	56
5.3.2	Proposed system model (III).....	57
5.3.3	User-centered design (III).....	59
5.3.4	The working prototype of the iGO application (IV).....	62
6	Pre-evaluation and feasibility testing	67
6.1	Overview of testing and study participants	67
6.2	Pre-evaluation of the application prototypes (I, II, IV).....	67
6.2.1	Persuasive mHealth healthy eating application iCrave (II)	67
6.2.2	Persuasive mHealth physical activity application iGO (IV).....	68
6.2.3	Validation of the value propositions through the case study on the persuasive mHealth applications (I)	69
6.3	Feasibility of the persuasive healthy eating application iCrave (II)	70
6.3.1	Feasibility study (II)	70
6.4	Usability and feasibility of the persuasive physical activity application iGO (V-VI)	72
6.4.1	Usability study (V)	72
6.4.2	Feasibility study (VI).....	78
7	Results	83
7.1	Persuasive mHealth healthy eating application iCrave (II).....	83
7.1.1	Quantitative results (II).....	83
7.1.2	Qualitative results (II).....	87
7.2	Persuasive mHealth physical activity application iGO (V-VI).....	89
7.2.1	Usability study (V)	89
7.2.2	Feasibility study (VI).....	91
8	Discussion	95
8.1	Comments on value propositions (I)	95
8.2	Design process (II–V)	95
8.3	Feasibility of application for healthy eating (II)	96
8.4	Feasibility of application for physical activity (VI)	97
8.5	Theoretical and practical contribution (I-VI)	100
8.5.1	Theoretical contribution	100

8.5.2 Practical contribution.....	101
8.6 Future perspectives (II, V–VI)	102
8.6.1 Application for healthy eating (II).....	102
8.6.2 Application for physical activity (V–VI).....	102
9 Conclusion	105
List of references	107
Original publications	123

1 Introduction

1.1 Overview

The value of human health and wellbeing was coined over 2 000 years ago by Virgil (Publius Vergilius Maro, an ancient Roman poet of the Augustan period), when he stated, “The greatest wealth is health.” With the growth of civilisation, human beings have come to increasingly understand about the importance of maintaining a healthy lifestyle. The United Nations Sustainable Development Goals: goal three is intended to “ensure healthy lives and promote well-being for all at all ages,” for health “is a driver, indicator and outcome of sustainable development.” Comprehensively, goal 3 sets out to end the global non-communicable diseases by 2030 (UN, 2019). Non-communicable diseases have become a significant health concern (Murray et al., 2013), and the anticipation of such circumstances is a primary public health goal (WHO, 2014).

Research has shown that maintaining a healthy life requires improving lifestyle (Zhang et al., 2011). People spend a significant amount of time at their workplace (Rongen, Robroek, Van Lenthe, & Burdorf, 2013; Hutchinson & Wilson, 2011) and due to this, there is a need to promote healthy eating and physical activity (PA) among them. Health promotion actions in the workplace are essential, focusing on changing personal health behaviours, such as healthy eating (WHO, 2016) and PA. The World Health Organization (WHO) has recognised the workplace as a priority setting in fostering health (WHO, 2010).

Persuasion is usually concerned with supporting to change behaviour (Perloff, 2013; Dillard & Shen, 2012; Crano & Prislin, 2008; O’Keefe, 2002). Persuasive applications have been proposed as an actual technique to promote behavioural change, and it has the potential for improving the health-oriented quality of life (Fogg, 2003). Modest evidence has been found for the effectiveness of mobile health (mHealth) interventions in eating and PA improvement (Schoeppe et al., 2016). Studies in which the interventions used mobile applications, along with other interventional approaches, have confirmed improvements in health behavioural outcomes, compared to simple app interventions (Glynn et al., 2013). These findings have shown that higher mHealth app usage is related to developments in healthy eating and PA (Gilliland et al., 2015). Using theory-driven behavioural change techniques may be a promising approach to improving healthy eating and PA. Interventions are more likely to be effective if they are embedded in

health behavioural change theory (de Korte, Wiezer, Bakhuys, Vink, & Kraaij, 2018). However, most studies on mHealth apps were not grounded in behavioural change theory (Hedin, Katzeff, Eriksson, & Pargman, 2019; Jusoh, 2017; Vollmer, Fair, Hong, Beaudoin, Pulczinski, & Ory, 2015; Middelweerd, Mollee, van der Wal, Brug, & Te Velde, 2014; Direito et al., 2014). Health applications in which behavioural change was operationalised lack the use of theoretical concepts (Cowan et al., 2013; West et al., 2012; Breton, Fuemmeler, & Abroms, 2011). Thus, the use of theory and evidence is essential when designing mHealth applications envisioned to foster behavioural change (Abroms, Padmanabhan, Thaweethai, & Phillips, 2011; Rabin & Bock, 2011). So far, little evidence has been gathered on theoretical approaches in designing persuasive applications (Kelders, Kok, Ossebaard, & Van Gemert-Pijnen, 2012; Pinzon & Iyengar, 2012).

In Service-Dominant Logic (SDL), service or application is considered as the basis of exchange, and actors and other health application providers co-create value (Vargo & Lusch, 2016) and the SDL concept (application for users rather than goods) has been applied in the literature. Value propositions (VPs) define the cause of accepting the application (Lindic & Silva, 2011). On the other hand, to enhance health applications involving the relevant stakeholders (e.g., users, scientists, developers, clinicians, and consumers) is recommended (Conroy, Yang, & Maher, 2014). VPs are essential tools in interacting with the users and relevant stakeholders through guides and initiatives (Ballantyne, 2004). VPs convey relevant stakeholder (i.e., users') solutions by connecting them in a single platform (Gummesson, 2008). VP design has been applied, for example, for developing smart services in manufacturing (Neuhüttler, Woyke, & Ganz, 2018). One underlying concern highlighted is that mHealth projects are seldom designed from the perspective of the users to address their problems and create appreciable value, and VPs could serve to help relevant stakeholders to design and sustain appropriate and effective mHealth applications (Gorski, Bram, Sutermeister, Eckman, & Mehta, 2016). Therefore, VPs, as denominators, might enhance the efficacy of persuasive mHealth applications. There is no empirical evidence in the literature on using VPs to create value and incorporating theoretical constructs in persuasive applications to encourage a healthy lifestyle for the employees.

1.2 Research focus

This project involves users, fulfils their needs, and conducts interdisciplinary research in Finland, the United Kingdom (UK), Ireland, and Bangladesh to develop

sustainable persuasive applications for people working in offices. Many factors influence employees in remaining healthy and active in the workplace, e.g., rewards, self-determination, and interaction with colleagues. It is envisioned that persuasive mHealth applications using theoretical concepts will guide employees in maintaining healthy lifestyle actions. A feasible way for developing applications for a healthy lifestyle is to use established theories for healthy diet and exercise from current literature, in order to design an initial version of the prototype. No single theory can describe the complexity of human behaviour, as discussed previously in health intervention design studies (Head et al., 2014; Sniehotta et al., 2009; Resnicow & Vaughan, 2006). Utilising multiple theories for improved results has been recommended (Schaalma & Kok, 2009). The present study aimed firstly to fill the gap by developing interventions, and by incorporating state-of-the-art theories for the assessment of healthy eating and PA in the office environment. The project then utilises the persuasive applications to promote employees' healthy lifestyle actions in the working environment. Thus, this study seeks to answer the key research question:

What is the feasibility of persuasive mHealth applications in promoting employees' healthy lifestyle actions (healthy eating and physical activity) in the workplace setting?

1.3 Structure of the thesis

To answer the research question, four VPs have been proposed by adopting two original foundational premises (FPs) of SDL, to co-create value for persuasive mHealth applications. In a preliminary case study, this proposed VPs were validated by analysing two developed mHealth applications. These applications were developed by incorporating Elaborated Intrusion (EI) theory of desire for healthy eating promotion and self-determination theory (SDT) for PA promotion in the workplace. Once a prototype had been built, it was implemented among the selected users for a one-week evaluation testing. Once sufficient information from the users had been found, the final version of the prototype was regenerated. The design of the PA applications was followed by a user-centered design (UCD) process, according to the ISO standard 9241-210:2019 (ISO, 2019).

As a possible solution for improving eating habits, an mHealth application iCrave, has been developed, which allows users to track their snack cravings and enables them to record whether they choose to eat healthily or unhealthily, or

whether they forgo eating. The application assists users at the moment of desire for an unhealthy diet by fostering a craving-reduction imagery task and allowing them to record their subsequent choices. As a possible solution for improving PA, an mHealth application iGO has been designed and developed to support employees in promoting their physical activities, such as walking. It allows them to improve their PA and enables them to track whether they select PA by encouraging self-determination tasks and allowing them to save their choices.

The mHealth applications for healthy eating and PA were validated. An experimental study design with a mixed method (quantitative and qualitative) was carried out on a group of healthy adults to measure the feasibility of the applications empirically. The key actions of the participants (progress in achieving healthy eating, PA promotion) were measured, and the data from the applications were retrieved from the data server built into the applications. To analyse participants' data quantitatively, users were provided with questionnaires after using the applications. To obtain qualitative information, face-to-face interviews were conducted. The result of the study demonstrates that the design of the applications was a successful approach and could create the design space for future persuasive mHealth applications.

The flowchart of the thesis progression is presented in Fig. 1. The details of the work are presented in six sub-studies (I–VI). VPs for persuasive mHealth applications are proposed in Sub-study I, and a case study is presented in Sub-studies II and IV. In Sub-study I, the first author conducted the narrative synthesis literature review on SDL and proposed four key VPs for the persuasive and mHealth applications and the co-authors collaborated through their guidance.

Sub-study II is committed to designing and developing iCrave applications in the context of healthy eating, by incorporating the theoretical construct EI theory of desire, its implementation, and experimental evaluation. In Sub-study II, the second author (Md Sanaul Haque) was responsible for the research methodology part i.e., to conduct the main study, collecting the data through questionnaires fill up, interviewing participants, and analysing the data both quantitatively and qualitatively. The first author conducted the literature review, designed the study and developed the mHealth application with the collaboration of co-authors.

To promote PA in the workplace, an SDT theory-driven system model is proposed in Sub-study III. In Sub-study III, the first author conducted literature review and proposed a theory-driven gamified application model by utilizing Ryan's SDT theory model of behavioural change and applied UCD process to

prototype the app by involving the participants and developed a paper prototype. The co-authors collaborated through their guidance.

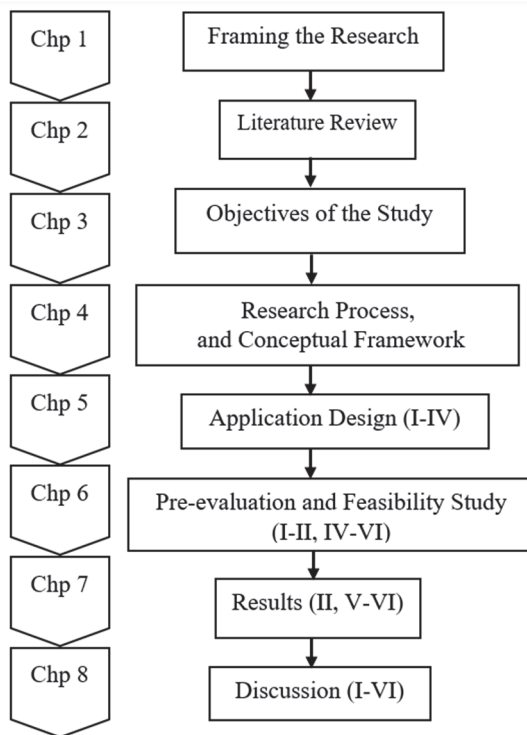


Fig. 1. Flow chart of the thesis progression.

Sub-study IV utilises the proposed system model to design, develop, implement, and evaluate iGO application in the context of PA. In Sub-study IV, the first author designed, executed and tested an application for improving physical activity behavior at workplace to motivate individuals for healthier behavior. The co-authors collaborated through their guidance.

The usability and feasibility results of the application are presented in Sub-Studies V and VI. In Sub-study V, the first author designed and conducted an eight-week long usability evaluation, using the UTAUT model to motivate individuals for healthier behavior towards physical activity. The co-authors collaborated through their guidance. In Sub-study VI, the first author designed and conducted a four-week feasibility study to promote physical activity in the workplace. The co-authors collaborated through their guidance.

2 Literature review

A literature review of the study is presented in this chapter. Firstly, the chapter describes healthy lifestyle. Then the chapter describes the value propositions in persuasive mHealth applications, and this includes value, value co-creation, and value propositions (VPs). Behavioural change intervention utilising mHealth has also been looked at. This includes healthy eating behavioural change intervention and physical activity behavioural change intervention. Next, the following are described: game-design elements, user-centered design (UCD) and unified theory of acceptance and use of technology (UTAUT). Lastly, feasibility of mHealth interventions are defined, and the gap in research is addressed.

2.1 Healthy lifestyle

Unhealthy lifestyle (unhealthy eating and physical inactivity) is one of the leading causes of non-communicable diseases such as cancer, heart disease, stroke, and diabetes (WHO, 2014; Lopez, Mathers, Ezzati, Jamison, & Murray, 2006). On the other hand, there is increasing recognition of the value of health-promoting lifestyle behaviours (Khaw et al., 2008). Improvement behaviours, for example, healthy eating and PA, are fundamentals for reducing the frequency of these types of disease (WHO, 2014). A recent study has demonstrated that employees who purchased the least healthy food from the hospital cafeteria were more likely to have an unhealthy diet outside work, be overweight or obese, and have risk factors for cardiovascular disease and diabetes, compared to employees who made healthier purchases (McCurley et al., 2019).

Technology-enhanced solutions can play a major part in maintaining health-promoting lifestyle behaviours (Pedersen, Halvari, & Williams, 2018; Joseph-Shehu & Ncama, 2017). Systematic reviews found beneficial effects of workplace nutrition interventions on employees' dietary behaviour and multi-component PA interventions to be effective in increasing their PA (Schroer, Haupt, & Pieper, 2014). Recently, mHealth solutions, specifically persuasive applications targeted at changing behaviours, have become well-known in the health domain (Chatterjee & Price, 2009). mHealth opens the possibility of health monitoring and can encourage healthy behaviours to prevent health problems, contribute to a change in people's lifestyle, and thereby improve their health (Boulos, Brewer, Karimkhani, Buller, & Dellavalle, 2014). Hence, technology-enhanced interventions are possible solutions to motivating people towards healthy lifestyles.

Much effort has been put into the development and evaluation of mHealth interventions, to help motivate employees to maintain healthy lifestyles in the workplace. Some related systems have been facilitated around selective actions to change people's attitudes, risks and behaviours, in addition to widespread interventions such as workplace health promotion programmes (Wierenga et al., 2013; Rongen et al., 2013; Chau et al., 2010).

Other related systems have been facilitated to promote an active lifestyle in lower-educated working young adults, and employees at certain universities. For example, to improve employees' health behaviours in terms of PA, Vanderbilt University has implemented a web-based incentive program known as Go for the Gold (GFTG) (Byrne et al., 2011). However, it is still unclear whether this type of program applied theoretical approaches and a standard design process when designing the application. Simons et al. (2018) highlighted utilising the attitude-social influence-self-efficacy (ASE) model (De Vries, Backbier, Kok, & Dijkstra, 1995) to develop an mHealth app for healthy lifestyle promotion.

However, research demonstrates that while workplace-based interventions may be useful, not all these interventions are beneficial, or the overall effects are minor (Rongen et al., 2013; Wierenga et al., 2013; Lamotagne et al., 2013; Chau et al., 2010; Bhui, Dinos, Stansfeld, & White, 2012; Hamberg-van Reenen, Proper, & Van den Berg, 2012; Cancelliere, Cassidy, Ammendolia, & Côté, 2011; Speklé et al., 2010; Richardson & Rothstein, 2008; Van der Klink, Blonk, Schene, & Van Dijk, 2001). This type of intervention is not designed and developed specifically to support employees in the workplace in maintaining healthy lifestyles through healthy eating and physical activity. Hitherto, little empirical evidence has been gathered on the types of support valued by employees in the workplace. None of the systems consider applying the combination of VPs, multiple theories (e.g., the EI theory of desire and the SDT effects on the need of autonomy, competence and relatedness), and a standard design thought process.

2.2 Value propositions in persuasive mHealth applications

To drive mHealth applications, measurement and improvement of perceived value have been suggested, but the value itself remains often misunderstood (Porter, 2010). If value improves, users (customers, consumers, patients, actors, etc.) can benefit, as well as the sustainability of the applications (Porter, 2010).

The terms "value," "value creation" and "value co-creation" are very popular in market research. Market researchers use these concepts when aiming to fulfil the

user and other stakeholders' true needs and wants. Since increasing the value of a service also increases user and other stakeholders' benefits of that service, the study of value has also been appreciated in health science of late (Lusch & Vargo, 2014). It is important to find the VPs of persuasive mHealth applications that help to create better value for users and other stakeholders.

2.2.1 Value

Value of a product or service is the trade-off between benefits received and sacrifices made by an individual (Zeithaml, 1988; Woodruff & Gardial, 1996). Value is the residual benefit after subtracting sacrifices. This explains value from the perspective of benefitting an individual who might be a customer, patient or end-user. Value in the healthcare sector is defined through the relationship with the quality of health and wellbeing services and the incurred costs. Costs have been referred as the economic aspect of value. Value is the user and other stakeholders' oriented health outcomes relative to costs of health and wellbeing services (Porter & Teisberg, 2006; Porter, 2010). Value is increased by the enhancement in service quality (HFMA Report, 2011). Later, scholars substituted the term "benefits" with "experiences". Value should be recognised in the context of user and other stakeholders' experiences. Experience is the basis of the value concept (Heinonen & Strandvik, 2009). Thus, value is defined as a positive experience obtained by users and other stakeholders. Users sense positive experiences through receiving services from service providers.

On the other hand, other stakeholders, for example, service providers, sense positive experiences through delivering positive services to users. Through consumption/using a service, the value is realised and the use of the value is actualised (Grönroos, 2008). Value is embedded in the user and other stakeholders' everyday experiences (Heinonen, Strandvik, & Voima, 2013). Value is a benefit or an increase in one's wellbeing, which is perceived and determined by the users and other stakeholders while using and delivering a product or a service (Lusch & Vargo, 2014); and this derived definition of value has been used in the present study, as it is more applicable to the research contexture. In this current study, service relates to the persuasive mHealth applications that are meant to be provided to users and the services that are delivered by service providers.

A positive experience can result in increased customer (user) satisfaction, which leads to a competitive advantage (Westmonroe Report, 2015). User satisfaction means the extent to which the mHealth applications meet user

expectations. User satisfaction reflects the expectations and experiences that the user has with a service or application. Expectations reflect both past and current product (service or application) evaluations and user experiences. However, the users' positive experiences can be measured by capturing the user satisfaction that reflects the interpersonal care experience, for example, user-service provider communication (correlated with the mHealth applications and measurement of quality). The quality of health and wellbeing services should include assessments among the user and health service providers (i.e., other stakeholders), in order to gain a common understanding of users' situations (Parasuraman, Zeithaml, Valerie, & Berry, 1988). Although experts place more emphasis on users in defining value, value has different definitions from the perspectives of various stakeholders, for example, employers' value, providers' value, and manufacturers' value. Competitive labour costs motivate employees in healthcare cost control and transformation. The healthcare application should be user-focused (Sepulveda & Darling, 2012). Waste exists in the healthcare delivery application (Skinner, Elliot, & Wennberg, 2005). Employers' value stands for reducing healthcare spending. Relevant stakeholders must be bold in their efforts to increase the value obtained from health care, and to increase value, healthcare systems should be focused on delivering higher quality, effective, and efficient health and wellbeing services. From the perspective of providers, for example, physicians, value can be described as the reduction of cost that improves the quality of mHealth applications. The Institute of Medicine has formed a cohesive model that cost is placed in the context of quality, and quality is defined as reducing the misuse, underuse and overuse of the health and wellbeing services (Yong, Olsen, & McGinnis, 2010). Healthcare advisors focus on longitudinal outcomes to improve value, particularly in reducing the overuse and misuse of applications (Yong et al., 2010). The quality and cost data of mHealth applications should be accessible to providers. Therefore, well-structured payment layout and information delivery are vital for leveraging value among providers. Payers understand value from the patients' perspective, for example, developing applications for patients (technological innovations relate to improved health) that can be achieved through educating relevant stakeholders on safe and effective mHealth applications (Yong et al., 2010). Value from the perspective of user and other stakeholders' experience, quality of service (i.e., reducing misuse), and the underuse and overuse of the mHealth applications or services have been highlighted (Lusch & Vargo, 2014; Heinonen & Strandvik, 2009; Porter & Teisberg, 2006).

2.2.2 Value co-creation

Value co-creation has been highlighted by SDL (Vargo & Lusch, 2016). This is a process in which health and wellbeing application providers, users, and others actively work together to create value for the users (Grönroos, 2008). Co-creation of value is an interactive process of offering opportunities to users by bringing together a group of actors (Jacob, 1992). Value co-creation has been highlighted by SDL, which is constructed on 11 foundational premises (FPs) (Vargo & Lusch, 2016). Eight of these FPs were placed in the initial SDL concept (Vargo & Lusch, 2004). Later, two of the new FPs (Vargo & Lusch, 2008) were added to the initial SDL concept (Vargo & Lusch, 2004). Moreover, one further FP has recently been added (Vargo & Lusch, 2016). The five original FPs (FP1, FP6, FP9, FP10, and FP11) are called axioms and the other six are derived from these for the essence of SDL (Table 1). Users communicate with health and wellbeing application providers at each stage of the application design and delivery (Ballantyne, 2004). Users can sense a positive experience through the value creation process of health and wellbeing applications. The co-creation of value approach meets the needs of users.

Table 1. SDL foundational premises and axioms².

Axioms	FP ¹	Description
Axiom 1	FP 1	Service is the fundamental basis of exchange
	FP 2	Indirect exchange masks the fundamental basis of exchange
	FP 3	Goods are a distribution mechanism for service provision
	FP 4	Operant resources are the fundamental source of strategic benefit
	FP 5	All economies are service economies
Axiom 2	FP 6	Value is co-created by multiple actors, always including the beneficiary
	FP 7	Actors cannot deliver value but can participate in the creation and offering of the VP
	FP 8	A service-centered view is inherently beneficiary oriented and relational
Axiom 3	FP 9	All social and economic actors are resource integrators
Axiom 4	FP 10	Value is always uniquely and phenomenologically determined by the beneficiary
Axiom 5	FP 11	Value co-creation is coordinated through actor generated institutions and institutional arrangements.

¹ Foundational premises; ² axioms and description adopted from Vargo & Lusch, 2004; Vargo & Lusch, 2008; Vargo & Lusch, 2016.

2.2.3 Value propositions

Users take part in creating and offering the VPs (Ballantyne, 2004). Actors cannot deliver value but participate in the creation and offering of VPs (Ballantyne, 2004).

This indicates that users in health applications participate in creating and offering VPs. Involving users and communities is necessary for improving health and wellbeing applications (KPMG, 2014). Ryhov Hospital and Jönköping County Council, Sweden, initiated the idea of “Esther” to change health-oriented applications. This represented the importance of care redesign that focuses on user needs and preferences and established and deployed VPs in improving health applications (Schnarr, Alessi, & Schnarr, 2014). Health application providers are facing difficulties in improving applications, for example, in the cost and quality of applications (Vargo, Maglio, & Akaka, 2008). Collaborating with users and relevant stakeholders to create value has been considered as a challenge (Grönroos, 2008).

Related work on value propositions

Health Technology Assessment (HTA) (HTA, 2014) is widely used in the European Union (EU) to seek answers to the key issues: Does technology work? For whom does it work? What is the benefit to the individual? At what cost? How does it compare to alternatives? To address these issues, HTA consults with a range of stakeholders. HTA focuses on nine domains (health problem, technology description, clinical effectiveness, safety, cost-effectiveness, ethical concerns, organisational aspects, social impacts, legal issues) (HTA, 2014). HTA may be a complicated approach to assessing health technology. Some of the domains are closely related to proposed VPs, for example, technology description, cost-effectiveness, and patient satisfaction. HTA does not consider the engagement of users or empirical measurement but practiced expert validation. It aims to use the theoretical concept and empirical approach. However, empirical evidence in the literature is unclear on the use of VPs to create value, and incorporating theoretical constructs in persuasive applications, to encourage a healthy lifestyle for employees. VPs may be proposed and evaluated into persuasive applications, such as mHealth behavioural change interventions for healthy eating and PA promotion.

2.3 Behavioural change intervention utilising mHealth

In a movement towards more psychologically-inspired design, recent persuasive mHealth applications have begun to apply theories and strategies from psychology and health research (Brown, Chetty, & Harmon, 2012; Maitland & Chalmers, 2011; Lee, Kiesler, & Forlizzi, 2011; Maitland, 2011; Consolvo, McDonald, & Landay,

2009; Torning & Kukkonen, 2009). While knowledge of context-general psychological principles is highly useful for persuasive design, it is also essential to understand the specific psychological constructs that underlie the behaviours in a particular design context. Recent work has suggested that context-specific psychological constructs can be usefully investigated from the perspective of a decision theory framework (Hsu & Blandford, 2014). Decision theory explains how behavioural choices are underpinned by psychological rewards and costs valuations (Fehr & Rangel, 2011). Behaviours are chosen when they are associated with greater rewards and fewer costs. This notion of rewards and costs is fundamentally a hedonistic concept, relating to emotional experiences of pleasure and displeasure in the brain. An understanding of the rewards and costs associated with healthy and unhealthy behaviours can inform the design of persuasive mHealth applications: systems can then aim to increase the rewards and decrease the costs associated with healthy behaviours.

Technology is a useful tool for supporting behavioural change, for example, PA through persuasion. Two types of behaviour (intrinsic and extrinsic) influence the techniques of persuasion. Intrinsic behaviours persuade individuals through internal motivators, for example, the good feeling associated with being healthy; and extrinsic behaviours persuade individuals through external motivators, for example, winning badges as rewards for achieving tasks. Persuasive applications focus largely on external behaviour (Rogers, 1995), for example, a tracker for exercise (Brown et al., 2012), which is convenient and influencing.

It is essential to evaluate the effectiveness of mHealth applications (Conroy et al., 2014). Although mHealth is growing, the evidence for efficacy is still limited (Marcolino et al., 2018). Modest evidence has been found for the effectiveness of mHealth behavioural change interventions in the improvement of healthy eating and PA (Schoeppe et al., 2016). Studies involving interventions that used an mHealth application along with other intervention approaches have confirmed improvements in health behavioural outcomes, compared to the use of simple app interventions (Glynn et al., 2013). These findings show that higher mHealth application usage is related to developments in healthy eating and PA (Gilliland et al., 2015). Moreover, scholars and researchers recommended that to initiate and maintain behavioural change, multiple health applications are necessary for the users.

In order to benefit from an intervention (Davis, Campbell, Hildon, Hobbs, & Michie, 2014), it is vital to have a theoretical understanding of the behavioural change. Using theory-driven behavioural change techniques may be a promising

approach to achieving improvements in healthy eating and PA among employees in the workplace. However, most existing mHealth apps are not grounded in behavioural change theory (Vollmer et al., 2015; Middelweerd et al., 2014; Direito et al., 2014). Health applications in which behavioural change is operationalised often lack the use of theoretical concepts (Cowan et al., 2013; West et al., 2012; Breton et al., 2011). Thus, the use of theory and evidence is essential when designing mHealth applications envisioned to foster behavioural change (Abroms et al., 2011; Rabin & Bock, 2011). There are, however, limitations that have been found in utilising theoretical approaches in designing persuasive applications (Kelders et al., 2012; Pinzon & Iyengar, 2012). Applying these theoretical approaches is a relatively new domain for the healthy lifestyle actions in the workplace. Moreover, involving relevant stakeholders (e.g., users, developers and scientists) is a key to enhancing health applications (Conroy et al., 2014). Previous studies have failed to extensively examine persuasive mHealth applications in facilitating a healthy lifestyle (Hamari, Koivisto, & Pakkanen, 2014).

2.3.1 Healthy eating behavioural change intervention

A previous study used such a decision-theoretic approach to investigate the psychological constructs that discouraged and encouraged weight management behaviour (Hsu & Blandford, 2014). It was found that the need to restrict the pleasure of eating was one of the most widely experienced struggles involved in weight loss. On the other hand, another widely expressed view was that people felt noble after resisting food temptations and making healthy choices. They felt pride and satisfaction associated with being good to themselves and having self-control. It was wished to design an application that addressed both of these psychological weight loss constructs: to help people with their struggle against food temptations, while simultaneously enhancing their ability to feel good about healthy choices. As a method of reducing the difficulty of unhealthy temptations, this study considered research on the psychology of cravings, which describes both how cravings may be sustained in the mind and how they can be reduced. This is known as the elaborated intrusion (EI) theory of desire (Andrade, Pears, May, & Kavanagh, 2012; May, Andrade, Batey, Berry, & Kavanagh, 2010; Kemps & Tiggemann, 2007; Harvey, Kemps, & Tiggemann, 2005) and is described briefly below.

Elaborated Intrusion (EI) theory of desire

The EI theory of desire is a theory concerned with how appetitive cravings (including food) are sustained through cognitive processes (Hamilton, , Fawson, May, Andrade, & Kavanagh, 2013; May, Andrade, & Kavanagh, 2012; Andrade et al., 2012; Knauper, Pillay, Lacaille, McCollam, & Kelso, 2011; May et al., 2010; Kemps & Tiggemann, 2007; Harvey et al., 2005; May, Andrade, Panabokke, & Kavanagh, 2004). This theory suggests that cravings involve a cycle of mental elaboration of an initial intrusive thought (Kavanagh, Andrade, & May, 2005) (Fig. 2).

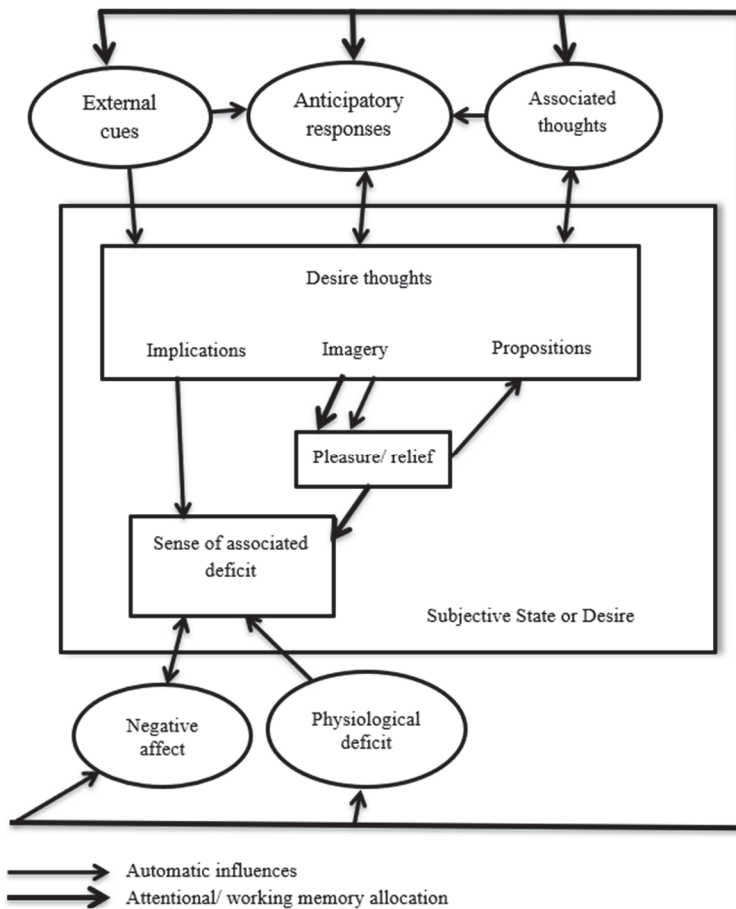


Fig. 2. The EI theory of desire (Kavanagh et al., 2005).

Because these thoughts are initially pleasurable, the individual is motivated to elaborate the thought and sustain the craving by retrieving cognitive associations and creating mental imagery of the target. Imagery sustains motivation, since it is emotionally charged (Holmes & Mathews, 2005; Bywaters, Andrade, & Turpin, 2004). These mental imagery elaborations recruit working memory functions and may include the senses of sight, taste, touch, and hearing. Because cravings are thus presumed to be sustained through specific cognitive processes, the EI theory of desire proposes that an alternative task that recruits similar mental resources could conversely disrupt the elaboration of desire-related intrusive thoughts and thus reduce cravings (May et al., 2012). Consistent with this idea, many studies have found that engaging in visual or olfactory imagery minimises the strength of food cravings, both for cravings induced in the lab (Hamilton et al., 2013; Kemps & Tiggemann, 2007; Harvey et al., 2005) and naturally occurring “in the wild” (Knauper et al., 2011). In contrast, auditory imagery tasks were not found to reduce cravings. While the above results are promising, they only measured the self-reported decrease in craving levels, and effects on consumption were not assessed.

2.3.2 Physical activity behavioural change intervention

The UK National Institute for Health and Care Excellence (2007) concluded that interventions were more operative if they were variables simultaneously targeted at the individual and community level (Abraham et al., 2009). Consequently, to make the most of effective intervention, a selective behavioural change theory from the established theories can be selected to reflect specific contexts (Glanz & Bishop, 2010) in designing the mHealth behavioural change interventions, for example, a persuasive mHealth application for PA.

Persuasive applications have been designed for psychological encouragement, such as displaying a virtual garden to persuade emotional connection to the personal level of PA (Baumer et al., 2012). Promoting physical activities through a persuasive application is a potential way to support a person’s healthier lifestyle, for example, by sending them a reminder to do exercises and monitoring the daily data about their health condition. It is shown that physical activities increase work productivity (Croce & Horvat, 1992). The evaluation of the usefulness of health applications to encourage PA has been recommended (Middleweerd et al., 2014). State-of-the-art behavioural change efforts are essential for increasing PA promotion (Robertson et al., 2017). However, mHealth apps are not generally

grounded in behavioural change theory (Vollmer et al., 2015; Direito et al., 2014), such as SDT.

Self-determination theory (SDT)

Two motivational approaches are accepted by the human, namely intrinsic and extrinsic motivation (Deci & Ryan, 2000). According to SDT, people can be intrinsically and extrinsically motivated to act (Deci & Ryan, 2002; Deci & Ryan, 2008). An intrinsic level of motivation is completed through the fulfilment of the three psychological needs of autonomy, competence, and relatedness (Fig. 3). *Autonomy* shows a sense of having the option to measure social environment and distributing selections that conform to carrying out a daily task (Deci & Ryan, 2002). *Competence* indicates a sense of completing the task in a social environment. *Relatedness* specifies the feeling of working to connect with others (Niemiec, Ryan, & Deci, 2010). Hence, SDT is a potential method for overcoming the challenges of physical inactivity in the work environment and a lack of social interaction among employees. Workers can be motivated intrinsically, that is, they feel gratified in performing their daily walking routine. Then, they are extrinsically more motivated to complete their PA task, since they want to finish the job, for example, they can track their progress through being awarded points and badges based on a leaderboard (PBL), while carrying out their daily walking. However, employees who are unmotivated may not demonstrate an awareness to perform any level of their daily PA task. Thus, intervention strategies that are purported to satisfy the three needs of SDT might encourage positive behavioural change (Fortier, Duda, Guerin, & Teixeira, 2012).

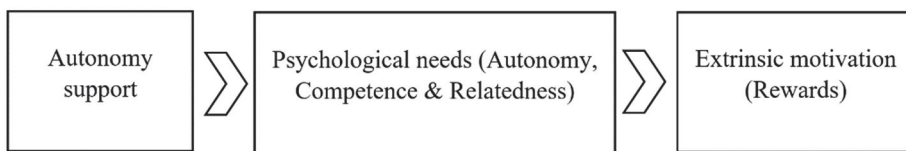


Fig. 3. SDT sequence (Deci & Ryan, 2000).

2.4 Game-design elements

Gamification is the use of game design elements in non-gaming contexts (Deterding, Sicart, Nacke, O’Hara, & Dixon, 2011) and motivating individuals by

making their experience more fun and playful (Deterding, Björk, Nacke, Dixon, & Lawley, 2013). Human behaviour is motivated by extrinsic aspects such as incentives or rewards (Garbers & Konradt, 2014; Govindarajulu & Daily, 2004). The reward is offered to “an individual as a result of the accomplishment of a specific task or the achievement of a target behaviour” (Deci & Ryan, 2008). This acts as the construct to measure how to fit the reward, as an approach can persuade individuals to perform a target behaviour. The use of virtual points and badges, etc., is a way of representing rewards (Oyibo & Vassileva, 2017). Furthermore, competition is a persuasive technique derived from the theory of competition (Oinas-Kukkonen & Harjumaa, 2009), referring to “the act of seeking or endeavouring to gain what another is endeavouring to gain at the same time” (Mead, 2002). The leaderboard is a way of representing competition in which user activity is demonstrated (Orji, Vassileva, & Mandryk, 2014). The implementation of rewards is a practical way to foster user behaviour in non-gaming contexts (Mekler, Brühlmann, Opwis, & Tuch, 2013). In PA research, points, badges (Chen & Pu, 2014; Thorsteinsen, Vittersø, & Svendsen, 2014; Zuckerman & Gal-Oz, 2014; Riva, Camerini, Allam, & Schulz, 2014; Spillers & Asimakopoulos, 2014; Kuramoto, Ishibashi, Yamamoto, & Tsujino, 2013; Reynolds, Sosik, & Cosley, 2013) and leaderboards (Chen & Pu, 2014; Thorsteinsen et al., 2014; Zuckerman & Gal-Oz, 2014; Spillers & Asimakopoulos, 2014; Kuramoto et al., 2013) (PBL) can persuade individuals to complete a specific activity.

2.5 User-centered design

User-centered design (UCD) is an iterative application design process that focuses on how the users use the application (Stanford Report, 2016). According to researchers, UCD is a design process that suggests inserting the needs of end-users within the foundation of design and development, by including users early in the different stages of the software lifecycle (Smáradóttir et al., 2016). UCD typically uses different terms from those used in design thinking, but with similar operational characteristics. It consists of five steps: *empathise*, *define*, *ideate*, *prototype*, and *test* (Fig. 4). *Empathise* is described as a sense of understanding when answering a problem. *Define* indicates making sense of the information collected from the empathise step and concludes with a problem statement, that is, a point-of-view (POV). *Ideate* focuses on creating ideas for designing prototypes that fit users’ recommendations and needs. Examples of ideation are body-storming, mind-mapping, and sketching. *Prototype* denotes an initial stage of an application release.

This prototype can be a hard copy/paper object (or an interactive display in smart devices) to support creating the final design. *Testing* confirms that the prototype and results are polished, reconnoitring the needs of the users and clarifying the POV. Multiple ideas were considered to build a prototype by using several game elements. Ideation occurred at this time leading to prototyping to generate the final design. Few participants then tested the prototype.

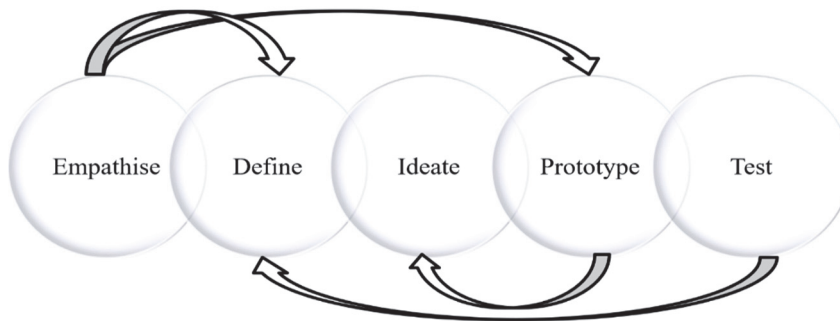


Fig. 4. User-centered design process (Interaction design, 2019).

2.6 Unified theory of acceptance and use of technology

The unified theory of acceptance and use of technology (UTAUT) model was formulated by integrating eight technology acceptance models (Venkatesh, Morris, Davis, & Davis, 2003). These include: the theory of reasoned action (Fishbein & Ajzen, 1975), social cognitive theory (Bandura, 1986), the technology acceptance model (Davis, 1989), the theory of planned behaviour (Ajzen, 1991), the model of PC utilisation (Thompson, Higgins, & Howell, 1991), the motivational model (Davis, Bagozzi, & Warshaw, 1992), the combined-technology acceptance model-theory of planned behaviour (Taylor & Todd, 1995) and the innovation diffusion theory (Rogers, 1995). The UTAUT model leverages individual acceptance of individual research by combining the theoretical technology acceptance models from the literature. It incorporates four moderators to justify for dynamic influences, including age, gender, voluntariness, and experience. According to UTAUT, the use of technology can be influenced by the four key constructs: *performance expectancy*, *effort expectancy*, *social influence*, and *facilitating conditions* (Table 2). Factors performance expectancy, effort expectancy, and social influence affect the users' behavioural intention. Facilitating conditions and behavioural intention

influence the actual use of the technology (Venkatesh et al., 2003), such as a persuasive mHealth application.

Table 2. UTAUT four key constructs¹.

Four constructs of UTAUT	Definition
Performance expectancy	“The degree to which an individual believes that using the system will help him or her attain gains in job performance”
Effort expectancy	“The degree of ease associated with the use of the system”
Social influence	“The degree to which an individual perceives that important others believe he or she should use the new system”
Facilitating conditions	“The degree to which an individual believes that an organizational and technical infrastructure exists to support the use of system”

¹ Adopted from Venkatesh et al., 2003

2.7 Feasibility of mHealth interventions

Early conceptual models of health education (Green, Kreuter, Deeds, Partridge, & Bartlett, 1980) and contemporary versions of health promotion (Bartholomew, Parcel, Kok, & Gottlieb, 2006) indicate that interventions should prioritise changeable behaviours; focus on empirical-evidence linking behaviour to health; be related to the users; and have the potentiality to meet the goals of the interventions. On the other hand, effectiveness studies can be regarded as evaluating success in the practical context, non-ideal conditions (Greenwald & Cullen, 1984). Due to resource constraints, not all of the interventions can be examined for both efficacy and effectiveness. Proper guidelines are necessary for assisting the evaluation and focus of those interventions with the greatest likelihood of being effective (Bowen et al., 2009). Feasibility studies are relied on to deliver a set of findings which help to determine whether an intervention should be proposed for efficacy testing (Bowen et al., 2009). In recent times, feasibility testing has become popular in the context of fostering mHealth interventions (Vereenoghe & Westermann, 2019; Guo et al., 2018; Caplan, Lovera, & Liberato, 2018; Jonassaint, Shah, Jonassaint, & De Castro, 2015). To conclude, a feasibility study can examine the practicability of the mHealth interventions and determine if the interventions will support users in promoting their needs, for example, maintaining healthy lifestyle actions.

2.8 Gap in research

It has been criticised that the majority of mHealth interventions provide no evidence for their effectiveness or feasibility (Lindhiem, Bennett, Rosen, & Silk, 2015). There is a need for evidence from rigorous experiments to study the effectiveness of mHealth interventions (Hollis et al., 2017), and furthermore, to research how best to integrate these mHealth applications into support provision (Montague, Varcin, Simmons, & Parker, 2015). To design experiments for effectiveness, feasibility tests are vital (National Institute for Health Research, 2017). The present study has been adhered to the recommendations for thorough feasibility testing (Leon, Davis, & Kraemer, 2011; Lancaster, Dodd, & Williamson, 2004) and performed preliminary work needed to notify the study design, find, and rectify possible shortcomings in study procedures and measurement.

3 Objectives of the study

The main objective was to develop and evaluate the feasibility of persuasive applications incorporating state-of-the-art theories for the assessment of behavioural change, especially related to healthy eating and PA, in the office environment. The specific aims were to:

1. Propose key VPs for the persuasive mHealth applications.
2. Design and develop persuasive application incorporating the EI theory of desire for healthy eating, and to evaluate the feasibility of the application to improve eating behaviours.
3. Propose a theory-driven system model for developing a persuasive mHealth application, incorporating the SDT theory and UCD process for PA.
4. Develop a persuasive mHealth application for encouraging PA behavioural change in the workplace.
5. Evaluate the usability of a persuasive mHealth application in promoting PA in the workplace.
6. Study the feasibility of a persuasive mHealth behavioural change intervention in promoting PA in the workplace.

These aims were formed to answer the following research sub-questions:

RQ1. What are the key VPs for persuasive mHealth applications? (I)

RQ2. Is it possible to integrate a theoretical construct in designing persuasive mHealth application; and to what degree does this application change eating behaviours? (II)

RQ3. Is it possible to incorporate a theoretical concept in designing a gamified mHealth system model for employees' PA promotion? (III)

RQ4. Is it possible to integrate a theoretical construct in designing persuasive mHealth application; and can this application change PA behaviour? (IV)

RQ5. What are the effects of using a persuasive mHealth applications in promoting PA? (V)

RQ6. What is the likelihood of the persuasive mHealth application in motivating employees to increase their daily walking in the workplace? What are the

employees' views of the application regarding the SDT's three basic needs in their daily walking promotion? (VI)

4 Research process and conceptual framework

This chapter is two-fold. Firstly, the chapter describes how the existing Peffers' design science research process model (Peffers et al., 2006) has been utilised to scaffold the research methodology for the present study. The chapter then describes the conceptual framework of the PhD project through the lens of Peffers' model.

4.1 Adopting Peffers' design science research process model

Following Peffers et al. (2006), the design research process typically consists of six phases: 1. Problem identification and motivation; 2. Objectives of the solution; 3. Design and development, 4. Demonstration; 5. Evaluation; and 6. Communication. These are briefly outlined (Fig. 5).

4.1.1 Problem identification and motivation

An unhealthy lifestyle (unhealthy eating and sedentary behaviour or insufficient PA) is a general problem. People spend a large part of their day in the office (Van der Klink et al., 2001) and thus working hours or working environment play a big role in everyday life (Ryan, Dall, Granat, & Grant, 2011). For example, eating more food in general and eating junk or unplanned food in the workplace are key concerns (Leung, Barber, Burger, & Barnes, 2018). Data from industrialised countries, including Sweden, the United States of America and Australia, suggest that increased sedentariness in the workplace is an international phenomenon (Straker & Mathiassen, 2009). mHealth solutions targeted at changing behaviours are a possible solution, but current applications are not grounded in scientific methods, such as theoretical concepts. To motivate employees towards healthy lifestyle promotion, theory-driven behavioural change techniques were utilised to encourage improvements in healthy eating and PA among employees in the workplace.

4.1.2 Design and development

To develop persuasive mHealth applications, firstly, four VPs were proposed by adopting two original FPs of SDL, axiom FP6 (A2) and FP10 (A4) (Vargo & Lusch, 2016; Vargo & Lusch, 2008; Vargo & Lusch 2004), to co-create value for mHealth applications (I). A preliminary case validated the proposed VPs (I), by analysing

the two developed mHealth applications. These applications were developed by incorporating theoretical bases, that is, the EI theory of desire (Kavanagh et al., 2005) for the healthy eating promotion-based app ‘iCrave’, and SDT for the PA promotion-based app ‘iGO’.

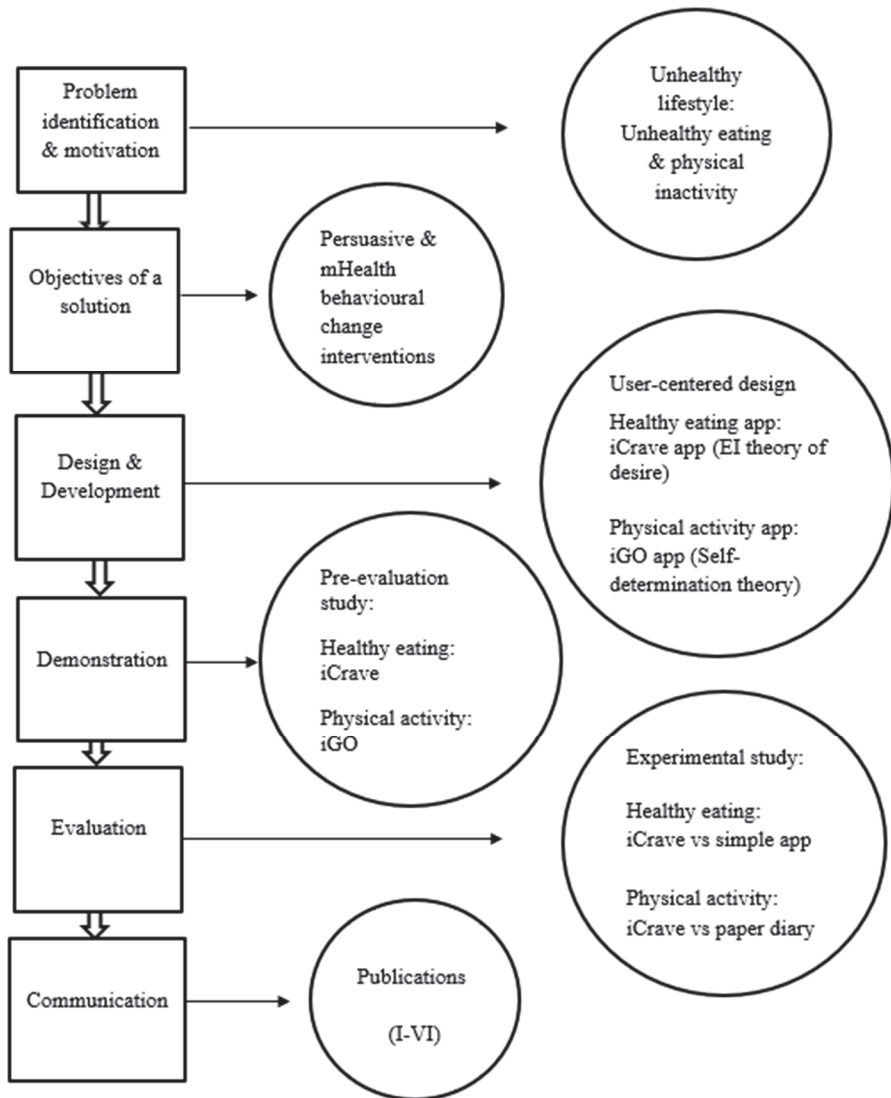


Fig. 5. Adopting the design science research process model (Peppers' et al., 2006) and possible research entry points.

Once a prototype had been built, it was implemented among the selected users for one-week evaluation testing (II, IV). Once sufficient feedback had been collected from the users, the final version of the prototype was regenerated. The design of the application was followed by a UCD process. The UCD iterative process (*empathise, define, ideate, prototype, and test*) was incorporated, whereby employees as target users were brought to bear on the task of developing feasible ideas for a new PA-based mHealth application (III).

4.1.3 Demonstration

A preliminary study of the prototypes was conducted. Users (N = 23 for iCrave and N = 26 for iGO) used the applications for a week, and their eating and regular PA behavioural changes were assessed (II, IV). Individual semi-structured interviews were conducted, focusing on the value of the applications. The results demonstrated that the persuasive health and wellbeing applications could improve the healthy diet and PA behaviour of the users, involving them and their needs.

4.1.4 Evaluation

To evaluate the iGO app for healthy eating, an experimental study design was carried out on a group of employees for a week. They were randomly assigned to one of two groups: the experimental group used the iCrave app, and a control group used a simple application during weekdays for a week (II). Similarly, to evaluate the iGO app, firstly, an eight-week long usability evaluation of the application was conducted, using the UTAUT model (V). Afterwards, an experimental study design was carried out on a group of employees. Participants were randomly assigned to one of two groups: the experimental group used the iGO app, and the control group used a paper diary during the weekdays for four weeks (VI).

4.1.5 Communication

The results of the study were successfully reported in reputable scholarly international peer-reviewed publications and conferences/workshops, including: Precision Medicine Powered by pHealth and Connected Health, ICBHI 2017 (I); SIGCHI Conference on Human Factors in Computing Systems (II); Data-Driven Gamification Design Workshop; MINDTREK 2017 (III); International Conference on Medical Engineering, Health Informatics, and Technology, MEDITEC 2016

(IV); Personalization in Persuasive Technology Workshop, Persuasive Technology 2018 (V); and a journal paper at JMIR Formative Research (VI). Furthermore, other publications based on a doctoral consortium paper, an abstract and a poster paper were presented at various reputable conferences, such as: MUM 2017 (Germany); STEPsCON 2018 (Germany); NORDOC 2018 (Finland); and QUIS 2019 (Sweden).

4.2 Conceptual framework

Firstly, the key VPs for the persuasive mHealth applications were proposed. Secondly, the iCrave for healthy eating was designed and developed. Lastly, the iGO for PA was designed and developed. A more detailed description can be found below and, in the papers, (I–VI). Fig. 6 presents the conceptual framework for the PhD project, through the lens of Peffers' model (Peffers et al., 2006).

A literature review was conducted to identify key VPs. From established theories in the research domain, the EI theory of desire was applied to design and develop the healthy eating application iCrave, followed by the UCD iterative process. The iCrave prototype was pre-evaluated during the course of a one-week study period, after which a one-week feasibility study was conducted, using experimental design on users.

Similarly, SDT was applied to design and develop the PA application iGO, followed by the UCD iterative process. The iGO prototype was implemented for one-week pre-evaluation testing. The working version of the application was utilised to conduct a usability study for eight weeks and then a feasibility study for four weeks. The pre-evaluation studies for the iGO and iCrave applications were used to validate the proposed VPs through a case study with the built applications. In the feasibility study, participants in the experimental group used the iGO application, whereas participants in the control group used a paper diary. During the feasibility study, the mixed-method (quantitative and qualitative) approach was applied. Pre-questionnaire form, before using the applications (except for the physical activity application), and post-questionnaire form, after using the applications, were employed for quantitative analysis. To obtain qualitative information, face-to-face interviews were conducted.

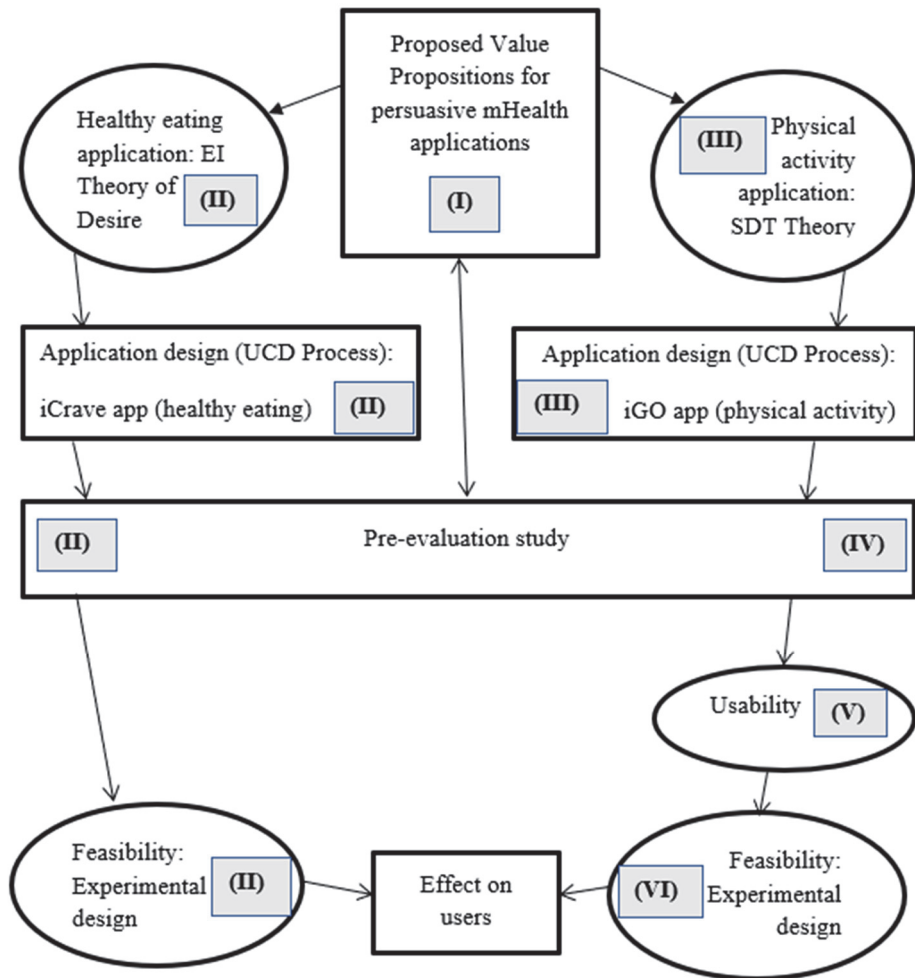


Fig. 6. Conceptual framework of the Ph.D. project through the lens of Peffers' model.

5 Application design

The application design chapter is manifold. Firstly, the chapter describes how the key VPs were identified. The details of the work are presented in Sub-study I. Secondly, it outlines how the game elements (rewards) were utilised and the psychological theory (the EI theory of desire) that was incorporated to develop the lite prototype of the iCrave app for improving eating behaviour. The details of the work are presented in Sub-study II. Thirdly, the chapter describes how the game elements (PBL) were applied and how an established psychological theory (SDT) was incorporated to propose a gamified system model. The chapter then outlines how this proposed persuasive and gamified system model was utilised to develop a low-fidelity paper prototype of an app using design thinking technique (i.e., the UCD process) for PA promotion. The details of the work are presented in Sub-study III. The results of the study led to the conducting of a second iteration of the UCD, that is, redeveloping the mid-fidelity working version of the iGO prototype and testing it on users for a week, as part of a pre-evaluation study. The details of the work are presented in Sub-study IV. Lastly, the chapter describes how the second iteration of the UCD was utilised to develop the working version of the app, and how it was tested on users by means of quantitative and qualitative approaches.

5.1 Identifying key value propositions (I)

From these original foundational premises of SDL, axiom FP6 (A2) and axiom FP10 (A4) (Vargo & Lusch, 2016; Vargo & Lusch, 2008; Vargo & Lusch 2004), were adopted in this study, since these FPs target dedicated users to determine the value (Table 1). To identify VPs, a literature search was conducted through several databases, keywords and eligibility criteria (i.e., inclusion and exclusion criteria) and the articles were verified for selection for further analysis. The inclusion criteria were as follows: studies published in the English language; accessibility with full text; research examining the influence of values on applications focusing on health and wellbeing; and the effect of values in the context of application tools to support health and wellbeing. Hence, a narrative literature review approach was used and 13 unique studies were selected and searched on the online repository systems: ACM Digital Library, Science Direct, Web of Science, Scopus, and EBSCO, using the combination of search terms “value”, “VPs” and “VPs and health”. The second literature search specifically targeted papers in the context of health-based information systems. From these two types of literature searches,

articles were chosen based on whether they imitated VP in the persuasive health and wellbeing applications. The approach was conducted through careful reading of each article. Although these articles did not prompt an exact value, they were matched and searched under the terms “value” and “VP”. The values useful to the users were then selected. A similar value was coined out from several articles and marked as a sole VP. Four values grouped into four broader classes were marked and categorised based on their relativity. Each VP was identified by resembling user benefit within the persuasive health and wellbeing applications (Table 3). The identified key VPs are summarised in Table 3. More details are given in Sub-study I.

Table 3. Proposed four VPs for persuasive mHealth applications.

VPs	Description
Service Effectiveness and Efficiency Focusing on Increased Health and Wellbeing	An effective and efficient application includes necessary quality application provided to the users in due time (Huerta, Ford, Peterson, & Brigham, 2008) and communication between users and stakeholders (Huerta et al., 2008; Kaelber, Jha, Johnston, Middleton, & Bates, 2008; Pilon et al., 2014). Users are satisfied by perceiving higher value from the application. An effective and efficient application attracts potential users to the existing pool, as well as retaining existing ones. Stakeholders provide an effective and effective application that focuses on user health and wellbeing and have the benefits of innovation and the opportunity to enrich their experiences (Abidi, 2007).
Cost Reasonableness and Smart Resource Management	Cost reasonableness refers to more benefits at a lower cost. However, costs should not be reduced to such a low level that it affects the quality of the application, leading to the ultimate impairment of the value of the application (Brown & Saint, 2013). Costs should be reasonable per the quality of application provided (Krey, Bettina, Matthias, & Steven, 2010). Costs can be a combination of monetary costs, psychic costs and time costs (Narayan & Nerukar, 2006). Monetary cost is the money spent for the generation of the application. Lower monetary costs help the users to choose economically beneficial health and wellbeing applications. Psychic cost is related to mental dissatisfaction resulting from extensive and tiresome application procedures (Narayan & Nerukar, 2006). Smart resource management means scientifically effective and efficient use of available resources to create high-quality applications (Huerta et al., 2008).

VPs	Description
Cutting-edge Technology to Furthering Information Accessibility	Users require proper access to the necessary information. Not all relevant stakeholders should have access to all information. Rather, specific information should be made available to particular types of stakeholder, for example, users, healthcare professionals. Also, specialists need information access (Helman, Addeo, & Walters, 2011; Manary, Boulding, Staelin, & Glickman, 2013) and professionals need timely access to personal health records of their patients/users (Kaelber et al., 2008; Lundberg et al., 2013). Using cutting-edge technology, users and relevant stakeholders can get timely access to information with confirmed security and privacy.
Sustainability from Open Innovation Health and Wellbeing Platform	Shifting from traditionally closed innovation to open innovation, i.e., to the open-source approach, has been recommended for user-oriented health and wellbeing applications (Lundberg et al., 2013). Open innovation health and wellbeing platforms may bring impressive outcomes, for example, novel concepts and solutions in health and wellbeing applications that are dedicated to the users. Scholars also emphasise the empathic support and exchange of information as essential elements of communication (Bullinger, Rass, Adamczyk MOeslein, & Sohn, 2012). Open innovation helps the application providers to reduce costs (Huizingh, 2011), which may encourage users to use the application. Moreover, it allows users to get the most recently innovated application easily and conveniently, because application providers constantly change and upgrade their applications, based on the needs of users (Reinhardt, Bullinger, & Gurtner, 2015).

5.2 Designing a persuasive mHealth healthy eating application (II)

A mobile application for improving snacking behaviour was designed and implemented. The application was designed to alleviate the struggle for excessive consumption, while enabling users to emphasise the times where they successfully made healthy choices by either choosing a healthy snack or resisting a snack entirely.

A simple mobile app was designed which is called by iCrave to help people improve their snacking habits. It allows users to track their snack cravings and allows them to record whether they choose to have a healthy or unhealthy snack or to forgo a snack. iCrave helps users in the moment of desire for unhealthy/excessive snacking by prompting a craving-reduction imagery task and allowing users to record their subsequent choices (Fig. 7).

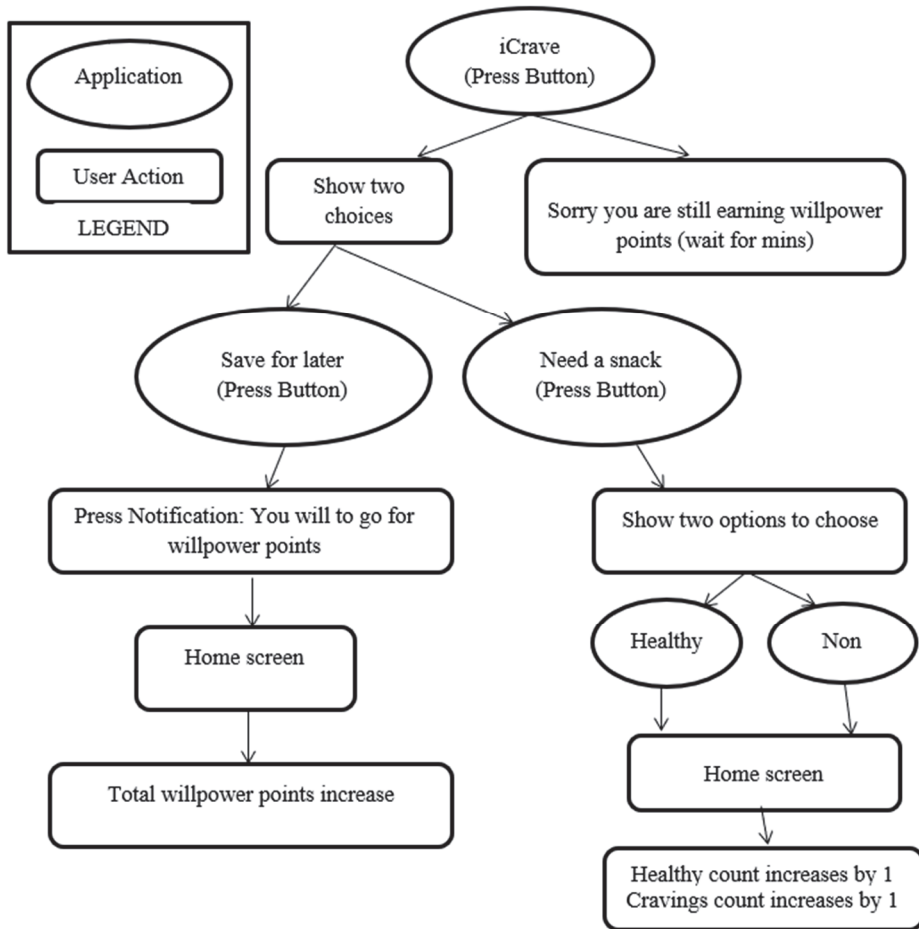


Fig. 7. Application flow of the iCrave application.

5.2.1 iCrave application (II)

The operation of iCrave worked as follows: when the user experienced a snack craving, they pressed the main “iCrave” button. The application showed a text prompt asking them to imagine a specific passive or active scene for 10 seconds, during which time a 10-second countdown timer was shown. There were 20 different suggested visualisations, based on those used in previous work, which appeared in block random order (Harvey et al., 2005; Baddeley & Andrade, 2000). This type of text-prompted imagery exercise has been shown, in previous research,

to reduce craving intensity (Hamilton et al., 2013; Andrade et al., 2012; May et al., 2012; May et al., 2010; Kemps & Tiggemann, 2007; Harvey et al., 2005; May et al., 2004). To check whether imagination intensity was correlated with effectiveness, and also to emphasise engagement with the visualisation task, after the 10-second imagery task, users were asked to rate on a 5-point scale how vividly they imagined the scene, ranging from “No image at all” to “Perfectly vivid, just like the real thing”. Users were allowed to make one of three choices on the application by either not eating at all, and therefore “saving” their craving, or choosing a healthy or unhealthy snack. If the user chose to not eat at all, they were congratulated on “saving” their craving and the system kept track of a 20-minute period, during which time they were not allowed to choose to eat or save a craving again. A 20-minute period was chosen, because research has shown that it takes at least 10 minutes for the brain to register fullness after consumption (Liu, Gao, Liu, & Fox, 2000); and post-consumption experiences, such as happiness and guilt, peaked 5–30 minutes after eating (de Lauzon et al., 2004). If the user chose to snack, there was no counter and they were allowed to snack again immediately afterwards. Ranking list of the users was not included in iGrave. On the main screen, a counter was shown that tracked the total number of events of cravings, savings (no snacking), healthy and unhealthy snacks. This simple level of tracking was chosen to minimise user burden, while still offering a reasonable level of monitoring. Initial prototype evaluations verified that the design was simple and intuitive to use. An “undo recent activity” button was provided to allow users to correct mistaken entries or report snacks they might have eaten while on the 20-minute saving period (see Fig. 8). Below the main principles that inspired the design are summarised.

5.2.2 Enhancing rewards of health choices (II)

Typically, when a person feels the temptation to consume excessive/unhealthy foods, there is little reward available for resisting the temptation. Previous work has found that people feel good about resisting food temptations (Hsu & Blandford, 2014). However, the moment of feeling good can be diminished if it becomes lost in memory. Current applications only track intake, and we do not know of any applications that specifically allow users to record moments where food is avoided. By recording moments of forgoing snacking, despite experiencing cravings, we allow users to remember these moments of successful self-control. To encourage the idea that forgoing immediate rewards should allow for greater rewards later, the act was called a “saving” of the craving on the app. Previous research had shown

that simple tracking is useful for improving eating habits (Consolvo et al., 2009). The effectiveness of iCrave was evaluated for improving snacking by comparing its effects to that of a basic tracking application.



Fig. 8. Screen shots of the iCrave application based on (II).

5.3 Designing a persuasive mHealth physical activity application (III-IV)

5.3.1 Game-design elements (III)

From the game elements found in the literature, some possible game elements were selected. In general, empirical research has found that the implementation of reward, that is, PBL, is a practical means to encourage users behaviour in non-gaming contexts (Mekler et al., 2013). Specifically, within the PA research, the game elements rewards, that is, points and badges (Chen & Pu, 2014; Thorsteinsen et al., 2014; Zuckerman & Gal-Oz, 2014; Reynolds et al., 2013; Riva et al., 2014; Spillers

& Asimakopoulos, 2014; Kuramoto et al., 2013), and leaderboard (Chen & Pu, 2014; Thorsteinsen et al., 2014; Zuckerman & Gal-Oz, 2014; Riva et al., 2014; Spillers & Asimakopoulos, 2014) can persuade people to accomplish a specific activity such as PA promotion, that is., exercise/walking in the working environment.

5.3.2 Proposed system model (III)

The approach used here was a combination of the theoretical concept of SDT, regular game elements (PBL), and positive and motivating outcomes (exercise and weight control). Ryan’s existing SDT theory model of health behavioural change (Ryan, Patrick, Deci, & Williams. 2008) was utilised for scaffolding the proposed system model. Ryan’s SDT theory model indicates that the satisfaction of autonomy, competence and relatedness brings positive outcomes for mental health (higher quality of life, less anxiety, depression, and somatisation) and physical health (workout/exercise, weight loss, glycaemic control, non-smoking medication use, healthier diet, and dental hygiene). This study, however, has highlighted the physical health elements, particularly exercise/walking and weight control (Fig. 9).

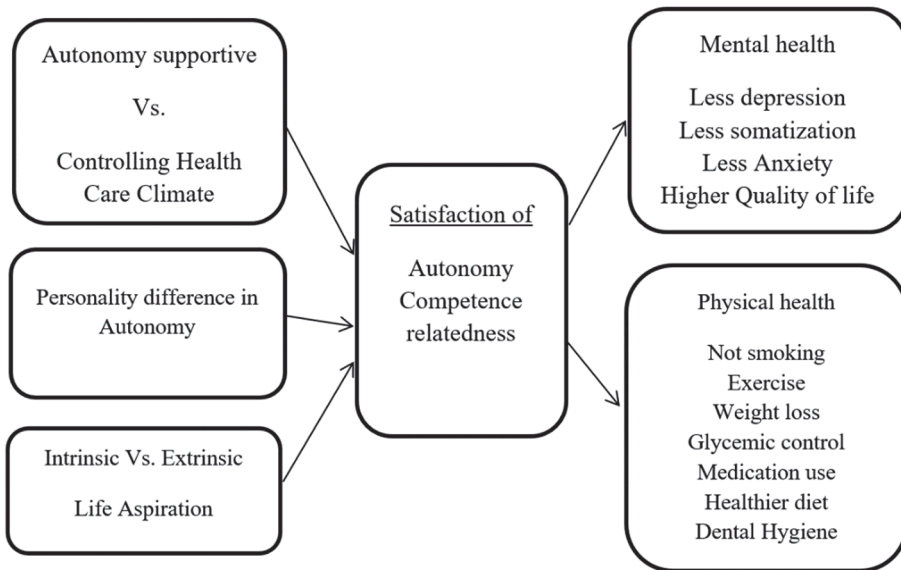


Fig. 9. Ryan’s SDT theory model of behavioural change (Ryan et al., 2008).

SDT was selected, as it runs principally as an analysis for the psychological level, seeks the sources of, and reasons for, the individual’s level of motivation, as well as their thoughts, reactions, and emotions. Thus, the SDT theory indicated the purpose of motivation in improving motivational progress and wellbeing (Wilson, Mack, & Grattan, 2008). SDT facilitates a gateway to understanding the background to PA-related behavioural consequences, for example, walking/exercise, the three basic psychological needs, and autonomy-supportive elements that support the purpose of PA. This helps to conceptualise a system model; for instance, a proposed system model for employees to engage in PA (Fig. 10). As an example, assume that there is a mobile application to which SDT is applied, and that employees update their daily activities (10 minutes of walking after breakfast/lunch). On the application, if the employee selects the option to go walking on their own, it implies their expression of the psychological need of *autonomy*. If the employee chooses to go for walking with others/colleagues, it indicates their feeling of the psychological need *relatedness*. Active peering with others (e.g., displaying a leaderboard on the application to perceive the accomplishments of others) implies their expression of the psychological need of *competence*.

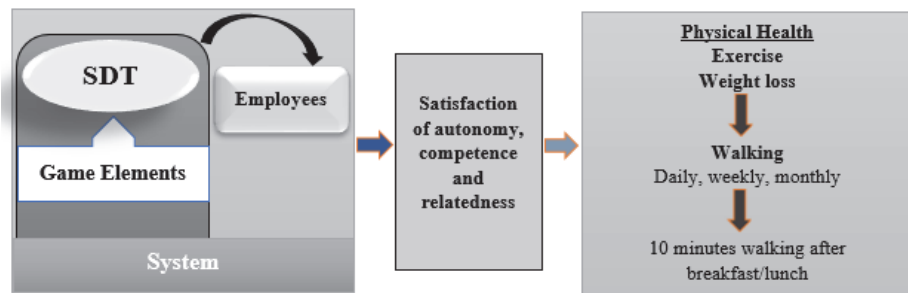


Fig. 10. Proposed system model through the lens of Ryan’s SDT theory model of behavioural change (III).

Extrinsic motivation was selected to use the game elements (e.g., rewards – scoring points and earning badges to monitor the progress of daily walking after the breakfast/lunch period). The entire sequence of using SDT was integrated: autonomy support (the three basic psychological needs of autonomy, competence and relatedness) and extrinsic motivation (rewards), using these game elements to build an application. For PA promotion, users monitored their daily achievements

when walking after the breakfast/lunch period. An example of a milestone is that the user would start to walk for 20 minutes per day. They could divide this task into two parts, that is, 10 minutes of walking after breakfast and another 10 minutes of walking after lunch and would get rewards (scoring points and earning badges) in return.

Other milestones can be similarly monitored, for example, positioning the person as 1st, 2nd or 3rd on the leaderboard, based on the total number of points earned. Their PA can be measured by the app on a daily basis, to track their walking. Data-driven approaches can be used to measure the user's fulfilment of autonomy, competence, and relatedness. To do this, an application followed by the system model is expected to record the everyday data of the users' activities and a comparative analysis of several weeks can be conducted. The application may count how active users are by calculating, for example, their earned rewards and their time spent in using the application.

5.3.3 User-centered design (III)

Empathise

Eight employees living in Finland were interviewed face to face. Participants were of three different nationalities. The purpose of the interviews was to perceive the views of employees regarding their willingness for PA promotion in the office environment. The employees were asked to describe their experiences of overcoming physical inactivity at the office, such as how they conduct PA when sitting for long periods of time and their thoughts about anything that might motivate them and any technology-mediated tools that might support them to do PA. Six employees (75%) reported the lack of PA in the working environment. Seven employees (88%) strongly recommended a technological tool with which they could do PA – mainly for walking and weight control – and to connect with others, such as having the option to walk alone or to walk with others. They wanted to see their daily progress on a leaderboard. They showed their interest in experiencing something that would make them competitive; for example, lower-point holders would appear on the leaderboard with a fat face. They showed an interest in using the game elements: scoring points and earning badges for 1st, 2nd and 3rd place. Some interviewees recommended exchanging the points in real-time vouchers or gifts, for example, a voucher for tea or coffee. The above observation

informed the research to move to the *define* step, in order to come up with an actionable problem statement.

Define

Based on the results of the interviews, the following problem statement was drawn up:

“Employees sense a lack of being physically active in their working environment. A technological tool using game elements can help them to overwhelm the state of their physical inactivity and can help them to be motivated to walk and track their everyday walking history.”

The above POV has drawn attention to how an application might be built with the aid of game elements to which users can experience more fun in their PA promotion.

Ideation

The POV from the *define* step led to designing the prototype of the PA application. The idea of designing the prototype was to observe users’ responses and how they responded using game elements following the SDT sequence. The prototype was designed by adding PBL game elements.

Prototype

The objective of building the prototype was to verify whether users could run a gamified persuasive application, and to see how they would react to using an application that incorporated SDT, using game elements. A low fidelity paper prototype (Fig. 11) was built, which allowed the user to input their initial details to log in (name, age, and weight, etc.). After logging into the application, the user would have the option to undertake PA with others or alone (Fig. 11). Once a user selected an option to walk, a timer was activated for 10 minutes, and they received one point for every five minutes of PA completed. After the walking session, users could track their tier activities on the leaderboard.

Test

Ten employees were invited via email or telephone. Out of these, five employees confirmed their availability to take part in the study. The prototype was not interactive, that is, participants used printed paper to access the paper prototype. Each participant was allocated for 15 minutes to test the prototype (Fig. 11). The aim was to observe the usability issues of the prototype and to see how users valued the SDT sequence using game elements. Employees were informed briefly about how to use the prototype, for example, they were asked to pretend to use the prototype as if they were using it in real-time. The participants were asked to report whether the prototype motivated them to promote their PA in the working environment. The intention was to obtain qualitative data on how the participants used the prototype and how they responded to the game elements in the prototype. The collected data showed their progress in completing the tasks facilitated by the prototype.

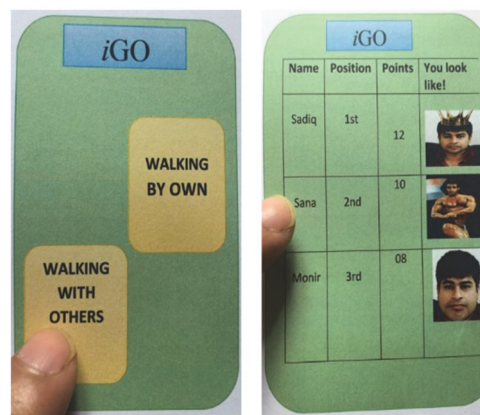


Fig. 11. Testing the prototype of the PA promotion app (III).

Based on the first iteration of the UCD process on a persuasive mHealth application for promoting PA in the work environment, the following results were found. Four participants felt that choosing the options to go for a walk with others or alone gave them freedom of choice. Three participants expressed an interest in a reminder that can be set before using the application. Overall, most participants reported positively about using the paper prototype, that is, it motivated them to go for PA. Participants showed an interest in earning points and badges (gold, silver and bronze). Participants were interested in viewing the leaderboard, except for one

participant, who was confused about the ranking list. This prototype should be updated to build an actual PA promotion app with a built-in reminder, for example, alarm/vibration, and a detailed feature with the game elements. The findings of the study suggest that adopting SDT using game elements to design a system model, incorporating Ryan’s SDT theory model of health behavioural change, was a successful approach to motivate employees in their PA promotion. However, it was thought that the concrete motivational outcome might differ when implemented in an actual PA promotion app. Therefore, it was planned to examine the effect of the system model implemented in an actual gamified persuasive application.

5.3.4 The working prototype of the iGO application (IV)

A working prototype of the iGO app was designed to help workers in promoting their PA, such as exercise and walking. iGO is a simple persuasive health and wellbeing application that allows users to promote their PA and enables them to record whether they choose PA by promoting self-determination tasks and to save their selections. The overall concept of the iGO app is shown in Fig. 12. Users’ key factors (comprising the intrinsic motivation and the level of autonomy, competence, and relatedness about their PA promotion) and responses were collected from the system. In addition, their activity was logged automatically by the system.

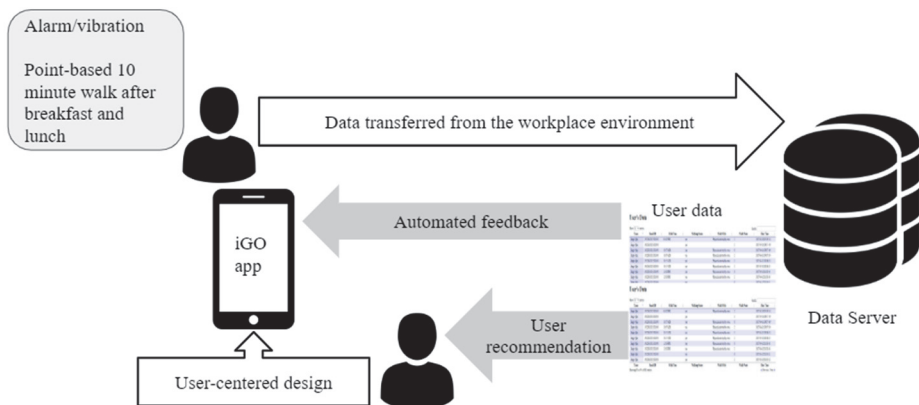


Fig. 12. The overall concept of the mHealth app iGO developed using the UCD process. Daily walking data are gathered, and users receive notifications and are rewarded for their progress on the leaderboard.

The application flow of the iGO mHealth app is shown below in Fig. 13.

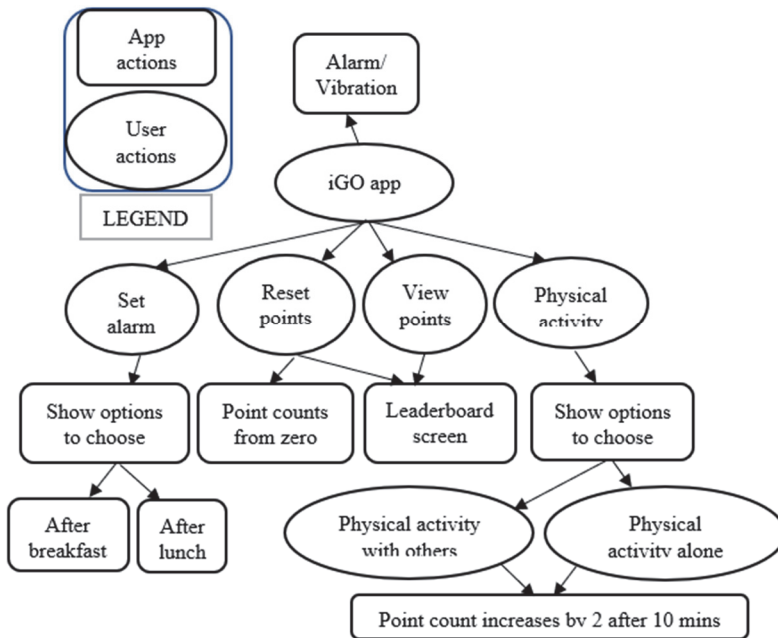


Fig. 13. Application flow for the iGO mHealth application.

The procedure of the iGO can be described as: an alarm/vibration reminder goes on just after the breakfast recess, and the application then shows an option regarding whether or not the user had breakfast, whereby they click “Yes” or “No”. If the user did not have breakfast and clicked “No”, the alarm appears again after 10 minutes and asks the user to choose their preference. If the users click “Yes”, then the app will ask them to choose “PA with others” or “PA on own”. When the user chooses the button “Physical activity with others”, the timer starts to count up to 10 minutes and the user receives two points (five minutes = one point), if they engage in exercise/walking. After completing the session “PA with others”, the system asks the user to press the “PA alone” button. When the user chooses the button “PA alone”, the timer starts to count up to 10 minutes and the users receive two points if they engage in body movement. Points are deducted if they choose the “No PA” button. Similarly, an alarm/vibration goes on just after the lunch break and follows the above procedure. At the end of the day, an interactive social display, that is, a result dashboard, appears on the application to show the score of the individual user. Users receive a personal image in accordance with their points, for

example, those with the highest points will receive a positive portrait image, while others will receive portrait image with a fat face.

From user’s perspective, designing the application should focus mainly on the application’s operation; for example, what its functions are, how they are demonstrated, and they benefit the users. Therefore, the aim of the iGO application was to collect data and represent the data after analysis, so that the users receive useful information which serves to make them more interested in using the application (Tuovinen et al., 2016). User data recording their earned points were stored in a secured database. The number of earned points after PA were displayed on the result dashboard and on the user’s individual profile. The accelerometer sensor in the smartphone tracks the footsteps of the users, targeting for 1 000 steps in 10 minutes, based on the recommendation of 3 000 steps in 30 minutes (Marshall et al., 2009). Here, 500 steps were counted as one reward point. Reminders are sent via alarm/vibration during breakfast and lunchtime. The leaderboard appears as an interactive social display, when selecting “viewpoints” from the main menu.

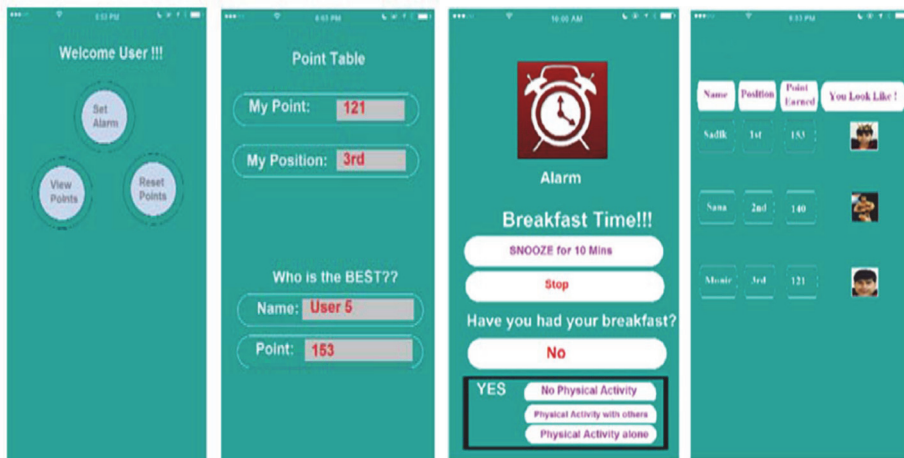


Fig. 14. Screen shots of iGO application based on (IV).

Fig. 14 represents screen shots of the iGO. Users manage the application, for example, sending out the alarm/vibration. Users have the option to use/skip the application by pressing the “Yes” or “No” button when asking whether they have had breakfast/lunch. Users express their views and can choose their options and choices through the application, and thus, the application prompts autonomous support. Clicking the button “PA with others” indicates their expression of the

psychological need *relatedness*, as it urges them to feel associated with others. Clicking the button “PA alone” indicates their expression of the psychological need *autonomy*, as it “refers to being the perceived origin or source of one’s behavior,” (Wilson et al., 2008). Social interactive display, that is, a result dashboard appearing on the application, expresses the psychological need *competence*, “as feeling effective in one’s ongoing interactions with the social environment and experiencing opportunities to exercise and express one’s capabilities.” Also, scored points with added personal goodwill images indicate rewards for users, which are the extrinsic motivation. Therefore, the attempt to integrate the SDT sequence with the application has been fulfilled. The next section describes how the usability of the prototype was tested.

6 Pre-evaluation and feasibility testing

Firstly, the chapter describes the pre-evaluation of the app prototypes for healthy eating and physical activity before the full applications were implemented. Proposed VPs were validated through a case study involving these applications. Then, the chapter describes main evaluation for the feasibility testing of the healthy eating application as well as for the usability and feasibility testing of the physical activity application.

6.1 Overview of testing and study participants

The overview of study participants and testing is described in Table 4. More detailed description can be found below and in the Sub-studies II, IV and VI.

Table 4. Overview of testing and study participants.

Sub-study	No. of participants (Female/Male)	App	Testing	Methods
II	23 (8/15)	iCrave prototype	Pre-evaluation	Questionnaire
IV	26 (10/16)	iGO prototype	Pre-evaluation	Questionnaire
II	53 (18/35)	iCrave app	Main evaluation	Questionnaire, interview
VI	84 (35/49)	iGO app	Main evaluation	Questionnaire, interview

6.2 Pre-evaluation of the application prototypes (I, II, IV)

6.2.1 Persuasive mHealth healthy eating application iCrave (II)

Before the full application was implemented, the general usability of the design was tested on a “lite” prototype. This “lite” prototype allowed users to track craving, savings and healthy vs. unhealthy snacks but did not prompt the craving-reducing imagery task. The aim of the prototype pilot was to evaluate whether the interface was intuitive to use; whether people would readily use the app during snack cravings; and whether it felt intuitive to use a “Save” button if the user chose to forgo snacking. As with the full application, if the user chose to “Save” their snack craving, they would not be able to use the application for 20 minutes. The prototype was deployed on a mobile-friendly web application, so that it could be used on all mobile platforms. The iCrave prototype did not store user data onto a database;

individual user data (snack counts, etc.) were stored in cookies in the individual's web browsers.

Twenty participants were recruited from the local community in London; all were healthy adults (aged 20–34) who had an interest in improving their snacking habits. They used our prototype app over a week-long period. Post-questionnaires verified that people were willing to use the app when they experienced a craving, and readily used the “Save” button when they felt they could forgo the snack. Of these 23 participants, 13 were randomly selected for interview and were asked about their experience using the app. Even when using only the lite prototype version, most felt that the app helped them to make healthier choices. “It slowed down my rate of taking unhealthy foods and also motivated me.” “After using this app, I become cautious of taking junk food, started avoiding junk food.” “I use the iCrave app to remind myself that I should control my appetite.” To evaluate usability, participants were asked how easy/hard they felt the app was to use. They all reported it was very usable. “Very easy”, “simple”, “convenient”, “very user friendly, I like it very much”. The main complaints were all centred on the fact that it was not deployed as an app but only as a mobile site. Given the positive qualitative results and positive survey results, it was concluded that the prototype evaluation verified the basic usability of our design and warranted the implementation of the full application.

6.2.2 Persuasive mHealth physical activity application iGO (IV)

The overall usability of the designed prototype was tested before the full application was implemented. Initially, test users were selected for a week-long study and it was aimed to conduct the main evaluation study later (more details are described below). Test users used the application before the breakfast and lunch recesses in the workplace, in an office environment. The aim of the application test was to evaluate whether the application was friendly to use, and whether the users practised the application after the breakfast/lunch for PA purposes; for example, if they chose the “Yes”, button, to go for PA. The prototype was installed in an Android mobile-friendly web application; user data was stored on the database; and the earned points were calculated accordingly.

For testing, 26 participants were recruited: 10 females and 16 males. All participants were employed adults aged between 25 and 41 years. Prior to the start of the test, an informed consent form was provided to the participants, outlining the research study and what was expected from them. A brief introduction was

provided to the participants, explaining that it would motivate them to increase PA towards better productivity. Participants used the application for one week in their office environment. Post-questionnaires confirmed that participants were interested in using the application. Fifteen participants were interviewed and asked to describe their experience in using the iGO application. They were selected based on their availability and interest in being interviewed. While using the iGO application, most participants felt that it convinced them: “Before using the app, I was feeling lazy but after using the app, I felt amazing.” “The app is reminding me at least to do some physical things which is great.” “I felt like losing weight which is great!” “Walking after meals does not make me feel to have extra weight on my body.”

To evaluate the usability, participants were asked to describe how hard or easy they felt it was to use the iGO application. Most participants reported the application as being satisfactory and user-oriented: “User friendly, works as personal assistant.” “Very easy and convenient.” “Pretty good.” “Simple, easy to use.” “Good thinking app.” However, some users complained that the application was compatible only with an Android operating system, as they were using the iOS operating system and were more flexible on it. The report from the application usability showed positive impacts in terms of using the iGO application. The participants’ overall experiences surrounding the iGO application were positive.

However, in the iGO design (IV), users received a positive portrait image if they scored highest points and those who scored less received a portrait image with a fat face. After testing the application, users suggested skipping this idea, due to privacy concerns. A newer version of the iGO was upgraded based on users’ recommendations; the one on the leaderboard in the 1st position will receive a Gold Badge, the 2nd will receive Silver Badge and the 3rd will receive a Bronze Badge (see Fig. 17).

In the context of the users, designing application should be based on the operation of the application, such as what the functions are and how they support users. The aim of the iGO app was to collect users’ data and to analyse them, so that users can receive useful information related to using the application (Tuovinen et al., 2016).

6.2.3 Validation of the value propositions through the case study on the persuasive mHealth applications (I)

The four proposed VPs were validated through a case study regarding the built persuasive applications. As described in the previous sections of the pre-evaluation

studies, users (N = 23 for iCrave and N = 26 for iGO) used the applications for a week to measure their eating and regular PA behavioural change. Both applications were designed with the aim that users were satisfied by perceiving higher value from the application, that is, value in the sense of their healthy eating and PA promotion. The applications were designed so that the users would have a positive experience in terms of their eating and PA. This relates to the fulfilment of the first VP. These applications were free for the users to use, that is, they could download them from the Google play store for a smartphone or they could use the applications on a website. The applications were designed as user-friendly and simple to operate, that is, maintaining the psychic cost. This is related to fulfilment of the second VP. Gamified and persuasion technique was applied within the applications, adding some game elements such as points and badges. For iCrave, a QR code was applied to be scanned by the phone. For iGO, an algorithm was applied, allowing the sensor of the smartphone to track walking steps. Users inserted their information when logging in and could then monitor their daily activities. The admin could only access users' data on receiving consent from them. This reflects the fulfilment of the third VP. Lastly, to design the applications, the literature was searched for established theories that could be applied to the application and tested empirically. iCrave was designed by incorporating the EI theory of desire and iGO was designed by incorporating the SDT theory, and the design followed the UCD process. The applications were tested empirically by end users to gather information in relation to the app's upgrade, usability issues etc. Users found that the applications motivated them in healthy eating and PA, which implies the fourth VP.

6.3 Feasibility of the persuasive healthy eating application iCrave (II)

6.3.1 Feasibility study (II)

Study design

This one-week experimental study was carried out on a group of office-based employees. Participants were randomly assigned to one of two groups. In the experimental group, participants used the iCrave application during the week. In the control group, participants used the basic tracking application (iCrave with limited properties such as no imagery tasks or rewards). Participants in both groups

were asked to use the app when they experienced a snack craving and indicate whether they were going to consume a healthy or an unhealthy snack before eating. Thus, any biases from reporting consumption beforehand would have applied to both groups.

Participants

Fifty-three participants were recruited from the local community in London, through email lists at the university. Participants were randomly assigned to either condition (Experimental Condition: N = 26, 16 males, 10 females; Control Condition: N = 27, 19 males, 8 females). There were 18 iOS users in each of the experimental and control conditions. The rest used Android. All participants were between 20–34 years of age, except one who was 53. Participants were adults over the age of 18. They were paid £7 each to participate in the study.

Materials

iCrave application was used for the experimental group and a simple application (snack tracker app) for the control group. The iCrave application extended the prototype version with the following additional features: when the iCrave button was pressed, the app prompts a 10-second imagery task for craving reduction, followed by a request for the user's vividness rating for the imagery task. The snack tracker was almost identical to the full iCrave app, although it did not prompt an imagery task or vividness rating; nor did it provide the choice of a "Save" button to record the forgoing of a snack. Thus, the snack tracker looked exactly like Fig. 10, except the two centre screens were omitted, the "Save for later" button was not available in the right screen, and the "Saved" tally was not available on the home screen. The full iCrave and snack tracker apps were implemented on both iOS and Android platforms and recorded all user data on a secure database.

Procedure

Before the start of the experiment, participants were given a consent form along with a brief overview of the application and a short paragraph explaining standard portion sizes for common healthy and unhealthy snacks. Participants were provided with a brief introduction to the app for their condition, explaining that it would allow them to track their consumption of healthy and unhealthy snacks. Participants

in the experimental condition were also told that they could “save” their cravings by resisting a snack altogether. All participants were then asked to fill out responses to a pre-study survey, which asked them to rate on a 7-point Likert scale: their motivation to snack more healthily; confidence in ability to snack healthily; likelihood of eating unhealthy snacks without thinking; strength of cravings for unhealthy snacks and snacks overall; ease of resisting unhealthy snacks; and the average number of unhealthy snacks and overall snacks they consumed a day. Participants were then instructed to use their app for the next week, to try to improve snacking. At the end of the week, participants filled out a post-study survey asking them again to rate strength of cravings for unhealthy snacks and snacks overall; likelihood of eating unhealthy snacks without thinking; ease of resisting unhealthy snacks; and the average amount of snacks they consumed per day the previous week. They were also asked to rate on a 7-point Likert scale how well they did in overcoming unhealthy snack habits during the week of the experiment compared to before the experiment.

Measurement

The main outcome variables of the experiment were the number of healthy, unhealthy, and overall snacks consumed in the two conditions. These values were stored in a database for each user (stored using an anonymous user ID). As with the pilot study, post vs. pre experiment survey answers were also compared between the two conditions for questions that were asked both before and after the experiment. Finally, it was assessed whether vividness of imagery affects the snack choice. Post-experiment qualitative interviews were also conducted with seven participants who used the full iCrave app.

6.4 Usability and feasibility of the persuasive physical activity application iGO (V-VI)

6.4.1 Usability study (V)

Research model

The UTAUT model was used to analyse the acceptance and use of the persuasive application (iGO PA promotion app) by employees in their offices, to promote their

physical activities. According to the UTAUT model, the use of a PA app can be influenced by the four factors: performance expectancy, effort expectancy, social influence, and facilitating conditions (Fig. 15). In this study, the curbing effect of age, gender, voluntariness and experience was not considered. It can be assumed that these factors do not have a significant effect on the results, due to the homogeneous professional background of the participants and their intentions towards physical activities. The research model was modified accordingly.

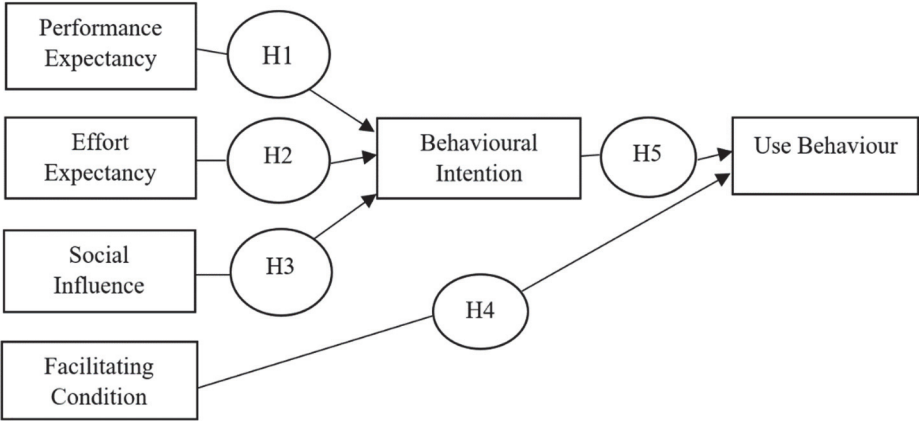


Fig. 15. UTAUT model for a persuasive application in promoting physical activity. Hypotheses (H1-H5) of the study are shown here. UTAUT = Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003).

Hypotheses

The UTAUT model incorporates the eight-technology acceptance theoretical models and consists of the core factors of usage intention (Venkatesh et al., 2003). In the present study, it was hypothesised (Fig. 15):

H1) Performance expectancy positively influences user’s intention to use persuasive application for promoting PA;

H2) Effort expectancy positively influences user’s intention to use persuasive application;

H3) Social influence positively influences user's intention to use persuasive application;

H4) Facilitating conditions of persuasive application positively influences users' behaviours regarding the actual use of a persuasive application; and

H5) Behavioural intentions to use a persuasive application positively influence users' behaviours of the actual use of a persuasive application.

Data collection

To evaluate user acceptance, end-user data in relation to the acceptance and use of the persuasive application to promote PA were collected. Participants were recruited for using the iGO app. The Android OS-based iGO app was designed for the participants to send reminders for them to do daily physical activities after breakfast and lunch and record their daily physical activities. After an eight-week period of using the iGO app, participants filled in a questionnaire that was modified from the question items of (Venkatesh et al., 2003). The questions related to performance expectancy, effort expectancy, social influence, facilitating conditions, and behavioural intentions, and user behaviour were as follows: (1) "Using the iGO PA app improves work productivity at office"; (2) "Finding the iGO PA app is easy to use"; (3) "Colleagues' and others' thinking approach on the users to use iGO PA app;" (4) "Resources, for example, internet access, while using app"; and (5) "Intentions to use the iGO app in future PA" and (6) "overcoming PA during the month while actually using the iGO PA app". The questionnaires were analysed quantitatively using mean and standard deviation and correlation analyses.

Participants

To recruit the participants, an invitation to participate in the study was sent (by email/telephone) to 56 employed/self-employed individuals residing in Finland, UK, Ireland and Bangladesh. Participants were adults, mostly employed in multinational ICT companies. Some were self-employed in their own business and others were fully employed and studying part time. Forty-seven participants responded to the invitation by email/telephone. Of these, 31 participants agreed to take part in the eight-week pilot study, and the information and consent form and pre-questionnaire were sent to them. The pre-questionnaires were completed by 28

participants, who formed the study group for the pilot study (Fig. 16). The pilot study was designed for participants to use the iGO app on their Android smartphones for eight weeks. A smartphone was issued, under returning terms and conditions, to those who did not own an Android smartphone. Six participants dropped out due to professional reasons and relocation/shifting to new cities, etc. Thus, 22 participants completed the study.

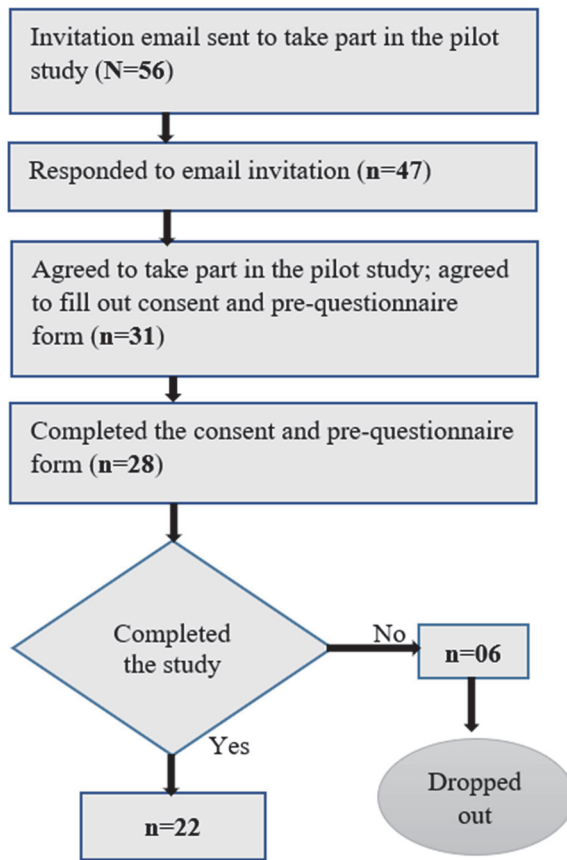


Fig. 16. Flow chart of study participants.

The working version of the iGO

The leaderboard shows the rank list of users, their names, photos, and earned points (Fig. 17). Users had the option to customise their picture and name visibility

settings when signing into their iGO account. Walking data were gathered on web server (Fig. 18).

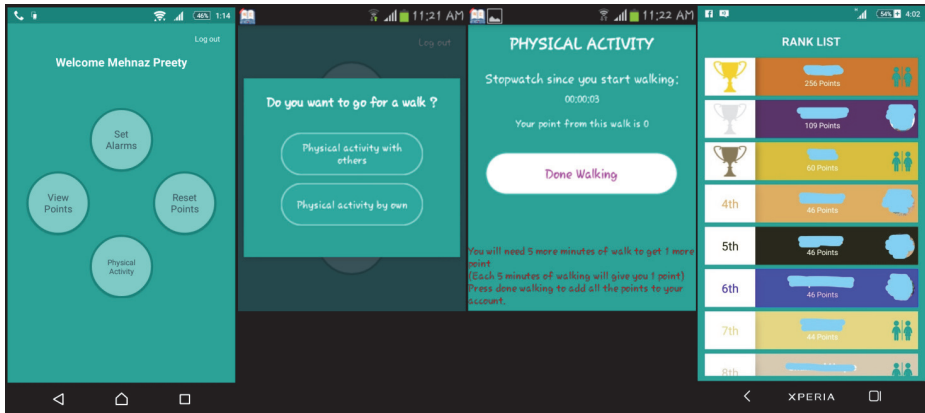


Fig. 17. Screen shots of the upgraded iGO PA application based on (V).

User's Data

Show: 10 entries

Name	Email ID	Walk Time	Walking Status	Walk With	Walk Point	Date Time
[blurred]	1922682021301050	04:02 PM	yes	Physical activity by own	2	2017-04-10 15:03:14
[blurred]	1922682021301050		yes		2	2017-04-11 09:57:40
[blurred]	1922682021301050	10:57 AM	yes	Physical activity by own	0	2017-04-11 09:57:49
[blurred]	1922682021301050	10:57 AM	yes	Physical activity by own	2	2017-04-11 09:57:50
[blurred]	1922682021301050	10:57 AM	yes	Physical activity by own	1	2017-04-11 10:06:24
[blurred]	1922682021301050	10:57 AM	yes	Physical activity by own	2	2017-04-11 10:06:25
[blurred]	1922682021301050	12:03 PM	yes	Physical activity by own	0	2017-04-12 11:03:41
[blurred]	1922682021301050	12:03 PM	yes	Physical activity by own	2	2017-04-12 11:03:43
[blurred]	1922682021301050		yes		0	2017-04-12 11:05:11
[blurred]	1922682021301050		yes		2	2017-04-12 11:05:12

Showing 81 to 90 of 862 entries

Fig. 18. A user tracks his walking footsteps after the lunch recession, and the data are gathered in the web server.

Procedure and materials

The iGO app was installed on participants' smart devices (Android phones/tablets) Participants were requested to use the iGO app daily for at least 10 minutes after

the breakfast and lunch, while walking during the recession at the office. It was recommended for them to carry the smart device when walking. A total of 20 minutes was assigned for each participant to use the iGO app (10 minutes after breakfast and 10 minutes after lunch). A reminder was sent via alarm/vibration to participants during breakfast and lunch time, to use the iGO app. Their walking after breakfast and lunch was monitored, and they earned reward points for every five minutes that they used the iGO app. A total of 1 000 footsteps during the 10 minutes was rewarded with two points. Participants could choose to walk with colleagues or alone, by choosing options from the app. Participants were instructed to use the iGO app for at least eight weeks. The participants started to use the iGO app between March and May 2017. A post-questionnaire was sent after eight weeks, when they had finished using the iGO app. The post-questionnaire addressed to the usability issues of the iGO app and was designed to observe how motivated the participants felt in the context of their working progress and physical health. Factors used to design the UTAUT post-questionnaire were performance expectancy, effort expectancy, social influence, behavioural intentions, facilitating conditions and user behaviour. It was used to analyse the effectiveness of the persuasive application in promoting PA. The questionnaire had a 7-point Likert scale of 1:7 corresponding to “Completely disagree”: “Completely agree”. The purpose was to analyse the data of the users and measure the acceptance and use of the iGO app. Correlation analysis was used to analyse data. If Y is the independent variable and X is the dependent variable, the correlation is $Y = f(X)$. In this study, the following criteria were used to test the hypotheses.

To obtain a more accurate analysis, ANOVA was used for calculating the range of correlation coefficient and p-value for each hypothesis to confirm their statistical significance. Several values are accepted for interpreting the correlation coefficient, R (Rodgers & Nicewander, 1988). Whereas +1 and -1 show perfect positive and negative relationships, values between 0 and 0.3 indicate a weak positive and between 0 and -0.3 indicate a weak negative relationship, values between 0.3 and 0.7 denote (0.3 and -0.7) show a moderate positive while -0.3 to -0.7 denote negative, and values between 0.7 and 1.0 indicate a strong positive and between -0.7 and -1.0 shows a strong negative relationship (Rodgers & Nicewander, 1988). Moreover, the relationships were considered statistically significant if $p < 0.05$.

6.4.2 Feasibility study (VI)

Study design

An experimental study was carried out on a group of office-based employees for four weeks. Participants were randomly assigned to one of two groups: The experimental group used the iGO app, and the control group used a paper diary during weekdays for four consecutive weeks.

Participants

The four-week experimental study was conducted in four sites in four countries: (1) the city of Oulu, Northern Finland (population approximately 199 000); (2) Carlow, South Leinster, Ireland (population approximately 26 000); (3) the megacity of London, United Kingdom (population approximately 8 136 000) and (4) the megacity of Dhaka, Bangladesh (population approximately 1 984 0000). The four countries were selected due to practical reasons with existing collaboration. To recruit the participants, ten multinational ICT companies (two from UK, two from Ireland, three from Finland, and three from Bangladesh) were selected randomly, one research institute from each country (University of Oulu, Finland, Queen Mary University, UK, Institute of Technology, Carlow, Ireland and Bangladesh University of Professionals, Bangladesh), as well as people in start-up companies (Finland, UK, Ireland, Bangladesh). List of the companies was collected with personal communication with University researchers and professionals. The participants were invited amongst people working in the IT sector, with suggests similarities in IT skills and technology acceptance. We contacted each site by email and asked to forward an invitation email for their employees. The first author of the study contacted directly the people in start-ups. Total number of invited people was 220. The people were randomised to experimental (n = 115) and control (n = 105) groups before sending the invitations (Fig. 19).

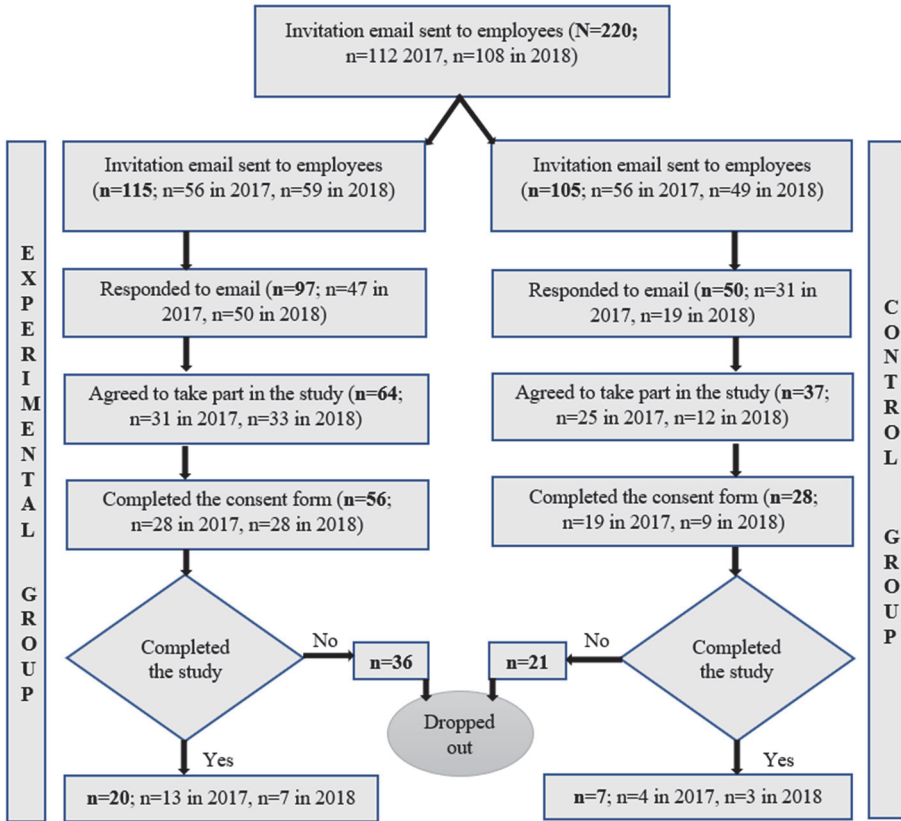


Fig. 19. Flow chart of study participants.

They were contacted to confirm their willingness to participate in a four-week trial. We obtained informed consent from all participants before conducting the study. The consent form was in English in all countries. The participants had possibility to withdraw from the study in any phase. Based on the study design, review by ethical committee was not required.

The flow chart of the study participants is shown in Figure 19. The final study population consisted of 84 working-age volunteers working in an office setting, who filled the consent form. The characteristics of the participants are given in Table 5. A participant was considered completing the study if he/she used the app or paper diary for 4 weeks and returned the end questionnaire.

Table 5. Baseline characteristics of the study population (N = 220).

Variable	Invited, n = 220		Consented, n = 84		Completed, n = 27	
	E ¹ = 115	C ² = 105	E = 56	C = 28	E = 20	C = 7
Gender, n (%)						
Female	44 (38.3)	42 (40.0)	23 (41.0)	12 (42.9)	10 (50.0)	4 (57.1)
Male	71 (61.7)	63 (60.0)	33 (59.0)	16 (57.1)	10 (50.0)	3 (42.9)
Work situation, n (%)						
University	62 (53.9)	50 (47.6)				
IT Industry	36 (31.3)	41 (39.0)				
Start-up	17 (14.8)	14 (13.4)				
Study completion, n (%)						
United Kingdom	32	30	18	9	6	2
Female	11 (34.4)	13 (43.3)	7 (38.9)	3 (33.3)	2 (33.3)	1 (50.0)
Male	21 (65.6)	17 (56.7)	11 (61.1)	6 (66.7)	4 (66.7)	1 (50.0)
Ireland	22	19	12	5	6	1
Female	10 (45.5)	7 (36.8)	5 (41.7)	1 (20.0)	3 (50.0)	0 (0)
Male	12 (54.5)	12 (63.2)	7 (58.3)	4 (80.0)	3 (50.0)	1 (100)
Finland	26	24	15	8	5	3
Female	11 (42.3)	9 (37.5)	6 (40.0)	4 (50.0)	3 (60.0)	2 (66.7)
Male	15 (57.7)	15 (62.5)	9 (60.0)	4 (50.0)	2 (40.0)	1 (33.3)
Bangladesh	35	32	11	6	3	1
Female	12 (34.3)	13 (40.6)	5 (45.5)	4 (66.7)	2 (66.7)	1 (100)
Male	23 (65.7)	19 (59.4)	6 (54.5)	2 (33.3)	1 (33.3)	0 (0)

¹ Experimental group; ² Control group

In the experimental group, 115 participants were asked to participate in the four-week trial using the iGO app. Out of these participants, 56 completed the consent procedure (average age 39 years, age range = 24–49 years); and finally 20 participants completed the study (12 males and eight females, with an average weight 72.2 kg, average BMI = 24.8 kg/m²). The reasons given for dropping out of the trial (n = 36) were: their lack of time, holidays, laziness and personal issues (44%); their unwillingness to use the mHealth app because they disliked its outlook or were already using an mHealth app (17%); they did not feel a need for this type of service or were already taking care of themselves (8%); and other reasons (20%). A further 11% did not give a reason for declining.

The control group (n = 105) was asked to participate in the four-week trial with a paper diary. Out of these 105 participants, 28 completed the consent procedure (average age 39 years; age range = 26–49 years); and finally, 7 participants completed the study (5 males and two females, with an average weight of 71.4 kg, average BMI = 24.5 kg/m²). The reasons given for dropping out (n = 21) were:

their lack of time, holidays or laziness and personal issues (28%); their unwillingness to use the paper diary because they disliked it, since it was only paper, with no alarm (35%); they did not feel a need for this type of service; they were already taking care of themselves (13%); and other reasons (26%).

Materials

The iGO app was used for the experimental group and a paper diary for the control group. The paper diary had a simple chart to record the walking after breakfast and lunch. The diary did not incorporate SDT needs and PBL elements. Users completed their data manually. Participants were instructed to fill up their walking record on the paper diary every day for four weeks during their breakfast and lunch recession. Alarm/vibration as a reminder were not included on the paper diary. Participants data were then gathered manually.

Questionnaire

Based on users' feedback in Sub-study (III), a quantitative questionnaire was initially designed, validated, and tested. Four experts with a similar research background conducted the validation. Six end-users (living in Finland and Ireland) took part in co-designing the questionnaire. The questionnaire uses a 7-point Likert scale with answers ranging from Much worse to Much better (increasing physical activity) and Completely disagree to Completely agree (autonomy, competence, and relatedness). Similarly, a set of qualitative questions was designed and tested to find out how the mHealth app or paper diary helped users to improve their PA; any personal approaches used in the app or paper diary to help with their PA; any ways in which the iGO mHealth app or paper diary failed to help users, or made their PA worse, and how the app could be improved.

Interview

Semi-structured 20-minute interviews were conducted and audio recorded with all participants in the experimental group who completed the study. They were asked about the external contexts as well as their opinions and feelings on the usage of the iGO app. To evaluate responses to open questions, conventional content analyses were performed by the first author. Microsoft Excel was used to store and organize the data collected during the interviews. Analysis was carried out in three

steps: 1) the data was repeatedly read in for familiarity, 2) words or phrases corresponding the key themes were highlighted and coded, 3) the context and frequency of theme-related sentences were used.

Procedure

The iGO app was first installed on participants' smart device. Samsung android phones were lent to any participants who did not have a compatible phone. Participants were instructed to use the mHealth app or a paper diary for four weeks. Participants in the experimental group were asked to use the mHealth app daily for at least 10 minutes after breakfast and 10 minutes after lunch, while walking during their break time. The participants customized the breakfast and lunch times at their preferred times. Based on the set time, the phone gave vibration/alarm as a reminder with which participants were able to start walking and after walking for 10 minutes, they get notification from the iGO that they complete their goal. The participants filled in the quantitative questionnaires at the end of the study.

Statistical analysis

The statistical tool SPSS 25.0 was deployed to analyse the quantitative data. The differences between the experimental group and control group were compared using the T-test. The p-value for each of the psychological needs of autonomy, relatedness, and competence was calculated separately. $p < 0.05$ was considered statistically significant. To evaluate responses to open questions, conventional content analyses were performed by the first author. Microsoft Excel was used to store and organize the data collected during the interviews. Analysis was carried out in three steps: 1) the data was repeatedly read in for familiarity, 2) words or phrases corresponding the key themes were highlighted and coded, 3) the context and frequency of theme-related sentences were used.

7 Results

This chapter is two-fold. Firstly, the chapter presents results of the one-week feasibility study for the persuasive mHealth healthy eating application iCrave. Then results of the eight-week usability and four-week feasibility studies for the persuasive mHealth physical activity application iGO are presented.

7.1 Persuasive mHealth healthy eating application iCrave (II)

7.1.1 Quantitative results (II)

Pre-study comparison of conditions

Based on the pre-study questionnaire, it was verified that there were no significant pre-experimental differences in BMI between the experimental ($M = 21.7$; $SD = 2.9$) and control ($M = 20.5$; $SD = 2.8$) conditions $p = 0.2$. Nor were there any significant differences in age ($p = 0.48$); motivation to improve snacking ($p = 0.53$); confidence in ability to improve snacking ($p = 0.60$); tendency to engage in unhealthy snacking without thinking ($p = 0.57$); cravings for overall snacks ($p = 0.43$) and unhealthy snacks ($p = 0.55$); ability to resist unhealthy snacks ($p = 0.40$); average daily consumption of snacks overall ($p = 0.99$); and unhealthy snacks ($p = 0.79$). Thus, it was concluded that the characteristics of participants in the two conditions were well counterbalanced, enabling a valid comparison of the effects of the iCrave application vs. the snack-tracker application.

Post-study comparison: usage and snacking

A comparison was made between how the consumption of healthy and unhealthy snacks, and overall app usage varied over time and between conditions. Overall usage is equivalent to the total snacks consumed on the tracker, and the total snacks plus savings for the full iCrave app. The mean overall usage over the whole week per participant was 7.2 times, $SD = 3.4$ for the experimental condition and 8.3 times, $SD = 4.9$ for the control condition. A repeated-measures ANOVA with fixed effect of time (days into the experiment) of overall usage found no significant effect of condition, $p = 0.39$. A significant effect of time was found $F(6,306) = 2.71$, $p = 0.014$, with marginal interaction of condition $p = 0.09$. The visual inspection of

usage over time showed that while usage varied over days, the overall decrease with time was small. This was confirmed using Ordinary Least Squares Pooled Errors (OLSPE) regression fit to usage data with parameters of condition and time, which revealed a small negative slope for the parameter of time: -0.048 , $t(369) = 2.8$, $p = 0.005$. OLSPE fits to usage for individual conditions found slope for time = -0.04 , $t(180) = 2.9$, $p = 0.004$ (experimental) and slope for time = -0.05 , $t(187) = 1.69$, $p = 0.09$ (control). Thus, there was no significant difference between conditions in terms of the number of times the apps were used, and the decrease in usage over time was small for both conditions.

A repeated-measures ANOVA applied to unhealthy snack consumption found a significant effect of condition, $F(1,306) = 14.5$, $p = 0.0004$, no effects of time $p = 0.43$, and no significant interaction, $p = 0.29$. Thus, participants in the experimental condition consumed significantly fewer unhealthy snacks compared to the control condition (Experiment: $M = 1.65$, $SD = 1.3$ Control: $M = 3.5$, $SD = 2.8$) and this did not significantly differ over time.

A similar analysis was applied to the consumption of healthy snacks. While control condition participants consumed more healthy snacks, this difference was not significant, $p = 0.27$. There was a significant effect of time $F(6,306) = 2.37$, $p = 0.03$, and no interaction, $p = 0.5$. As was the case for overall usage, the visual inspection of trends over time showed that while the consumption of healthy snacks varied over days, the overall decrease with time was small. An OLSPE regression fit to data with parameters of condition and time revealed a small negative slope for the parameter of time: -0.03 , $t(369) = 2.0$, $p = 0.05$. Thus, amounts of healthy snacks consumed did not differ significantly between conditions. While there was variation in healthy snack consumption with time, the variation did not differ between conditions and the overall decrease over time was small.

The overall snack consumption was also analysed. Participants, as found in the experimental condition, consumed significantly fewer snacks overall, compared to controls (Experiment: $M = 5.0$, $SD = 2.8$, Control: $M = 8.5$, $SD = 5.0$) (Fig. 20). Because no significant differences were found in the consumptions of healthy snacks, this decrease in overall snack consumption was driven primarily by the fact that unhealthy snacks were reduced in the experimental condition, while the consumption of healthy snacks remained the same. A repeated-measures ANOVA applied to overall snack consumption found significant effects of condition $F(1,306) = 9.2$, $p = 0.004$, and time, $F(6,306) = 2.36$, $p = 0.03$, with marginal interaction, $p = 0.092$. As before, OLSPE regression fit to the full data with parameters of condition and time found a small negative slope for time, -0.045 ,

$t(369) = 2.7, p = 0.007$. Fits to individual conditions separately found slope for time = $-0.039, t(180) = 2.8, p = 0.006$ (experimental) and slope for time = $-0.05, t(187) = 1.69, p = 0.09$, (control).

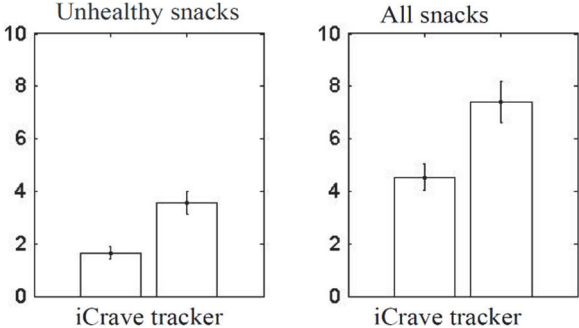


Fig. 20. Means and standard errors of total snacks consumed during the week of the experiment. Users of the iCrave application consumed significantly fewer total overall snacks and total unhealthy snacks over a week, compared to users of a simple snack tracker.

Even though the iCrave app and snack tracker were very similar, it is possible that the fact that the hassle of the additional imagery task required by iCrave caused participants in the experimental condition to under-report their snack consumption. Thus, participants were also asked at the end of the study how many unhealthy snacks they consumed over the week. Results suggested that participants in both conditions under-reported on the app. However, a comparison of unhealthy snack consumption based on post-experiment reports still supports the main findings that participants in the experimental condition consumed significantly fewer unhealthy snacks, $F(1,51) = 4.2, p = 0.04$. Thus, it was concluded that the full iCrave app was more effective in reducing unhealthy snack consumption than a basic tracker.

It was necessary to check that iCrave did not somehow increase the user’s amount of snacking compared to the week before the experiment by drawing excessive attention to it. To confirm this, t-tests were used to compare the average number of daily snacks reported in the post-experiment survey with the number reported in the pre-experiment survey. Results analysed across all participants in both conditions found that participants reported consuming fewer snacks during the week of the study compared to before the study, $t(52) = 2.3, p = 0.03$. When these results were analysed for each condition separately, a trend towards decreased snacking was still found: the experimental condition results were near statistical

significance, $t(52) = 1.9$, $p = 0.07$, whereas the control condition results showed no change, $t(52) = 1.3$, $p = 0.21$. This analysis suggests that participants might have reduced snacking during the week of the experiment.

Table 6. Perceived improvement in snacking and self-reported ease of resisting unhealthy snacks.

Comparison condition	iCrave ³ (n = 26)	Tracker ³ (n = 27)	P-value
Perceived improvement in snacking ¹	1.0 (0.85)	0.19 (1.5)	0.02
Self-reported ease of resisting unhealthy snacks ²	0.4 (1.1)	-0.5 (1.4)	0.009

¹ Answers were on a 7-point Likert scale of -3: 3 corresponding to "Much worse": "Much better";

² Answers were on a 7-point Likert scale of -3: 3 corresponding to "Extremely hard": "Extremely easy";

³ Values are given as mean (SD).

Post-study comparison: survey answers

One-way ANOVA was conducted comparing experimental vs. control participant answers to the post-survey, regarding how successful participants felt in overcoming unhealthy snacking habits, and how easy they found it to resist unhealthy snacks during the week. Participants in the experimental condition reported significantly greater perceived improvement in overcoming their unhealthy habit, compared to controls ($F(1,51) = 5.4$, $p = 0.020$) (see Table 7), and found it easier to resist unhealthy snacks ($F(1,51) = 7.4$, $p = 0.009$) (see Table 7).

Table 7. Self-reported agreement to statement about likelihood eating unhealthy snacks without thinking and self-reported agreement to statement about having strong cravings for unhealthy eating.

Comparison statement	iCrave (n = 26)	Tracker (n = 27)	P-value
Self-reported agreement to statement about likelihood eating unhealthy snacks without thinking ¹	-0.464 (1.3)	0.11 (1.5)	0.16
Self-reported agreement to statement about having strong cravings for unhealthy eating ¹	-0.6 (1.5)	0.04 (1.8)	0.16

¹ Answers were on a 7-point Likert scale of -3: 3 corresponding to "Completely disagree": "Completely agree"

Pre vs. Post-study changes in survey answers

Another way of assessing the effects of the application is to compare the changes in answers to questions that were asked both pre- and post-experiment. Experimental participants showed significant changes in their answers to post-study survey questions, compared to the same questions in the pre-study survey, whereas control participants did not. Paired within-participant t-tests comparing pre-study vs. post-study answers for the same participants showed that experimental participants after the week had significantly reduced cravings for snacks overall ($t(25) = 5.27, p < 0.001$) and reduced cravings for unhealthy snacks ($t(25) = 3.1, p = 0.005$); and that they found it much easier to resist unhealthy snacks ($t(25) = 5.4, p < 0.001$). In contrast, control participants only showed a significant decrease in their reports for cravings for snacks overall, $t(26) = 2.2, p = 0.04$, and no other changes in post- vs. pre-study answers were significant.

Imagery vividness and snacking response

To check whether this lack of correlation existed for craving reduction “in the wild”, experimental participants were examined regarding whether there were any differences in reported vividness of imagery corresponding to events where they chose to either save, healthy snack, or unhealthy snack. A one-way ANOVA showed significant differences in vividness ratings across the different snack choices: Save: $M = 3.8, STD = 1.0$; Healthy: $M = 3.8, STD = 0.92$; Unhealthy: $M = 3.2, STD = 0.88$ ($F(1,51) = 10.8, p < 0.001$).

7.1.2 Qualitative results (II)

Post-study interviews were conducted with seven randomly selected participants, who participated in the experimental condition and used the full iCrave app for a week. Participants were asked about the external contexts, as well as their inner thoughts and feelings that surrounded the usage of iCrave. They were asked to describe moments at which iCrave prompted them to either forgo a snack or choose a healthy snack, as well as moments at which iCrave was not effective.

Resisting snacking entirely

Participants were asked to describe their experiences in instances where the use of iCrave helped them to resist snacking entirely. Responses supported the idea that cravings for snacks were indeed reduced. Participants reported the reduction in desire for food. “There is a loss of appetite.” “It made me feel like I don’t want to eat snacks.” “The attraction of snacks is reduced.” Participants also described how the imagery task gave them the presence of mind to make better judgments and exert self-control about snacking. For example, “Before I wanted a cookie ... afterwards I felt it would be better that I did not eat a cookie.” “Afterwards, I felt like I could control myself.”

Choosing healthy over unhealthy snacks

Participants were also asked what their experiences were when iCrave helped them to choose a healthy snack. Responses suggested that in these instances, iCrave shifted initial unhealthy preferences towards healthier choices. For example, “Before, I wanted chocolate immediately. (Afterwards) I preferred the vegetable salad.” “It made me prefer healthy food.” As with the situations where iCrave helped participants to avoid snacks entirely, participants described how iCrave gave them the presence of mind to choose a healthier option: “I wanted chips, but afterwards, I felt it is better to eat something healthy.” “After using the app, I wanted to order the healthy snack.” A few participants spoke of how iCrave caused them to reflect more generally on the importance of healthy choices: “After using the app, I thought, ice cream is not good for body. I shouldn’t just eat it, even when I’m not using the app.” “With the app, I became more aware of the food (I chose).”

Feeling good

All participants reported feeling good after the app had helped them either to avoid snacking or to eat healthier snacks. For example, “I felt good avoiding the popcorn.” “It was a good feeling to avoid the ice cream”. “I felt happy to get healthy food”. “I felt happy to change the choice of food so my life can be healthier.”

When iCrave did not work

Participants were asked what their experiences were when iCrave did not help them to avoid an unhealthy snack. These experiences appeared markedly different from the moments at which iCrave did support healthier choices. Participants spoke of how the app did not help them and they failed to feel any shift in their cravings. For example, “I felt it could not help me this time.” “Nothing changed, both before and after using the app I still wanted chicken.” “It didn’t work ... the feeling was the same both before and after using the app.” These remarks suggest that iCrave worked by shifting preferences and mental states, and the situations in which iCrave was ineffective were when this shift did not occur.

7.2 Persuasive mHealth physical activity application iGO (V-VI)

7.2.1 Usability study (V)

Quantitative results

Participants responded to the question item of performance expectancy between “Somewhat agree” and “Mostly agree” (mean value $M = 5.6$, standard deviation $SD = 0.9$) (see Fig. 21), participants mostly considering that the iGO app improved their work productivity. Participants responded similarly in response to the question items of effort expectancy ($M = 5.9$, $SD = 0.6$), social influence ($M = 5.5$, $SD = 1.0$) and behavioural intentions ($M = 5.8$, $SD = 1.2$) (see Fig. 21). Conversely, participants reported between “Neither disagree or agree” and “Somewhat agree” in terms of facilitating conditions ($M = 4.4$, $SD = 1.4$), that is, they did not have enough resources to use the iGO app. However, the overall satisfaction with the use of the iGO app to promote PA was between “Mostly agree” and “Completely agree”, that is, participants responded significantly in terms of the user behaviour ($M = 6.4$, $SD = 0.9$).

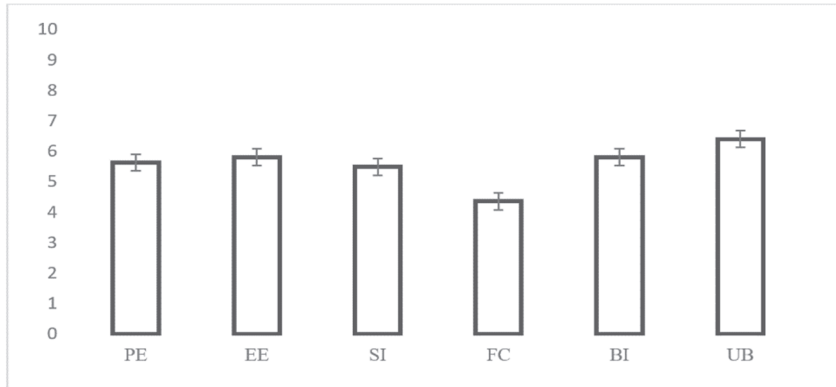


Fig. 21. Mean and standard deviation of performance expectancy (PE), effort expectancy (EE), social influence (SI), facilitating conditions (FC), behavioural intention (BI), use behaviour (UB).

Research hypothesis results

To study the H1, the correlation between variables performance expectancy and behavioural intentions was analysed (Fig. 15). The correlation between variables effort expectancy and behavioural intentions was analysed to test the H2. To study the H3, social influence and behavioural intentions were analysed. On the other hand, when testing the H4, the correlation between the facilitating conditions and use behaviour was analysed to test H5. Users indicated the following results relating to the hypotheses.

Performance expectancy positively correlated with users' intentions to use the iGO PA app ($p = 0.007$, $R = 0.561$) (see Table 8). This implies that when employees expect a persuasive application to promote their PA, they increase their intentions to use the application. Effort expectancy was positively associated with users' intentions to use the application ($p = 0.027$, $R = 0.470$). This indicates that when users expect a persuasive application to be convenient for them to use, they increase their intentions to use the application. Social influence positively affected users' intentions to use the application ($p = 0.007$, $R = 0.558$). This indicates that when employees interact with their colleagues for a suggestion to use a persuasive application, they increase their intentions to use the application. Facilitating conditions did not significantly influence use behaviour of actually using the application ($p = 0.361$, $R = 0.204$), see Table 8. Behavioural intention positively

influenced users' use behaviour of actually using the application ($p = 0.019$; $R = 0.497$) and thus, when users are more intent on using the application to promote physical activity, they use the iGO application more often.

Table 8. Confirmation of hypotheses.

Hypotheses	R	P	Strength	Support
H1: Performance expectancy positively influences users' intention to use persuasive application for promoting PA	0.561 ⁴	0.007 ²	Moderate	Yes
H2: Effort expectancy positively influences users' intention to use persuasive application	0.470 ⁴	0.027 ¹	Moderate	Yes
H3: Social influence positively influences users' intention to use persuasive application	0.558 ⁴	0.007 ²	Moderate	Yes
H4: Facilitating conditions of persuasive application positively influences users' use behaviours of actual use of a persuasive application	0.204	0.361	Low	No
H5: Behavioural intentions to use a persuasive application positively influences users' behaviours of the actual use of a persuasive application	0.497 ⁴	0.019 ¹	Moderate	Yes

¹ $p < 0.05$, ² $p < 0.01$, ³ $p < 0.001$, ⁴ $0.3 < |R| \leq 0.7$, ⁵ $0.7 < |R| \leq 1$

7.2.2 Feasibility study (VI)

Quantitative results

The overview of the quantitative questionnaire results is shown in Table 9. The results are presented as mean values on a 7-point scale.

Table 9. Users' agreement of iGO app (experimental group) or paper diary (control group) on different conditions.

Condition	Experimental group (n = 20)	Control group (n = 7)	p-value
Increasing physical activity ¹	6.15	4.30	0.033
Autonomy ²	5.05	3.30	0.004
Competence ²	4.86	2.00	0.014
Relatedness ²	3.15	3.43	0.535

¹ Likert scale of 1 to 7 ranging from Much worse to Much better, ² Likert scale of 1 to 7 ranging from Completely disagree to Completely agree.

Participants in the experimental group responded to increasing their physical activity or sitting idle using the mHealth app compared to the control condition

($p = 0.033$). Also, participants in the experimental group considered that the mHealth app increased their motivation for PA alone, compared to the control condition ($p = 0.004$). Participants in the experimental group considered that the mHealth app increased their motivation for feeling competent to view themselves in a social environment (i.e., on the leaderboard), compared to the control group ($p = 0.014$). There was no difference between experimental and control groups in consideration of the motivation for PA with others. Participants inputted their weight when installing the iGO app into the smartphones and transferred this to the post-questionnaires. A trend for weight loss was found when using iGO, with borderline statistical significance (72.2 vs. 71.4 kg, $p = 0.054$).

Qualitative results

Table 10. Qualitative results based on users' interview data.

Term	Description
Autonomy	Most experimental group participants (14/20, 70%) were motivated, set their daily goal of 10-minute walking after breakfast and lunch, and tracked their daily record when using the iGO app, which indicated autonomy. For example, participants mentioned: <i>"I sort of liked the way how it influenced me to go for walking and became my daily routine, liked it"</i> ; and <i>"I felt like using the app has changed my habit of sitting idle in the office after breakfast/lunch."</i>
Competence	Participants (13/20, 65%) felt competent using the iGO app to view themselves in a social environment to do daily walking. For instance, a participant noted: <i>"[It] assisted me to interact with the phone and to walk with others,"</i> while another mentioned: <i>"[It] became a habit, but I wanted to see more in the apps like more connection [among] people who are using it!"</i> They felt competent using the mHealth app, which indicates the fulfilment of the competence.
Relatedness	Only few participants (5/20, 25%) were motivated to do PA (e.g., walking with others) when using iGO. One participant felt connected with their colleagues and noted: <i>"[I] walked with colleagues and friends and made me mix with others while walking; a social platform."</i> Perhaps iGO allowed the participant to do daily walking along with colleagues from the same office room, and to track their progress from the data server. In this way, they might feel connected with colleagues. However, one participant stated: <i>"I cannot feel any betterment to walk with others."</i> The sense of being connected to others using the gamified prototype is not valid in this case. Therefore, the fulfilment of the last psychological need, relatedness cannot be agreed.

Term	Description
Game-design elements	<p>One participant ranked in the leaderboard reported: <i>"I liked the way ... it influenced me to go ... walking and [it] became my daily routine, liked it."</i> However, the social fun part of the game elements was not visible among the participants, who reported: <i>"Maybe add a way to create events to [attend];"</i> <i>"Should add more socialising features;"</i> and <i>"Maybe more social fun activities options."</i> Participants wanted to see different points measuring for two walking conditions. One participant mentioned, <i>"Some difference in the points for walking alone and walking with others."</i></p>
Other comments	<p>The log data showed that some regular users did not upload their name and picture to be visible on the leaderboard, even though users preferred a leaderboard with their details added to it when prototyping the iGO app. Within the control group, most participants suggested that some sort of reminder should be added in the paper diary. Participants reported: <i>"I wish there were a kind of alarm type feature or image that [could] draw ... attention towards the paper;"</i> and <i>"[A] paper diary can be easily ignored in the busy schedule, so it should be more attractive."</i></p> <p>Out of those who completed the study using iGO app, eight (8/20, 40%) participants received a Samsung phone from us whereas others used their own smartphones. The log data showed that those who used their own phone had more points and higher rank on the leaderboard. Moreover, data of the participants who completed the study in Ireland showed that those who were high on the leaderboard rank (4/6, 66%) were colleagues from the same offices and building.</p>

8 Discussion

The main findings of Studies I-VI are described in Table 11. More detailed descriptions can be found in the papers.

Table 11. Main findings.

Sub-study	Theory applied	Findings
I	SDL: axiom FP6 (A2) and FP10 (A4)	VPs for persuasive mHealth applications
II	EI theory of desire	Reduced unhealthy eating when using iCrave app
III	Ryan's SDT model	Positive impact in promoting PA
IV	SDT	Increased PA (self-reported by users)
V	UTAUT model	iGO app was satisfactory to motivate PA promotion
VI	SDT theory	Increased PA; fulfilment of SDT needs of autonomy and competence, but not the relatedness

8.1 Comments on value propositions (I)

In Sub-study I, four key VPs have been proposed for the persuasive mHealth applications. A method is recommended to involve users and relevant stakeholders for a value co-creation model (Demiris & Kneale, 2015). The approach in listing the VPs for persuasive mHealth applications might be one successful method, since the users and other actors are involved. The approach to finding the VPs of the mHealth applications was a combination of collecting information on the individual user and other relevant stakeholder experience, quality and cost of mHealth applications to increase the applications' efficacy and involving users in co-creating the value. However, the proposed VPs are limited to literature and expert validation (as found in the HTA core model) is not involved. Further study needs to concentrate more on the extract version of these four VPs, to highlight their importance for different types of users. In the future, expert validation of VPs should be performed.

8.2 Design process (II-V)

The testing of the prototype of the healthy eating application involved users from the local community in the UK. Users said they would have preferred to have the working mobile app, rather than the prototype, which was installed in the mobile website. However, users were involved in the co-design of the prototype of iGO

(II). Nevertheless, the design of the application could have followed a more standard version of the UCD iteration (such as the UCD five steps of *empathise*, *define*, *ideate*, *prototype*, and *test*. This lesson-learned has however, been considered to utilise this UCD iteration to design and develop iGO to promote PA.

During the UCD iterative process of the PA application, the prototype was tested but long term, since users ran the prototype of an app for only 15 minutes and pretended to use the application, when using the paper prototype to walk for 10 minutes. It was found that the app produced a positive impact on the employees in promoting their PA in their workplace (III). However, using the real PA promotion application may produce a different effect from walking consequences, such as weight loss (Hijikata & Yamada, 2011) and other health benefits (Reynolds, Mann, Williams, & Bernard, 2016). During the pre-evaluation study of the iGO (IV), users informed that the app worked well for PA promotion, but recommended that the app should be modified. The app was therefore upgraded and a usability study (V) was conducted before the main evaluation study (VI).

8.3 Feasibility of application for healthy eating (II)

The study was the first to evaluate whether this method of craving reduction results in reduced consumption “in the wild”. The results of the study hint at the possibility that the use of iCrave can provide more comprehensive benefits for snacking behaviour beyond the moments of using the app. In post-experiment questionnaires, participants who used iCrave reported that they were better able to resist unhealthy snacks than those in the tracker condition. While this might have been purely because they were using the full iCrave app, another possibility is that by practising the imagery task, they learned a cognitive strategy for reducing desire, which they could implement even when they were not using the app. Previous work has shown that the vividness of imagery did not correlate with reductions in cravings (May et al., 2010) and in this study, the vividness with which users were able to engage in the imagery task was related to the effectiveness of the iCrave app in improving snack choices. While results did not reach significance levels, users of iCrave reported having overall fewer cravings for unhealthy snacks and being more aware of eating unhealthy snacks, in comparison to users of the tracking app. Finally, in the qualitative interviews, some participants mentioned that iCrave prompted in them a greater awareness of food choices, even when they were not using the app. Longer-term studies will be needed to verify the possible broader effects of using iCrave, as mentioned above, and suggested in the current work.

This study focused on the use of iCrave to improve snacking behaviour. However, it would also be interesting to know whether iCrave can improve the healthiness of consumption during meals, as well as snacks. Though cravings are typically associated with snacks, they could also play a role in meal-time consumption. Another line of open enquiry is to understand in more detail the effectiveness of the individual components of iCrave. While the results found that imagery vividness correlated with healthy choices, the extent to which a 10-second delay without the imagery task might also be effective is unknown. Laboratory studies have shown that equivalent-length mind wandering tasks (Hamilton et al., 2013) and other cognitive tasks such as reciting the alphabet backward (Knauper et al., 2011), are not effective in reducing cravings. This suggests that a mere 10-second delay without imagery would not be as effective in changing behaviour. However, this remains to be empirically verified.

Another factor that may have contributed to the success of iCrave, besides the imagery task and delay, was the presence of the “Save” button. While the participants spoke of the imagery task shifting their choice preferences, it is possible that the mere possibility of being able to record moments of overcoming cravings also would be beneficial on its own, without a craving reduction task. Indeed, in user interviews for the lite prototype, which only contained a “Save” button, people reported enjoying recording their savings. However, the effectiveness of this “Save” button has yet to be systematically evaluated on its own.

8.4 Feasibility of application for physical activity (VI)

In the Sub-Study (VI), feasibility study of the built application: iGO app for PA promotion was shown. Based on the examination, the iGO app helped to overcome physical inactivity by increasing walking. The data supported compliance with two of the basic psychological needs – autonomy and competence – but not for the needs of relatedness. However, compliance in using the app remained low. Satisfaction with the SDT basic needs for autonomy, competence and relatedness is essential for establishing intrinsically motivated and sustained PA behaviour (Teixeira, Carraça, Markland, Silva, & Ryan, 2012). In this study, most participants were motivated and set their daily goal of 10-minute walking after breakfast and lunch. Participants felt competent using iGO to view themselves in a social environment to do daily walking.

Discontinuation has been found as central problems in technology-enhanced intervention studies (Berrouiguet, Baca-García, Brandt, Walter, & Courtet 2016)

and participants' age, gender, education, and employment status are appeared to envisage their risk of dropping out during the study (Kannisto, 2017). In this present study, the number of consented participants who did not continue the study is comparatively high. Participants were busy in their employment life. They were developers/programmers who were working in the technology-based industries and were young aged. This may indicate that the reason for discontinuation was their young age and employment status.

Studies have shown that interventions targeting PA promotion can be designed to focus on setting-specific issues that are open to change within demographic settings differentiated by gender, age, social disadvantage, and geographic location (Dollman, 2018). The users were from four different countries. Apart from UK and Ireland participants (English speaking natives), participants from Finland and Bangladesh have their own native language (Finnish and Bengali). However, they all speak English due to their international working environment in the office. Thus, participants were not affected by language factor when the app was in English. On the contrary, cultural differences may have significant effect on the use of behaviour change applications and need to be studied in more detail in the future.

On the other hand, weather conditions may have an effect on outdoor PA as demonstrated for older adults (Timmermans et al., 2016). UK, Ireland and Finland have varying day length and outdoor temperatures by seasons, in contrary to Bangladesh. Extremely cold temperatures and slipperiness may reduce outdoor activities during the winter period for example, in Finland, but not effect indoor behaviours. Similarly, extreme level of heat, having negative impact on human health and their productivity (Jones, 2018), may have limited walking outside of the office buildings in Bangladesh. The offices inside were well-equipped with air condition system but may have had comparatively limited space to even walk at their office corridors. In any way, the iGO was designed to encourage workers walking during their breakfast/recession period which they had been able to do in the office area and thus, they were not much affected by weather factors in the office area.

It was not individually looked at users' recommendations, age, and gender from a particular demographic location but had already averaged all users' preferences from four different countries when designing the app. The SDT needs of relatedness were absent here, i.e., the participants did not connect with others while walking. Previously, research has suggested that being connected to more people may help with PA promotion (Tong et al., 2019; Kang & Kim, 2015), and users tend to do more physical activities if they are socially connected with others for the same

purpose. In this study, the environment appeared not to be fully supportive of the participants' regular PA, perhaps due to the lack of actual daily interaction with colleagues. The low levels of relatedness may be explained by the fact that not many colleagues were using the iGO app at the same time. Previously, social features of an mHealth tool have been shown to have initiated positive changes in the social interaction among colleagues and signing up for the tool (Balk-Møller, Larsen, & Holm, 2017). Here, the leaderboard included participants from four countries. This may, however, demotivate participants since it may be more motivating to compete against participants that people know personally.

A choice of cognitive, emotional and social benefits is credited to gamification (Turan, Avinc, Kara, & Goktas, 2016). Building positive social relationships and fostering a sense of integration are the core social benefits noted for gamification (Rao & Pandas, 2013). In the present study, the game elements may not have brought enough social benefits to the users. Additional features could have been added for scoring. For instance, walking with others might give additional points. Competition allows users to identify their situation and compare their activities to others (Stibe, 2014). Although leaderboard is a way to represent competition on users' activity (Orji et al., 2014), competition was not noticed among the users in this study. Participants who focused more on PA than points may have earned more points than those who focused on earning points. To facilitate PA promotion, strengthening of motivation and changes in self-awareness are two essential mechanisms (Carter, Robinson, Forbes, & Hayes, 2018). This suggests that participants may have been motivated intrinsically by using the iGO app, and that their self-awareness was increased over the usage of the iGO towards their PA promotion in the workplace.

Using mobile reminders is a conventional approach in health research (Park, Li, Howren, Tsao, & De Vera, 2019; Ashwini, Sapna, Ishwari, Pallavi, & Achaliya, 2013; Franklin, Waller, Pagliari, & Greene, 2006). The use of digital triggers (e.g., alarm/vibration) can be automated into smartphones so that the users recognise the meaning of the alert. Triggers such as the adaptive control mechanism are framed to meet the needs and goals for short-term actions and longer-term behavioural change (Muench & Baumel, 2017). Reminders programmed in the iGO helped the users to react for a near-term response, for example, reminded them to walk. Researchers have highlighted that mHealth solutions are still methodological and need to resolve privacy issues (Helbostad et al., 2017), such as security features that include secure encryption and two-factor authentication (Navarro et al., 2018). The fact that some participants had no name or picture on the leaderboard could be

because of their preference for not disclosing their daily PA-based track record (total minutes of walking, earned points, etc.) to others.

Compliance with using the paper diary was comparatively low, compared to the mHealth app. Participants forgot to follow the paper diary; it was less attractive; there was no alarm system, and it was difficult to record the walking time on the paper. Walking can be beneficial to loss of weight (Hijikata & Yamada, 2011) and other health benefits (Reynolds et al., 2016; Aoi et al., 2013). mHealth interventions with theory-based podcasts, social support (Mateo, 2016), encouraged self-tracking (Yu et al., 2018; Mateo, 2016) and health coaching (Mao, Chen, Magana, Caballero Barajas, & Olayiwola, 2017) had earlier been shown to result in weight loss. During the four-week study under discussion, there was a trend for weight reduction among the experimental group. It remains open as to whether the mHealth app influenced participants to reduce their weight, since the follow-up time was relatively short, the sample size was limited, and self-reported weight data was used.

8.5 Theoretical and practical contribution (I-VI)

8.5.1 Theoretical contribution

The theoretical contribution of the thesis can be viewed to some degree. The proposed VPs have informed that health application providers and other relevant stakeholders should work together to provide high-quality and efficient mHealth applications to users. This thesis is a step towards the involvement of the relevant stakeholders in an iterative design process of developing applications using gamification with persuasion techniques. Although there has been a recent increase in persuasive technologies (Orji & Moffatt, 2018; Hamari et al., 2014) designed for psychological influence, by encouraging reflection and awareness about health promotion, it is also important to understand the specific psychological constructs that underlie their use in a particular design context. This study contributes to the human-computer interaction (HCI) community to deepen understanding of how psychological theories can be integrated to design and develop mHealth applications, as well as using game-design elements within the system model. In HCI, the users have their own specific stands to some extent, for example, user-centered design (Kübler et al., 2014). This study is an attempt to understand the users, their needs of healthy lifestyles such as healthy eating and PA, in their workplace setting, in particular, their psychological level of analysis, finding

reasons of users' motivation, their emotions, thoughts and reactions. Moreover, the thesis underlines the significance of the theoretical concept of health behavioural change theories (de Korte et al., 2018) in the design of persuasive technology for employees and proposes how to integrate them by addressing the key issue that social connectedness rarely happens during the utilisation of mHealth applications. To conclude, this thesis is an attempt to guide researchers to furthering research on the longitudinal study with a larger scale, in the context of mHealth applications. It also summarises and analyses the effects of the persuasive health behavioural change techniques in design and development of mHealth applications, based on previous literature.

8.5.2 Practical contribution

The practical contribution of the thesis is illustrated through the technological tools – persuasive mHealth applications for healthy lifestyle. To design and develop the mHealth app iCrave and iGO, the participation of the users was briefly studied, and other relevant stakeholders were involved, such as health applications providers, researchers and experienced designers, and developers. While building the mHealth applications, future researchers should also focus on the key VPs that resemble the application's benefits to the users. The number of mHealth apps is much higher than that of published studies related to mHealth apps, but it lacks the use of theoretical concepts and evaluation (Jusoh, 2017). The designers and developers can explore how behavioural change theories and persuasion techniques could be utilised in their own applications. Designers and developers can implement users' new ideas through the iterative design process of every step of the application development, such as applying design thinking processes more effectively. Also, privacy and usability issues within the mHealth apps are still vulnerable (Jusoh, 2017). This thesis is a successful approach to overcoming these issues, by developing two mHealth apps followed by scientific research. To make a value-based health application, designers and developers should be focused on usability testing and the issues related to it, and this can be done once they have built the applications. In addition, empirical studies should be conducted to give more insightful comments and feedback from the users, and to deal with their subjective and objective experiences. This can help them to revalidate users' recommendations of new ideas and to verify whether designers and developers have taken all viable decisions into account.

8.6 Future perspectives (II, V–VI)

8.6.1 Application for healthy eating (II)

The finding that a system which prompts an imagery task and records moments of overcoming temptation can improve snacking habits opens up questions about how the system might be designed to optimise effectiveness. One possibility is to allow users to engage in multiple repeats of the imagery task and/or to allow them to select a new imagery task, if the first imagery prompt is unappealing. Another option is to allow the user to choose whether they want to have an imagery task at all, thus allowing for more flexibility in usage. Additionally, a greater variety of craving reduction tasks can be incorporated to prevent adaptation. Previous laboratory studies have shown that other imagery tasks, such as staring passively at dynamic black and white visual noise, olfactory imagery, and tactile-visual manipulation, can also help to reduce cravings (May et al., 2010, Andrade et al., 2012, Kemps & Tiggemann, 2007, Harvey et al., 2005). Other studies have shown that imagining indulging in one's favourite activities also can help to reduce cravings (Knauper et al., 2011). Thus, future versions of iCrave can explore the usefulness of allowing users to create their own repository (e.g., text or photos) of craving-reduction material.

Future versions of iCrave can incorporate additional features that enhance the rewards of forgoing snack cravings and reduce the strength of cravings. For example, the application can enhance the association of accumulated savings with future non-food rewards. One can imagine a personal treats store where the user could pre-specify the treats, they would allow themselves, if they were to overcome a certain number of cravings or went for a certain time period without unhealthy snacks. Another method for celebrating savings might be to include an option for social features, where friends who are trying to snack less are connected and updates can be posted when each successfully overcomes a craving, thus allowing others to offer congratulations, feedback, or encouragement.

8.6.2 Application for physical activity (V–VI)

Following the usability study, the influence was measured only through the subjective experience of the participants with questionnaires, instead of actually measuring whether the app had the effect of encouraging the user to do more exercise or not. Based on the confirmation of the usability study hypotheses, the

iGO app needed to be upgraded to fulfil the requirements of facilitating conditions, such as the user having the option to use the iGO app when they were offline. The iGO installed in the smartphone should have been able to keep the record of offline activities and update the record into the data server when online. As an example, the social media network Facebook has a similar option of updating the user's status when the internet is available. Also, the sensor to track the physical activities was not compatible with all the smartphone models, that is, it worked only on those that had the built sensor. More options for the users (option to walking more than 10 minutes) and offline activities for the users might be useful. The number of dropouts was comparatively low. Only six of 28 participants dropped out during the eight-week study. However, most of the participants were busy with their personal and professional lives, which may explain the level of dropouts. The total number of participants taking part in the pilot session was limited, and the statistical strength would be increased with a higher sample size. A larger number of participants might demonstrate the specific effects of the persuasive application with greater accuracy. The usability issues have been tested, such as the effect of the iGO in terms of user PA promotion in the workplace. This usability study has informed the researcher on how to conduct a feasibility study and to analyse whether the application increased the users' PA, weight management and the psychological needs of autonomy, competence and relatedness.

Following the feasibility study, it had some limitations. First, the final sample size remained relatively low. Larger-scale studies are needed to confirm the findings. Many consented participants, who typically were young aged and programmers/developers by profession, discontinued the four-week study. A next generation solution should be redesigned based on the feedback received, in order to increase compliance. Secondly, the randomization was made before invitations. This may have had some influence in the difference in the number of participants between the groups. Another limitation of the study is that the weight was self-reported and collected only in the beginning and end of the study. However, this study was targeted of increasing PA, not for weight loss, which may reduce the possibility for bias.

The iGO app was still a prototype with somewhat limited graphical design and user interface. Some participants may have failed to connect with others due to the contemporary design of the mHealth app. Physical activity measured by the smartphone can underestimate number of steps as people may leave the phone on the office desks. Less measured minutes of walking may result in lower points, and therefore an inaccurate leader board which could demotivate participants to follow

ranks and points on the leaderboard. Furthermore, the accelerometer sensor was not installed in some smartphones and users were not able to track their steps. Hence, the real walking data of the users may be somewhat different from the data in web server. The increase of PA was obtained from questionnaire data. The accelerometer-based step count was used for calculating the rewards. However, the objective physical activity data was not used for other purposes in this study.

More features and options could be added, for example, socialising functions and social fun activities allowing users to interact with others (Maher et al., 2015; Patel et al., 2017). Adding a gamified social networking platform (Paliokas, Tzallas, Katertsidis, Votis, & Tzovaras 2017; LeGrand et al., 2018) with more user-friendly social features, such as a more specific social game element, might allow users to interact with others via chat messages in the mHealth app. Points could be awarded and redeemed in schemes such as the Tesco Clubcard (Rowley, 2005; Humby, Hunt, & Philips, 2003) and the Carrots Rewards App (Mitchell et al., 2017). The iGO app could have options for users to share each other's points and perhaps exchange points for social voucher cards.

9 Conclusion

This doctoral study was aimed to design and develop persuasive mHealth behavioural change interventions to foster healthy lifestyle actions. Based on the findings, the following conclusions can be made:

1. Based on the literature review approach, four key VPs were proposed to create value in the persuasive and mHealth applications.
2. The persuasive mHealth application iCrave was designed and developed to encourage healthy eating, by incorporating the EI theory of desire. The feasibility of the application was evaluated using an experimental design technique, which showed that the iGO significantly reduced unhealthy eating, compared to a simple application.
3. A theory-driven application model was proposed, incorporating the Ryan's SDT theory, to develop a persuasive mHealth application for PA promotion. Based on the model, an initial paper prototype was tested by applying the UCD process.
4. The persuasive mHealth application iGO was developed for promoting PA behavioural change in the workplace. The usability evaluation of the iGO was conducted over a week's study, by encouraging the participants to carry out self-determination tasks and allowing them to save their choices.
5. The usability evaluation of the application was conducted for PA promotion, using the UTAUT model. The iGO was found to be satisfactory for motivating users in PA promotion.
6. Based on a four-week feasibility study of the iGO application, the app supported users in increasing PA in the workplace, compared to the results from using a paper diary. The iGO app fulfilled the requirements of the SDT basic needs of autonomy and competence, but not the needs of relatedness, that is, it did not support participants in feeling connected with others.

It can therefore be deduced that persuasive mHealth behavioural change interventions promote healthy lifestyle.

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