Guido Giunti

3MD FOR CHRONIC CONDITIONS

A MODEL FOR MOTIVATIONAL mHEALTH DESIGN
GUIDO GIUNTI

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A Model for Motivational mHealth Design

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Abstract

Chronic conditions are the leading cause of death in the world. Major improvements in acute care and diagnostics have created a tendency towards the chronification of formerly terminal conditions, requiring people with these conditions to learn how to self-manage. Mobile technologies hold promise as self-management tools due to their ubiquity and cost-effectiveness. The delivery of health-related services through the use of mobile technologies (mHealth) has grown exponentially in recent years. However, only a fraction of these solutions takes into consideration the views of relevant stakeholders like healthcare professionals or even patients. The use of behavioral change models (BCM) has proven important in developing successful health solutions, yet engaging patients remains a challenge. There is a trend in mHealth solutions called gamification that attempts to use game elements to drive user behavior and increase engagement. As it stands, designers of mHealth solutions for behavioral change in chronic conditions have no clear way of deciding what factors are relevant to consider.

This doctoral thesis is framed in Consumer Health Informatics within the field of Medical Informatics and Information Systems. The focus of this work was to discover factors for the design of mHealth solutions for chronic patients; to do so, negotiations between medical knowledge, BCM and gamification were explored through an embedded case study research methodology. The data obtained was thematically analyzed to create the Model for Motivational Mobile-health Design for Chronic conditions (3MD).

The 3MD model guides the design of condition-oriented gamified behavioral change mHealth solutions. The main components are: 1) Condition specific, which describe factors that need to be adjusted and adapted for each particular chronic condition; 2) Motivation related, which are factors that address how to influence behaviors in an engaging manner; and 3) Technology based, which are factors that are directly connected to the technical capabilities of mobile technologies. 3MD also provides a series of high level illustrative design questions for designers to use and consider during the design process.

The work on this thesis addresses a recognized gap in research and practice, and proposes a unique model that could be of use in the generation of new solutions to help chronic patients.

Keywords: chronic conditions, consumer health informatics, gamification, health behavioral change, information systems, medical informatics, mHealth, user-centered design
Tiivistelmä

Krooniset sairaudet ovat maailman yleisin kuolinsyy. Akuutissa hoidossa ja diagnostiikassa on tapahtunut merkittäviä parannuksia, ja aikaisemmin kuolemaan johtaneista sairauksista on tullut kraanisia ja ihmisten on opitava hallitsemaan niitä itse. Mobiiliteknologioiden tarjoamat mahdollisuudet sairauksien itsehallintaan, koska teknologia on yleisesti saatavilla ja se on kustannustehokasta.


Tämä väitöskirja tarkastelee kuluttajille suunnattua terveysteknologiaa, joka hyödyntää lääketieteellistä informatiikkaa ja tietojärjestelmätieteilteitä. Työn tavoitteena oli selvittää kroonisia sairauksia sairastaville potilaille tarkoitetun mobiilien terveyssovellusten suunnittelu liittyvät tekijöt. Tämän vuoksi lääketieteen tietämystä, käyttäytymismuutosmallien ja pelilistämisen yhdistämistä tutkiin suunniteltavan tapaustutkimuksen avulla. Saatuja tietoja tunteamattaan analysoimalla luotiin kroonisia sairauksia varten motivoivan mobiilin terveyssovelluksen suunnitelumalli (3MD = Model for Motivational Mobile-health Design).

3MD-malli ohjaa sairauksien hallintaan tarkoitetun pelilistettyjen ja käyttäytymismuutosmallin tähtäävien mobiilien terveyssovellusten suunnittelua. Mallin pääkomponentit ovat: 1) Sairautta kuvaavat tekijät, jotka kuvaavat tekijöitä, jotka on mukautettava ja sovittava kullekin krooniseselle sairaudelle. 2) Motivaatiota liittyvät tekijät, jotka vaikuttavat innostavasti käyttäytymiseen. 3) Teknologian perustuvat tekijät, jotka liittyvät suoraan mobiiliteknologian teknisiin ominaisuuksiin. 3MD tarjoaa myös havainnollisia suunnittelukysymyksiä, joita suunnittelijat voivat käyttää ja pohtia suunnitteluprosessin aikana.

Tämä väitöskirja käsittelee yleisesti tunnistettua puutetta tutkimuksessa ja suunnittelukäytännössä ja esittelee ainutlaatuisen mallin, josta voi olla hyötyä uusien ratkaisujen luomisessa ja kroonisia sairauksia sairastavien potilaiden auttamisessa.

Asiakirjat: krooniset sairaudet, kuluttajille suunnattu terveysteknologia, käyttäjäilähtöinen suunnittelu, lääketieteen tietotekniikka, mobiilit terveyssovellukset, pelillistäminen, terveyskäyttäytymisen muutos, tietojärjestelmät
Avanti, sempre avanti…
Preface

First off, dear reader, you should skip this bit of text for now. I know I always do and I expect no difference. Go ahead, read what follows, see what you think of it; and then, only then, if it strikes your fancy, come back here and go through these final thoughts put together after the fact.

I have always been fascinated by the story of the ship of Theseus. That idea that an object, piece by piece can be replaced over time to the extent that nothing of the original thing remains, yet somehow it still is considered the same. How does a concept like that applies to human beings? How many parts of ourselves have we left behind and will never regain?

My sojourn began a few years ago as a man I barely remember now. To look at him, his motivations and way of thinking, it all now seems somewhat alien to me. I wonder what would this man think of my current self? Would he understand the changes? I imagine he would not necessarily see them as sacrifices, but rather as trade-offs. To gain something you must give something of equal value in return: the Law of Equivalent Exchange. I suppose I am lucky that, even after all, I feel I have gained more than I have given.

A large part of what makes us who we are is made from pieces of others. Few realize just how much. Fewer still actually get to experience that realization firsthand. We are kind of a mixture of habit and expectations. Things that we do because we always have and, things that we do because others or ourselves expect them from us. It is funny how so much of it is sustained because of others. Maybe this is because there was an “other” before a “me”; maybe it is because we are completed only through their presence. This thesis goes to those who, in many ways, shaped the person I am now.

Eternal thanks go to the European Union Horizon 2020 Framework Program and the Marie Skłodowska-Curie actions for funding the Connected Health Early Stage Researcher Support System Initial Training Network, without whom none of this would have been possible. You took me further than I ever thought I could.

I would like to thank my supervisors Prof. Minna Isomursu and Dr. Luis Fernández-Luque, and co-supervisors Dr. Octavio Rivera-Romero and Dr. Karin Väyrynen; for their support and guidance in this process. Although we spent most of the time in different cities, countries and even continents, it sure felt like you were with me all along.
Kind thanks go to my reviewers Prof. Sabine Koch and Prof. Kaisa Väänänen whose feedback improving the quality of this dissertation. I am also much obliged to Prof. Ilpo Koskinen and Dr. Kirsikka Kaipainen for being my opponents.

Prof. Harri Oinas-Kukkonen and Dr. Arto Lanamäki, my follow-up group from the University of Oulu who deserve my gratitude for their advice and dedication.

Special thanks go to my co-authors, whose collaboration I could not do without, and to my colleagues from Salumedia Tecnologias, working with you was a life lesson I will not soon forget.

There are also many who I would like to thank and acknowledge here, and it is difficult for these pages to contain all the ways in which they have made a difference. I will surely try, nevertheless.

Those who took a chance on me:

- Dr. Máximo Soto, I would not have even dared to do any of the crazy things I do if it were not for my time with you. Noblesse oblige.
- Dr. Analía Baum, you were my mama bear in health informatics and bore with me through thick and thin. Stick to high heel shoes.
- Dr. Diego Giunta, you taught me much more than research methods. You are a source of inspiration.
- Dr. Luis Fernández-Luque, you heard an Argentinian talk and still thought it was a good idea to offer him a job. Bless your Andalucian heart.
- Prof. Juan Ramón Lacalle-Remigio, I knocked at a strange door once and I am forever glad that it was you who I found behind it.

Those who have been a home away from home:

- Juaky, my first true friend in a strange land and time in life where I certainly needed one. Columns in databases were the way to go.
- Vaso, sweet Vaso, your friendship made me grow into a better man. I hope I have been as good an influence in you as you have been in me. We are Sancho.
- Fran, though apart, we are brothers. Always stay true to the Mayol-do.
- Estefi, finding a kindred spirit in you was just what the doctor prescribed. One day you will believe in you as much as I do.
- Minna, I hold you so very close to my heart. I salute your magical elven nature.
- Jelena, who knew someone could be so sweet and caring? Time is an illusion, my unexpected Russian friend.

Those who were and will be there:
– James, you are the master of the word “now”. Keep on making the world more colorful.
– Ferchus, the light in me welcomes the light in you. Let us be more careful with that though.
– Manu, I am so glad I found you, you beautiful unicorn.
– Nabo, from chocolatadas to flashes, you have been there and back again. Travel the path that has heart.
– Frank, discussion of ideas is to me synonymous to walking the nights with you.
– Sebas, it is such a shame that we share the same curse but at least we can support each other. And brunch is always nice.
– David, your words always aim true, even if your matchmaking does not.
– Checho, we may be two sides of the same coin but I am playing the long-con.
– Ulu, we started our first D together, now I got another. It was not the same without “Maria, la del barrio”.

Finally, to those who I would choose again:

– Papá, your integrity has been the standard to which I try to live up to. I hope I make you proud.
– Mamá, I love you more than you can imagine. Thank you for keeping the planes in the air.
– Carito, may you always want to come out and play with me.
– Abuelita hermosa, this one goes for all the hugs I could not give you.
– Abuelito, you would know what I want to say to you. See you on the road.

23/10/2018

Guido Giunti

MD (and now) PhD

Forever living at the far reaches of the bell curve
### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>3MD</td>
<td>Model for Motivational Mobile-health Design for Chronic conditions</td>
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<tr>
<td>App</td>
<td>Mobile software application</td>
</tr>
<tr>
<td>AIC</td>
<td>Akaike’s Information Criterion</td>
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<td>BC</td>
<td>Breast cancer</td>
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<td>BCM</td>
<td>Behavioral change model</td>
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<tr>
<td>BCSS</td>
<td>Behavioral Change Support System</td>
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<tr>
<td>CHESS ITN</td>
<td>Connected Health Early-stage researcher Support System Initial Training Network</td>
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<tr>
<td>CHI</td>
<td>Consumer Health Informatics</td>
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<tr>
<td>COST</td>
<td>European Cooperation in Science and Technology</td>
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<tr>
<td>EDSS</td>
<td>Expanded Disability Status Scale</td>
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<tr>
<td>eHEALS</td>
<td>eHealth Literacy Scale</td>
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<td>EHR</td>
<td>Electronic Health Records</td>
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<tr>
<td>ENJECT</td>
<td>European Network for the Joint Evaluation of Connected Health Technology</td>
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<tr>
<td>GST</td>
<td>Goal-setting theory</td>
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<td>HBM</td>
<td>Health belief model</td>
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<tr>
<td>HCI</td>
<td>Human Computer Interaction</td>
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<td>HP</td>
<td>Healthcare professional</td>
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<tr>
<td>ICT</td>
<td>Information and Communications Technologies</td>
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<td>IT</td>
<td>Information Technology</td>
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<td>mHealth</td>
<td>Mobile health</td>
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<tr>
<td>MS</td>
<td>Multiple sclerosis</td>
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<tr>
<td>OS</td>
<td>Operating System</td>
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<tr>
<td>PA</td>
<td>Physical activity</td>
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<tr>
<td>PSD</td>
<td>Persuasive Systems Design</td>
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<tr>
<td>PWMS</td>
<td>Persons with multiple sclerosis</td>
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<tr>
<td>ROC</td>
<td>Receiver Operating Characteristic</td>
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<td>RQ</td>
<td>Research question</td>
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<td>Salumedia</td>
<td>Salumedia Tecnologias</td>
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<tr>
<td>SCT</td>
<td>Social cognitive theory</td>
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<tr>
<td>SDT</td>
<td>Self-determination theory</td>
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<tr>
<td>SWLS</td>
<td>Satisfaction With Life Scale</td>
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<tr>
<td>TPB</td>
<td>Theory of planned behavior</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>TTM</td>
<td>Trans-theoretical model</td>
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<tr>
<td>UCD</td>
<td>User-Centered Design</td>
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Original publications

This doctoral thesis is based on the following original publications; these are referred in the text as Studies I–V. The publications are reproduced at the end of the thesis with kind permission from the publishers.


All studies were conceived and designed by me; I also led the overall study conduct and drafting for the different manuscripts. Detailed information on additional and specific contributions for each paper can be found below:

In Study I and Study II, I designed the data classification and coding systems and I was involved in data collection and data analysis.

In Study III, I gathered and supervised the efforts of the panel of experts, performed the statistical modelling and data analysis.

In Study IV, I designed the guiding questions and facilitated the sessions for the focus groups and one-on-one interviews, aided in the persona creation process, and also, as this was a research that took over the span of many weeks in different locations, I coordinated the work of the research team.

In Study V, I was in charge of the design team efforts, created the schematics for the theoretical requirement negotiation and performed the heuristic evaluations.
# Contents

Abstract

Tiivistelmä

Preface 9

Abbreviations 13

Original publications 15

Contents 17

1 Introduction 21

1.1 Research goal .............................................................. 24

1.2 Research questions .......................................................... 25

1.3 Thesis outline .............................................................. 26

2 Related research 27

2.1 Medical considerations .................................................. 27

2.1.1 Chronic conditions .................................................. 27

2.1.2 Empowering patients ................................................ 29

2.1.3 Patient journey .......................................................... 31

2.2 Behavioral change ...................................................... 34

2.2.1 Overview ............................................................... 34

2.2.2 Theories of learning .................................................. 37

2.2.3 Theories of health behavior .......................................... 37

2.2.4 Stage theories .......................................................... 38

2.2.5 Theories of reasoned action ......................................... 39

2.2.6 Theories of goal-directed behavior ............................... 39

2.2.7 Theories of self-regulation ......................................... 39

2.2.8 Social cognitive theory .............................................. 40

2.2.9 Behavioral change in mHealth .................................... 40

2.3 Gamification ............................................................... 41

2.3.1 Introduction to games ............................................... 41

2.3.2 Elements in gamification ........................................... 43

2.3.3 Users and player types ............................................. 44

2.3.4 Gameful design models ........................................... 46

2.4 Research gaps summary ................................................. 51

3 Research approach 53

3.1 Research domain .......................................................... 53

3.2 Embedded case study methodology .................................. 54

3.2.1 Setting ................................................................. 55
3.2.2 Study case .......................................................................................... 55
3.3 Data collection ........................................................................................ 56
  3.3.1 Embedded unit 1: breast cancer and multiple sclerosis
      mHealth apps review ............................................................................. 57
  3.3.2 Embedded unit 2: gamification presence in mHealth apps .......... 57
  3.3.3 Embedded unit 3: understanding the needs and barriers of
      stakeholders in chronic conditions ...................................................... 58
  3.3.4 Embedded unit 4: design of a gamified mHealth solution
      for chronic patients .............................................................................. 59
3.4 Data analysis ........................................................................................... 59
  3.4.1 Embedded unit 1: breast cancer and multiple sclerosis
      mHealth apps review ............................................................................. 60
  3.4.2 Embedded unit 2: gamification presence in mHealth apps .......... 61
  3.4.3 Embedded unit 3: understanding the needs and barriers of
      stakeholders in chronic conditions ...................................................... 62
  3.4.4 Embedded unit 4: design of a gamified mHealth solution
      for chronic patients .............................................................................. 62
  3.4.5 Overall analysis .............................................................................. 63
3.5 Ethical considerations ............................................................................. 63
3.6 Research funding ..................................................................................... 64

4 3MD for Chronic conditions: a condition-oriented model for
designing gamified behavioral change mHealth solutions 65
  4.1 Research questions .............................................................................. 65
  4.2 Overview .............................................................................................. 66
  4.3 Condition specific .............................................................................. 68
    4.3.1 Common condition problems ....................................................... 68
    4.3.2 Patient self-narrative ................................................................. 72
    4.3.3 Care process .............................................................................. 75
  4.4 Motivation related .............................................................................. 77
    4.4.1 Behavioral change aspects ............................................................ 77
    4.4.2 Gameful aspects ........................................................................... 80
  4.5 Technology based ............................................................................... 83
    4.5.1 Quantification ............................................................................. 84
    4.5.2 Tailoring ..................................................................................... 85
    4.5.3 Representation ............................................................................ 88
  4.6 Model summary ..................................................................................... 89
1 Introduction

Humanity entered the 21st century and discovered that things were not as they had always been. A distinct change had taken place as countries became more developed and the overall population aged. Gone were the days where predators and nasty infections were the main source of concern; a new kind of ailment now plagues the world and is known as chronic conditions.

Chronic conditions are by far the leading cause of mortality in the world, representing over 60% of all deaths (World Health Organization, 2014), and taking more and more precedence over “traditional” acute illnesses. This is in part due to the increased average life expectancy that has surpassed the age of 80 in recent years (Organization for Economic Cooperation and Development, 2017): as people live longer they also accumulate more health conditions. The change in demographics, however, is not the only factor behind the rise of chronic conditions. Major improvements in acute care and diagnostics have also created a tendency towards the chronification of formerly terminal conditions (Bedard & Siu, 2014; Weingart et al., 2008). Severe and disabling diseases that used to require hospitalization and were considered lethal, have now shifted most of the care to outpatient settings (Kobelt, 2006) requiring people to learn how to manage on their own.

Self-management is a dynamic, interactive, and daily process in which individuals engage to manage a chronic illness (Lorig & Holman, 2003). The act of self-management also refers to the ability of the individual, in conjunction with family, community, and team of healthcare professionals, to manage symptoms, treatments, lifestyle changes, and psychosocial, cultural, and spiritual consequences of health conditions (Richard & Shea, 2011). Studies show that behavior patterns are among the main determinants of health, with actual healthcare services following far behind the individual’s social circumstances (Schroeder, 2007). The fact that behavioral change is still a great barrier for patients (Jallinoja et al., 2007) is a problem for adoption, as the majority of self-management in chronic diseases takes place away from healthcare settings (Anderson & Funnell, 2010).

In order to adjust to the new practices and change of care paradigm, a fundamental restructuring in the way chronic diseases are handled is needed. Proposed new models of care suggest providing comprehensive strategies to manage chronic disease; focusing on mobilizing community resources, promoting high quality care, enabling patient self-management, implementing care consistent
with evidence and patient preferences, cultural competence, care coordination, and health promotion (Davy et al., 2015; Edward H Wagner, 1998).

Another great change that came over us in the 21st century is the way Information Technologies (IT) have entrenched themselves so deeply into our daily lives that living without them now is almost unthinkable. Already by 2017 the global use of smartphones had reached over 3.2 billion devices and this is without counting the myriad of other types of mobile devices available (Newzoo, 2016). With IT permeating society and becoming part of all other aspects of our world, healthcare could not be apart from that.

The ubiquity of IT has caused the healthcare industry to adapt quickly. Health IT is being used by healthcare institutions to assist clinicians provide care with tools like electronic health records (EHR), telemedicine services and others (Tang et al., 2006). Medical Informatics is “the field that concerns itself with the cognitive, information processing, and communication tasks of medical practice, education, and research” (Greenes, 1990).

The advancement of IT, however, has also changed the way patients seek clarification and explanations for their chronic conditions. Until very recently medical informatics focused on developing applications for health professionals, medical informaticians were looking at medical practice mainly through health professionals’ eyes without considering the perspectives of patients. Regardless, we are now seeing patients who actively seek, gather, and make decisions based on online information (Ferguson & Frydman, 2004). Through this new lens, patients are considered health consumers, individuals who are proactive, in control, and well informed of their personal healthcare.

The field of Consumer Health Informatics (CHI), as a subfield of Medical Informatics, researches the role of IT for healthcare consumers. CHI has been defined as a field that “analyses consumers’ needs for information; studies and implements methods of making information accessible to consumers; and models and integrates consumers’ preferences into medical information systems” (Eysenbach, 2000). CHI can play a vital role for patient engagement and patient empowerment as it allows patients to take charge of their own health and their interactions with health professionals (Anderson KM, Marsh CA, Flemming AC, Isenstein H, 2012; Hung et al., 2013). In this sense, mobile technologies hold promise because of their ubiquity, cost-effectiveness, less invasive nature, and their ability to provide immediate feedback and track activities (Fiordelli, Diviani, & Schulz, 2013; Mechael, 2009; O’Reilly & Spruijt-Metz, 2017). The delivery of
health-related services through the use of mobile technologies and other wearable devices is called mHealth (Whittaker, 2012).

The world is currently seeing a surge of digital health start-ups (Sung Kim, 2015) whose mHealth solutions usually fall into the general wellness, exercise and diet category (Jahns & Houck, 2013), neglecting condition-specific services. The use of mHealth software applications (apps) has grown exponentially in recent years (Riley et al., 2011), with over one hundred thousand apps available for download on online stores (Jahns, 2013). These numbers tell of a significant market size for CHI and of the ongoing demand for new tools to help patients manage their conditions. Unfortunately, only a fraction of these apps and services take into consideration the perspectives of relevant stakeholders like healthcare professionals and sometimes even patients themselves (Connor, Brady, De Beaux, & Tulloh, 2014; Hamilton & Brady, 2012; O’Neill & Brady, 2012; Ventola, 2014; Wong, Robertson, Connor, Brady, & Wood, 2015). In order to be effective, technology needs to be designed in a way that is meaningful to the target group. Health IT solutions are often created with little attention to the design process and its importance to the success of an IT solution (Dabbs et al., 2009; Schnall et al., 2016).

There is a problem solving methodology called Design Thinking which could be useful to address the challenge of CHI as it is used to address what is known as “wicked problems” (Buchanan, 1992). Wicked problems are those whose nature is highly ambiguous with many factors and unknowns and no clear yes or no solution (Buchanan, 1992). The use of user-centered design (UCD) follows Design Thinking approach and embraces a philosophy that places the needs and characteristics of intended users first and foremost (Dabbs et al., 2009; ISO, 2010; Pruitt & Adlin, 2005). In this manner, the goal of UCD is to create solutions specific to the user and the intended tasks (Dabbs et al., 2009; Pruitt & Adlin, 2005). Following UCD principles can generate systems that are easy to learn, have higher user acceptance and satisfaction, and lower user errors (Dabbs et al., 2009; C. M. Johnson, Johnson, & Zhang, 2005; Pruitt & Adlin, 2005). In addition, following good design principles early on not only can save time and money (Pressman, 2009), but also decreases design changes late in the development process (C. M. Johnson et al., 2005; Mayhew, 1999). The use of UCD has been gaining traction in the design of health IT solutions but it still is in its infancy.

Technology that is designed to change attitudes or behaviors through persuasion is broadly defined as persuasive technology (Fogg, 2003). Unlike technologies that focus solely on meeting the functional requirements or ease of
use, persuasive technologies always have an intentionality involved in the development, distribution or adoption (Fogg, 2003). To this matter, using behavioral change theories has proven important in developing successful health promotion activities: according to a meta-analysis of behavioral change interventions, those with a strong theory based approach have greater impact than those that do not, and interventions that incorporate more behavior change techniques tend to have greater effects (Webb, Joseph, Yardley, & Michie, 2010). However, finding ways that engage patients and encourage them to continue with an intervention is a difficult task (Cugelman, 2013).

In the past few years, more and more mHealth solutions have begun to use game elements to drive user behavior (Lister, West, Cannon, Sax, & Brodegard, 2014). These elements are incorporated into the greater context of the mobile application to bolster usability and compel continued and prolonged use (Kappen & Orji, 2017; Miller, Cafazzo, & Seto, 2016). This practice is commonly known as gamification (Deterding, Sicart, Nacke, O’Hara, & Dixon, 2011). However, gamification is not thoroughly understood yet. Common problems found in gamified system are the lack of systemic integration; too much focus on extrinsic motivations in the way of rewards; emphasis on the goals of the system creator instead of the users’ goals; and in that they are limited to a small set of feedback interface design patterns, rather than affording the structural qualities of games that give rise to gameful experiences (Deterding, 2013). It also presents a problem that gamified systems are hybrids, not only functional and not yet a “full-fledged” game (Deterding, Björk, Nacke, Dixon, & Lawley, 2013). Despite the existence of some health gamification frameworks, a systematic review (Mora, Riera, González, & Arnedo-Moreno, 2017) found that as far as gamification design frameworks are concerned, the health sector is the least developed.

As it stands, designers of mHealth solutions for chronic conditions, who intend to create behavioral change interventions and integrate motivational elements, have no clear way of deciding what the relevant factors to consider are. This presents a relevant gap in the knowledge that is yet to be answered appropriately in this field of study.

1.1 Research goal

This PhD thesis is framed in Consumer Health Informatics within the field of Medical Informatics research. Medical Informatics is a subset of Health Information Systems, which are Information Systems for the processing data,
information and knowledge in health care environments with the goal of contributing to a high-quality, efficient patient care (Haux, 2006).

The goal is to address the lack of a model that allows the integration of motivational elements in the design of mHealth solutions for chronic conditions.

1.2 Research questions

The gaps in the current body of knowledge raise the following research question (RQ):

- **RQ.** What design factors to consider when designing mHealth solutions for patients with chronic conditions to motivate health behavioral change?

To answer this broad research question it helped to subdivide it into smaller secondary research questions.

Since the focus of this research work was oriented to the design of mHealth solutions, exploring the purposes, features and stakeholders involved in currently available mHealth solutions was an important step for understanding the context in which the practice will take place. This notion produced the following secondary research question:

- **RQ1.** What is the state of the practice in mHealth solutions for chronic conditions?

In order to design mHealth solutions in a manner that facilitates achieving health behavior change it is important to understand what approaches can be used to motivate persons with chronic conditions to engage in and sustain the intended behavior. Therefore the following secondary research question was formulated:

- **RQ2.** What motivational approaches can be used in mHealth solutions for health behavioral change in chronic conditions?

In regards to the actual design of mHealth solutions for health behavioral change in chronic conditions, as it requires the dynamic negotiation of several elements belonging to different bodies of knowledge, it was clear that finding a way to consider the different elements and their interplay with each other was important. Thus the final secondary research question emerged:

**RQ3.** How can mHealth solutions for health behavioral change in chronic conditions be designed in a way that integrates different motivational approaches?
such as behavioral change theories, gamification techniques and user-centered design principles?

1.3 Thesis outline

This thesis dissertation is organized and structured as follows:

The first chapter, Introduction, explains the background and motivation for the research, as well as the scope and research question. The second chapter, Related research, provides an overview to the theoretical background and research works related to this dissertation. In the third chapter, Research approach, the methodology used in the research process is summarized, and ethical and funding considerations are disclaimed. The fourth chapter presents the findings in the form of a design model called 3MD for Chronic conditions. In chapter five, Discussion, the present thesis is examined in regards to: its contribution and novelty value, the context of the work, and its limitations. Finally, in chapter six, Conclusions and future work, important takeaway points are highlighted. Chapter seven provides the List of references used in this manuscript.

The original articles are included at the end of the thesis in the Original publications. The articles included in this dissertation are all published in English in peer-reviewed conference proceedings and journals, and can be found at the end of this dissertation in their entirety. All articles published by JMIR Publications and Elsevier are done so under a Creative Commons Attribution license, allowing for freely reproduction of the material as long as it is properly cited. Articles published by IEEE publishing are reproduced following their respective policies.
2  Related research

This section presents the theoretical background and scientific works related to this dissertation. Relevant medical concepts, behavioral change theories and gamification considerations are described.

2.1  Medical considerations

There are certain medical and clinical concepts that one should be familiar with when attempting to create mHealth solutions for chronic patients. This subsection provides some basic understanding on what the medical literature has to offer regarding chronic conditions and common issues that affect the persons living with them.

2.1.1 Chronic conditions

There is still some debate in the scientific community regarding what truly constitutes a chronic condition (Bernell & Howard, 2016), but the term generally refers to diseases or conditions that have complex causality, a long development period and course of illness, and have other health associated complications such as functional impairments or disabilities (Bernell & Howard, 2016; World Health Organization, 2014). Chronic conditions have a course that varies over time that is specific to the particular illness and can be very intrusive to everyday life. However, there are challenges that are common across conditions, such as recognizing symptoms and taking appropriate actions, handling complex treatment regimens, developing coping strategies, and dealing with frequent interactions with the healthcare system over time (E. H. Wagner et al., 2001).

The context of this thesis research (see Setting) provided the opportunity to work on two very different conditions, which are described below: breast cancer (BC) and multiple sclerosis (MS).

Breast cancer

BC is the most common cancer in women both in the developed and less developed world (World Health Organization, 2014). The World Health Organization estimates that more than half a million women died in 2011 due to BC worldwide (World Health Organization, 2014). BC is a global problem that affects all countries
alike. Incidence rates in Northern America and Europe are 92 and 89 per 100,000 respectively, while in Middle Africa and Eastern Asia they are 27 per 100,000 (Ferlay et al., 2015). Although these numbers may create the false impression that less developed regions fare better, this is an illusion; it is likely that the low incidence is due to a lack of early BC detection programs. Fortunately, thanks to advancements in treatments, BC survivorship is on a steady rise and this cancer is no longer thought of as an acute illness but rather a chronic condition (Bedard & Siu, 2014; Weingart et al., 2008). BC treatments are not without its downsides, as BC patients and survivors may need to endure breast surgery and chemotherapy with side effects that affect their quality of life and self-image among others (Brooks, 2006). To improve their quality of life, survivors of BC need to become aware of the long-term consequences of their treatment and be proactive in their approach to their overall health (Bodai & Tuso, 2015; Cho et al., 2014).

It is common to find mHealth solutions for BC in the scientific literature for activities such as tracking sleep patterns (Min et al., 2014), symptoms and treatment side effect management (Kearney et al., 2009; Min et al., 2014; Weaver et al., 2014), breast health and well being assessments (Armstrong, Semple, & Coyte, 2014; Bravo, O’Donoghue, Kaplan, Luce, & Ozanne, 2014), and even comprehensive lifestyle programs with nutrition and physical activity elements (McCarroll et al., 2015). There are even cases of behavioral change programs that use mHealth interventions like the one developed by Fu et al (Fu et al., 2016) that focus on self-care strategies to lessen symptomatic burden.

Bender et al (Bender, Yue, To, Deacken, & Jadad, 2013) published a review exploring the distribution of all kinds of cancer mHealth apps across the four major smartphone platforms at that time, which found that most apps (45%) focused on breast cancer but what kind of mHealth apps these are and who is behind them is still unknown.

**Multiple sclerosis**

MS is one of the world’s most common neurologic disorders. MS is an unpredictable, often disabling disease of the Central Nervous System that can adversely affect body function and it is the leading cause of non-traumatic neurologic disability in young adults in many countries (Browne et al., 2014). The most common symptoms are overwhelming fatigue, visual disturbances, altered sensation, cognitive problems and difficulties with mobility (Goldenberg, 2012). There are pharmacological treatments for the condition as well as other strategies
to manage MS symptoms. Quality of life is often impacted in many ways and MS symptoms often lead persons with MS to feelings of embarrassment and avoidance of social situations (Trisolini, Honeycutt, Wiener, & Lesesne, 2010). MS has a median survival time from the time of diagnosis of around 40 years (Weinshenker, 1994); therefore issues regarding progressive physical and cognitive disability, psychosocial adjustment and social re-integration are likely to affect persons with MS for a long time. Living with MS often requires individuals to self-manage and to be more engaged in their care (Goldenberg, 2012).

There have been recommendations that suggest the incorporation of standard MS management tools into mHealth solutions (Hansen & Okuda, 2018), and the scientific literature shows that some health apps do exists for fatigue assessment and fatigue management (D’hooghe et al., 2018), emotional support (Tietjen & Breitenstein, 2017) or self-management (Plow & Golding, 2017). However, the current landscape of mHealth apps for MS is unknown.

2.1.2 Empowering patients

As interesting as it may be for clinicians and other healthcare professionals to discuss about chronic conditions and their accompanying processes, for the people who have to live with one, this is not an academic matter. It is a daily lived experience. Dealing with chronic diseases requires balancing many metabolic and lifestyle factors. In fact, successful chronic disease management requires that persons with chronic conditions be able to make choices that helps them reach both their personal and health-related goals (Richard & Shea, 2011).

For many years, the ruling paradigm in healthcare held physicians and other health professionals as the experts who must guide people with chronic conditions, telling them what to do and how to do it. It was believed that patients brought very little to the table besides their condition and needed to be shepherded to the right path. The traditional approach was to get compliance by persuading and preparing patients to carry out instructions made by their care givers (Raymond, 1984). The key action for patients was to just follow the prescribed healthcare regimen (Resler, 1983).

However, as time passed, a realization started to dawn. For some reason, patients did not seem overly motivated to take care of themselves on the doctor’s orders. Instead, they reacted much better when they were internally motivated (Anderson & Funnell, 2010; Arnold, Funnell, Butler, Anderson, & Feste, 1995). When a physician orders a patient to walk a certain number of steps per day, if the
patient fails to meet this goal, not only do they still have to deal with the condition, they must now also deal with the sense of failure. Concepts like eating healthy, taking medications or losing weight only stayed if they were really important to patients on a personal level: doing things just because the doctor said so has limited power. This new found insight produced a change in the way chronic conditions are handled. The goal for chronic treatment is now that patients should be considered their own principal caregivers, with the health care providers acting as consultants who help and support them (Holman & Lorig, 2000). The idea is to provide patients with knowledge and skills, in order to heighten their self-awareness so that they can define and achieve their goals. This constitutes the philosophy of patient empowerment (Anderson, Funnell, Barr, Dedrick, & Davis, 1991).

According to Rappaport (Rappaport, 1987), empowerment is a process by which people gain mastery over their lives. In the case of patient empowerment, it is a process designed to facilitate self-directed health behavior change (Salmon, 2004). The goal of patient empowerment is that patients take responsibility and manage their condition; health professionals encourage them to solve their problems through education, not orders (Rappaport, 1987; Salmon, 2004). The emphasis in patient empowerment is placed in helping people with chronic conditions identify their problems and provide them with techniques that help them be more active so that they can make decisions, take appropriate actions, and alter these actions as they encounter changes in circumstances or disease (Nezu, 2013).

Through patient empowerment, interaction becomes collaboration, with ideas from patients and healthcare professionals connecting and building upon each other to create a better outcome and be more engaged in their care (Bodenheimer, 2002). Continuing with the example mentioned above, if both physician and patient collaboratively agree on the desirable amount of exercise and the short-term action plan succeeds, the patient can later propose a revised action plan to walk more. The implication in this paradigm now being that while professionals are experts about conditions and treatments, patients are the ones who are experts about what they can do and how they want to live their own lives. The main elements of patient empowerment are simplified and represented in Figure 1 to illustrate how they can guide designers to design empowering mHealth solutions.
It is important to note that patient empowerment is not without its perils. As was mentioned earlier, empowerment relies heavily in allowing patients the opportunity to make decisions about treatment options. It is because of this that more information is provided in the belief that this will enable informed choices. However, there are studies that show that this approach may need revisiting (Salmon, 2004). It is possible that patients see receiving information from professionals as a way to build a relationship with the care team (Salander, 2002; Salander, Bergenheim, & Henriksson, 1996). When seeking to empower people with chronic conditions we need to be aware that not all patients want the responsibility. In an interesting study, Ingelfinger (Ingelfinger, 1980) described how much despair he felt when given an active voice in treatment decisions about his cancer. Depending on the person and the situation, being ill can reduce how important it is to be in control (Beaver et al., 1996; Taylor, Hall, & Salmon, 1996).

2.1.3 Patient journey

There are current trends in the design of health IT that point out how solutions should engage users in meaningful ways (Ludden, van Rompay, Kelders, & van Gemert-Pijnen, 2015; Mirkovic et al., 2016) and understanding what the intended users go through helps the design process. Patient experience has been recognized
as one of the pillars of quality in healthcare, along with clinical effectiveness and patient safety (Doyle, Lennox, & Bell, 2013). This experience is their personal interpretation of the service process and how they related to it during the course of each interaction (R. Johnston & Kong, 2011). In essence, this is a mixture of what patients think, feel and say about the experience of a service, process or product. Journey maps are used to depict the healthcare service from the perspective of the patient, touching on a series of events that shape the overall experience (Trebble, Hansi, Hydes, Smith, & Baker, 2010; Zomerdijk & Voss, 2010). These methods are largely inspired by the field of human-centered design in which the user perspective is seen as a central component to the design process (Zomerdijk & Voss, 2010). The concept of the patient journey describes all the sequential steps in providing a patient’s care, including clinical and non-clinical steps. In Figure 2, a schematization of a cancer patient journey is represented with all the healthcare professionals involved along the journey as represented in an oncology magazine (Rutherford, 2017).

![Fig. 2. Diagram of a cancer patient journey. Source: DeepDive Oncology 2017.](image)

Understanding the context of a person is useful to approach their problems in a more integrative way. The basis for these concepts is the belief that we first make meaning of our lives and then act upon that construction. White and Epston (White & Epston, 1990) proposed that we create meaning by structuring our experiences into stories, which are accounts of our lived experiences put in sequence across
time. The story provides a sense of continuity and meaning as it gives the past a history, it brings order to the present, and attempts to predict a future.

An emerging narrative occurs from living with a condition. This narrative provides meaning, context, and sometimes perspective for the patient’s situation. In many ways it shapes how, why, and in what way we think of ourselves (Greenhalgh & Hurwitz, 1999). On being diagnosed with a chronic condition, there is an initial period of transformation from what is known to be a normal state of health into an abnormal one. There may be moments during the patient’s journey in which they face critical episodes of the condition or even from the treatment itself. Disease management is an ongoing situation for these conditions and transitioning into this new normal can be quite a problem. The new normal state may comprise rehabilitation, oncological treatment, insulin management, physiotherapy or sometimes even palliative care.

Narrative helps in grasping the complexity of the illness experience and understanding its relationship to a person’s life. In this manner, Frank (Frank, 1997) conceptualizes diseases as “a wound sustained by the body-self”. Diseases are then, a devastation of the physical body, in part due to the condition itself but also because of the medical treatment that the body must undergo. For Frank, there are three major types of illness narrative:

- Chaos stories, where the predominant factor is being thrown in disarray by the disease, submitting to its will and the disasters that it can cause on the patient’s life.
- Quest stories, in which the condition becomes a challenge that must be overcome with perseverance. The framing of this narrative being one of heroism where solidarity and inspiration can be found.
- Restitution stories, which concern a narrative that attempts to render the condition into a transitory circumstance. The condition is an inconvenience that happened but that it will soon sort itself out, restoring everything back to how it once was.

Reaching a normalcy state is key for living with chronic conditions and patients do their best to see themselves as essentially normal persons leading normal lives (Knafl & Deatrick, 1986). Normalizing the situation becomes a necessity and several mechanisms play a role. It is common practice for people in these situations to engage in acts of covering up behaviors, like minimizing physical activity to hide fatigue symptoms; desensitization measures, for instance making fun of their own
disability; and making trade-offs, such as accepting less desirable circumstances just to be able to do what they wanted to do (Robinson, 1993).

The healthcare team plays a powerful role in the way the patient journey is experienced. The treatments or management regimes interfere with normalization by interfering with pacing and doing normal things. Depending on the situation, people with chronic conditions can feel that the healthcare team’s effort is sabotaging their life or that they lack cooperation.

2.2 Behavioral change

In this subsection I will present a description of behavioral change theories and models in general and how they commonly have been used by designers in mHealth solutions. The items described below provide a point of reference for potential design factors.

2.2.1 Overview

Understanding human behavior is a complex task as many elements influence and shape the way we act without us realizing. Some elements are internal while others are external, and the interplay between each of them determines our perceptions, our beliefs and our willingness to do certain things or not.

Behavioral change theories attempt to provide models useful to explain why we do things, and propose frameworks to be followed in order to create new behaviors. These frameworks introduce various design factors for promoting behavioral change, as outlined in Figure 3. Some theories are mainly explanatory, suggesting what should be changed in a situation (theories of the problem); some focus on the actual change, proposing how to do it and design for it (theories of action); and others have elements of both. There are several theories and behavioral change models (BCM) that are used in health behavior science with the main goal of making the healthy choice the easy choice.
 BCMs tend to share similar elements but use them in different ways or constructs. There is some level of agreement in the health promotion and behavioral health fields regarding which variables are key determinants for behavior (Institute of Medicine, 2002):

- The person has formed a strong positive intention (or made a commitment) to perform the behavior
- No environmental constraints make it impossible for the behavior to occur
- The person has the skills necessary to perform the behavior
- The person believes that the advantages of performing the behavior outweigh the disadvantages
- The person perceives more social pressure to perform the behavior than not to do so
- The person perceives that performing the behavior is more consistent than inconsistent with their own self image
- The person’s emotional reaction to performing the behavior is more positive than negative
- The person perceives that he or she has the capability to perform the behavior under a number of different circumstances
The first three constructs are seen as necessary and sufficient to determine behavior while the remaining five are considered to be influencers of strength and direction of intention (Noar & Zimmerman, 2005).

The use of computerized health behavior interventions has expanded rapidly in the last decade and existing BCM have been used to guide mHealth interventions. There is a growing body of evidence suggesting that mHealth can support health behavioral change in areas such as smoking cessation, physical activity, and other healthcare problems (Conroy, Yang, & Maher, 2014; Geuens et al., 2016; Gurman, Rubin, & Roess, 2010; Oinas-Kukkonen, 2013; Partridge et al., 2015).

The use of instant feedback and positive reinforcement from learning theories are common use in mHealth applications (Conroy et al., 2014; Lister et al., 2014); Health Belief Model (HBM) has been used in mHealth interventions for self-management and health promotion (Brox, Fernandez-Luque, & Tøllefsen, 2011; Cañazzo, Casselman, Hamming, Katzman, & Palmert, 2012; Robertson et al., 2017); the Transtheoretical Model (TTM) has been used in mobile solutions for smoke cessation and other addictive behaviors (Finkelstein & Cha, 2016; Hassandra et al., 2017; Obermayer, Riley, Asif, & Jean-Mary, 2004; Whittaker et al., 2008); physical activity and fitness interventions use the Theory of Planned Behavior (TPB) (Geuens et al., 2016; Hurling et al., 2007; Lister et al., 2014), as well as self-regulation theories (Gouveia, Karapanos, & Hassenzahl, 2015; Lister et al., 2014; Moller et al., 2014; Payne, Moxley, & MacDonald, 2015; Zhao, Freeman, & Li, 2016). The basis for Social Cognitive Theories (SCT) can be found in many interventions using health apps for disease management (Atienza, King, Oliveira, Ahn, & Gardner, 2008; King et al., 2008; Russell-Minda et al., 2009) and goal setting is very often used in mHealth apps (Dicianno, Henderson, & Parmanto, 2017; Payne et al., 2015).

In the sections below an overview on commonly used BCMs in health promotion will be presented. However, it is important to keep in mind that each BCM carries its limitations and problems, as is known and described in the literature (Head & Noar, 2014; Reniscow & Vaughan, 2006; Sniehotta, 2009). A multi-theory approach is usually recommended in behavioral change intervention design (Schaalma & Kok, 2009) and this should be considered when designing mHealth solutions.
2.2.2 Theories of learning

Learning theories assume that experiences shape and condition behavior and that we “learn” and adapt to these experiences. Organisms, in our case human beings, respond to stimuli and if an enduring change in the way said organism responds is achieved, it is considered to have “learned” this behavior (Schwartz, Wasserman, & Robbins, 2002). In a sense, Learning Theory is the foundation of most behavioral science theories.

Two major learning theory perspectives are classical conditioning and operant conditioning. In classical conditioning, an innate response is produced because of an unconditioned stimulus (for example, nausea as a result of chemotherapy); and a conditioned response is a response that is produced through the learned association of the conditioned stimulus with the unconditioned stimulus (for example, eating certain foods after chemotherapy may create food aversions in cancer patients). Skinner et al. (Ferster, CB, & Skinner, 1957) discovered that depending on the type and frequency, some stimuli can be used as reinforcement of a behavior, resulting in said behavior happening more or less frequently. This is what is known as operant conditioning.

Feedback and reinforcement are effective methods to create changes in various behaviors (Albert Bandura, 1986) and they have been used in the design of mHealth solutions before (Conroy et al., 2014; Lister et al., 2014). When we provide feedback to a person on their performance in an activity, like grading when learning a study subject or actual weight loss due to an increase in physical activity; the person becomes aware and is driven to this behavior. It is important to note that most people prefer a smaller immediate reward, like eating chocolate or candy, over larger rewards that is deferred to a much later time, like being fit or healthy (Karelaia, 2009). Also, an interesting concept is that we learn behaviors better through positive reinforcement but we are very slow to unlearn them through lack of said reinforcement (Albert Bandura, 1986; Ferster, CB, & Skinner, 1957).

2.2.3 Theories of health behavior

The main concept behind these models is that human behavior depends mainly on how high we place a particular goal and how likely we estimate that a particular action will help us achieve that goal. The Health Belief Model (HBM) (Janz & Becker, 1984) and the Protection-Motivation Theory (PMT) (Boer & Seydel, 1996) are representatives of this theories.
The HBM is a descriptive model to understand the thinking behind actions. It proposes that an individual will only follow a recommended health-related action if they feel that it will help avoid a negative health condition. People will only engage in a health action like using a condom during sex if they see themselves as likely to get a condition (perceived susceptibility); the condition is considered serious or life threatening (perceived severity); and there is a good balance between the obstacles (perceived barriers) and what they will gain from doing the action (perceived benefits).

PMT suggests that people will try to control the danger and the fear associated with a negative health condition. Thanks to public awareness campaigns, it is common for people to associate smoking with lung cancer, which has been helpful in seeding the fear of cancer in the population. However, according to PMT, an individual who smokes may be afraid of cancer but that in itself will not be enough to motivate them to quit: they need to also be convinced that quitting is their best option in preventing cancer.

Designers of health messages can framed them in terms of their benefits (gain-framed messages) or their detrimental consequences (loss-framed messages). Using a gain frame is recommended as it is usually more easily processed and readily accepted (Werrij, Ruiter, van ’t Riet, & de Vries, 2012).

### 2.2.4 Stage theories

Stage theories are based with the understanding that people may experience different things in different moments regarding their condition and may need different methods to help them in each stage. The main representative for this kind of theory is the Transtheoretical Model (TTM) (Prochaska & Velicer, 1997).

The TTM proposes a set of stages through which a person goes through in their adoption of a new behavior. An individual moves from having no real motivation to change to increasingly more ready stages until the new behavior is internalized. The stages allow for people to move from pre-contemplation, contemplation, preparation, action and maintenance stages. This model has been used in particular in smoke cessation programs and it got extrapolated to other addictive behaviors.

Another example is the Precaution-Adoption Process Model (PAPM) (Weinstein, 1988) which is based on the TTM but specializes in raising the awareness level in risk behaviors of which people are unaware.
2.2.5 Theories of reasoned action

The foundations for this group of theories is based on the idea that intention is the main determinant of our behavior. In order for us to perform an action, we must first want to do it. The whole concept is based on attacking factors that may present an obstacle for us wanting to act.

The Theory of Planned Behavior (TPB) is a representative of this group. It states that the intention of performing an action represents that person's readiness to perform it, and it is considered to be the immediate antecedent of behavior (Ajzen, 1991). According to this model, intention is determined by three factors: the attitude towards the specific behavior; the way that person’s social circle views the behavior in question; and how much control over their behavior the person thinks it has.

2.2.6 Theories of goal-directed behavior

Setting specific goals is another approach that seems to be useful for behavioral change. A major representative of this group is Goal-setting Theory (GST) (Tosi, Locke, & Latham, 1991). GST proposes that having goals provide us with a measure for “excellent” performance. As we set an objective for ourselves, we become focused on it and can exert ourselves to a greater extent; we are more likely to persevere in our tasks and concentrate more. Goal setting is generally more effective for simple tasks, with well-defined parameters, in part because it is easier for a person to see the connection between effort and goal achievement (Wood, Mento, & Locke, 1987).

GST identifies five principles that were important in setting goals that will motivate others. These principles are: clarity, challenge, commitment, feedback, and task complexity. In traditional goal-setting, a single specific goal (or group of goals) is set by a third party to achieve.

2.2.7 Theories of self-regulation

Theories of self-regulation are mostly focused on how we function to self-correct specific things of our behaviors. They receive the label of “self-regulatory” because the process is iterative, with feedback loops, through which we see the discrepancies between our goals and outcomes and then feel dissatisfied (Scheier & Carver, 2003).
Self Determination Theory (SDT) is a macro-theory of human motivation that establishes psychological needs that motivate us to initiate behavior (Ryan & Deci, 2000). According to SDT, motivation can be intrinsic or extrinsic. Intrinsic motivation being the tasks that we perceive as enjoyable by themselves; while extrinsic motivation refers to factors outside of the task, such as our expectations that completing a task will result in a particular outcome (Ryan & Deci, 2000).

Basic needs are established within this theory: the need for competence, autonomy, and psychological relatedness. Autonomy within SDT refers to our sense of volition, how free we feel about what we are doing; competence deals with our need for challenge and how good we feel we are at doing things; and finally, relatedness talks about the feeling of connection with others, the positive social interactions that we have. For human behavior to be intrinsically motivated and thus continued, SDT puts emphasis on needs satisfaction (Ryan & Deci, 2000).

2.2.8 Social cognitive theory

The Social Cognitive Theory (SCT) (Albert Bandura, 1986) is an interpersonal theory that covers both determinants of behavior and the process of behavior change (A. Bandura, 2004). The basics for this theory is that people do not only learn new behaviors on their own, but rather, also on observing behaviors from others. According to this theory, this is because the survival of humanity is dependent upon the replication of the actions of others. If we see someone smoking a cigarette, depending on whether that person is commended or discouraged for that, we may choose to smoke ourselves. Observing a role model can prompt others to engage in a specific behavior. SCT may be applied to any behavior, but is usually applied to behaviors that are complex and require considerable behavioral capability.

2.2.9 Behavioral change in mHealth

Mobile devices have the capacity to interact with the individual with much greater frequency (Pharow, Blobel, Ruotsalainen, Petersen, & Hovsto, 2009) and they allow for tailoring not only during the beginning of an intervention process but also during the course of intervention (Patrick, Griswold, Raab, & Intille, 2008). As such, these mobile technologies are “always on” and are carried on the person throughout the day, offering more chances for interaction and intervention (Riley et al., 2011). Therefore, mHealth interventions for behavioral change would benefit
from contemplating the dynamic nature that mobile capabilities have to offer, rapid intervention adaptation based on the individual’s current and past behavior and situational context (Riley et al., 2011).

A behavior change support system (BCSS) is a sociotechnical information system with psychological and behavioral outcomes designed to form, alter or reinforce attitudes, behaviors or an act of complying without using coercion or deception (Oinas-Kukkonen, 2013). The creation of BCSS involves a variety of disciplines from human sciences to information systems.

There are BCSS design models such as the Persuasive Systems Design (PSD) (Oinas-kukkonen & Harjumaa, 2009b), which concerns the design of persuasive technologies in general. In this model, the need for recognizing the intent of persuasion, understanding the persuasion event, and defining and/or recognizing the strategies in use are key. Another BCSS design model is the IDEAS framework (Mummah, Robinson, King, Gardner, & Sutton, 2016), in this model behavioral change theory and design thinking are integrated to guide the development of digital health interventions. The Chronic Disease mHealth App Intervention Design Framework (Wilhide III, Peeples, & Anthony Kouyaté, 2016) is specific to mHealth and it focuses on chronic conditions, addressing issues present in the other frameworks. The issue of enjoying performing the specific behavior, however, is not addressed in any of these models.

2.3 Gamification

In the sections Medical Considerations and Behavioral Change, the importance of motivating persons with chronic conditions for them to engage and sustain in health behavioral change was highlighted. This subsection acts as an introduction to gamification as an approach to provide motivation in mHealth solutions for chronic conditions. In this subsection I describe the appeal and motivational aspects of games, the current understanding on gamification and design of gameful systems, and how gamification is approached in mHealth.

2.3.1 Introduction to games

The appeal that video games have for humankind cannot be questioned. They may have started as an obscure hobby for the more technologically inclined but they currently hold a position in our culture that is to be reckoned. Reports from the Entertainment Software Association (Entertainment Software Association, 2017)
estimate that the videogame industry generates over $11.7 billion in the United States alone, with this number looming even larger if we account for Europe (Ipsos MediaCT & ISFE, 2012), let alone the rest of the world.

Most households are home to at least one person, if not more, who plays video games regularly; and in this matter there are no gender or age differences: men, women, young and old, we all play and want to play. Humanity has played games since prior to written history (Juul, 2011) and some even propose that it precedes culture, the construction of language and myth (Huizinga, 1955). It would seem that the act of playing is inherent to us as species. In the words of Johan Huizinga (Huizinga, 1955):

“The incidence of play is not associated with any particular stage of civilization or view of the universe. Any thinking person can see at a glance that play is a thing on its own, even if his language possesses no general concept to express it. Play cannot be denied. You can deny, if you like, nearly all abstractions: justice, beauty, truth, goodness, mind, God. You can deny seriousness, but not play.”

Games seem to be good at presenting a particular kind of enjoyment, they represent a challenge that we tackle willingly. We freely engage with them and are able to get lost for hours on end regardless of the world out there. This is a state that positive psychology literature calls “state of flow” (Csikszentmihalyi, 1991), a satisfying feeling of heightened functioning where some activities allow a fine balance between the challenges perceived and the skills a person brings to it. Despite the fact that flow is an extremely desirable state, getting into it is not easy. If tasks are too difficult, they create anxiety; if they are too easy, it causes boredom. Games, however, seem to manage the Goldilocks zone with ease.

It is not surprising then that efforts to translate the same feeling of engagement and enjoyment to other areas of our life has been attempted. Among these efforts the concept of gamification is born. Gamification is generally understood as the use of game elements in non-game contexts (Deterding, Sicart, et al., 2011). In this dissertation, the terms gamification design and gameful design are used interchangeably, since they frame the same extension of phenomena through different intentional properties (Deterding, Dixon, Khaled, & Nacke, 2011).
2.3.2 Elements in gamification

Games are designed to enable a certain type of experience, they facilitate the experience of playing. In a sense, games are problem-solving activities that we approach with a playful attitude (Schell, 2008). They are closed, formal systems, that engage players in structured conflicts and resolve in an unequal outcome (Fullerton, Swain, & Hoffman, 2008). In order to design a game or game-like experience, one must comprehend the different aspects that make up a game.

When we take a game and strip away all the different layers of aesthetics, storytelling and technology, all that remains are the game elements and the different interactions and relationships between them. This is what game designers know as game mechanics (Schell, 2008). The most fundamental game mechanics are the rules. Rules define the space, the objects, the actions, the consequences of the actions, the constraints on the actions, and the goals of the game.

Game elements are varied but usually the literature on game design considers the following to be the basic set (Deterding, Dixon, et al., 2011; Reeves & Read, 2009; Zichermann & Cunningham, 2011):

- Points and leveling systems, which provide feedback and inform the user of their level of familiarity of the system.
- Leaderboards that are used to dynamically rank individual user progress and achievements as compared to their peers.
- Badges, achievements and trophies, which act as rewards for the accomplishment of specific tasks.
- Challenges and quests that constitute objectives and create a narrative within the system.
- Social features are used to support and reinforce interaction between users.

Each of these elements by themselves are not seen as “gameful” (Deterding, Dixon, et al., 2011) but combined and arranged in certain ways, they can tap into something greater and unlock a unique experience. The use of game elements and mechanics causes a new component to emerge: game dynamic. Game dynamics are the way by which the game activity guides human behavior.

Gamification takes from these components and tries to apply them to situations that are not normally understood as game related. It combines the principles of engagement, reward and incentive to encourage changes in behavior in a playful way. In the context of mobile applications, these elements are integrated as specific
features for purposes of bolstering usability and compelling continued use (Kappen & Orji, 2017; Miller et al., 2016).

Gamification can be seen as one form of persuasive or motivational design (Kapp, 2012). The use of gamification in health apps has become common practice in both commercial and academic fields (Lister et al., 2014). Usually, these apps focus on wellbeing and physical activity (Baranowski, Baranowski, Thompson, & Buday, 2011; Boulos & Yang, 2013; J. D. Johnston, Massey, & Marker-Hoffman, 2012; Khaled & Ingram, 2012; Skjæret et al., 2015), using game elements to entice users to exercise and work out. Many of these gamified applications are designed to support individuals in adopting good health behaviors via positive reinforcing experiences (Reeves & Read, 2009; Zicherman & Linder, 2010).

### 2.3.3 Users and player types

Asking gamers why they play videogames shows that there is no single and unified answer (Lazzaro, 2004). People find games engaging for different reasons, making it impossible to present a definitive solution that fits all. Like all human behavior, we must use caution when trying to understand play. Some individuals may enjoy the challenge, others may be trapped by the stories and some may love to get lost exploring virtual worlds. Previous studies show that our personality has an effect on the type of game genres and elements that we enjoy (Jia, Xu, Karanam, & Voida, 2016; D. M. Johnson, Wyeth, Sweetser, & Gardner, 2012), and it even affects our style of playing (Nacke, Bateman, & Mandryk, 2014). Personality also seems to affect how we experience psychological satisfaction in games (D. Johnson & Gardner, 2010) so it stands to reason that it would also affect gamification preferences.

There have been many attempts to create “player types” for design and analysis purposes. Game designer Richard Bartle observed the way users of an online game behaved and wrote down his observations creating what is now known as Bartle’s taxonomy (Bartle, 1996). According to it, players usually fall into four main groups: 1) achievers, who get pleasure from accomplishing in-game goals and objectives; 2) explorers, who enjoy navigating and discovering secret places of the game; 3) socializers, who mainly derive pleasure from the relationships they form with other people; and 4) killers who are interested in competing with and defeating others. At first glance this classification is useful to understand player behavior, however under closer scrutiny gaps appear. Bartle assumed that preference for one type of play (e.g., achievement) suppressed other types of play (e.g., socializing or
exploring). What about players who enjoy exploring with their friends? Or groups who compete against other groups? Does age influence the type of play?

Another problem with Bartle’s four types lies in that they were never intended to be a general typology, only a description of his observations in one particular context (Dixon, 2011). To address this problem, Marczewski developed the Gamification User Types Hexad framework (Marczewski, 2015), using SDT as theoretical background, research on human motivation, player types, and practical design experience (see Figure 4). The interesting thing about the Hexad model is that it has showed test-retest reliability and seems to be useful to predict user preference for different game design elements (Orji, Tondello, & Nacke, 2018; Tondello et al., 2016).

![Gamification User Types Hexad](image)

Fig. 4. Gamification User Types Hexad. Source: “Even Ninja Monkeys Like to Play: Gamification, Game Thinking and Motivational Design”.

According to Marczewski, user types are segmented and supported in the following way:
- **Philanthropists** are individuals motivated by altruistic purposes, willing to give without expecting a reward within the system.
- **Socialisers** want to interact with others and create social connections. The system is important to them but as a means to connect.
- **Free Spirits** desire the freedom to express themselves and act without external control. They like to create and explore within a system.
- **Achievers** seek to progress their status by completing tasks, or prove themselves by tackling difficult challenges. The system is a challenge to be overcome.
- **Players** are motivated by extrinsic rewards. The specific type of reward is not important, only that the system is providing it.
- **Disruptors** enjoy testing the limits of the system, looking to push past them. Sometimes they can be negative agents, sometimes their work improves the system.

Yee (Yee, 2006) also expanded on Bartle’s work creating an empirical model of player motivations. He identified three main components of player motivation with ten sub-components: achievement (advancement, mechanics, competition), social (socializing, relationship, teamwork), and immersion (discovery, role-playing, customization, escapism.

As with behavioral change models, the literature suggests that the different user or player types will have different needs and it could be useful to keep them in mind during the design process. Designing for players types is a complex task and it should be understood that, although motivation clusters are presented as user types, individuals tend to be motivated by more than just one of them exclusively. For a particular person, there may be a predominant tendency but it will also be probably motivated by more to some extent.

### 2.3.4 Gameful design models

Taking into account the popularity that gamification is seeing in these past few years, it is no surprise that many gamified health apps have appeared. However, implementing gamification is not as clear cut as it may seem. Gameful design is about intentionally designing for gamefulness in the development of non-game environments using game design thinking (Deterding, Dixon, et al., 2011). Inserting game elements such as points and badges into any non-game context will probably not result in a pleasant experience or achieve the intended objectives.
Instead of attaching game mechanics to various tasks, the tasks themselves need to be designed in a manner similar to game design (Dichev, Dicheva, Angelova, & Agre, 2014). Game design should be approached as a lens to improve the overall experience of the task.

There are models for game design such as the MDA framework (Hunicke, LeBlanc, & Zubek, 2004) that aim to help game designers. MDA stands for the abbreviation of “Mechanics, Dynamics and Aesthetics”, as this framework looks to break down games into these as distinct components (Figure 5). Mechanics describe the particular components of the game, at the level of data representation and algorithms, the rules on their own. Dynamics describe the run-time behavior of the mechanics acting on player inputs and the outputs of each other over time, the how it plays. Aesthetics describes the desirable emotional responses evoked in the player, the how it feels or should feel. MDA looks at games as artifacts composed of sets of behaviors set in motion.

![Image of MDA Framework](image)

**Fig. 5. MDA Framework for game design. Source: “MDA: A Formal Approach to Game Design and Game Research. Work Challenges Game”**.

Designers have used this kind of game design models before (Mora et al., 2017) to gamify activities, but it is clear that the process of gameful design is somewhat different from game design. Games are mostly directed towards pure entertainment, whereas gamification attempts to enhance engagement and user experience in
different contexts (Domínguez et al., 2013). The design approach of a gameful system is different than that of a conventional game.

Kevin Werbach’s gamification framework, commonly known as 6D (Werbach & Hunter, 2012), is one of the most popular and referenced gamification design frameworks. Generally created with the purpose of designing a service or product with business goals, it conceives the following steps:

- defining business objectives and expected behaviors,
- describing the players,
- devising the activity loops without forgetting the fun,
- and finally, deploying the gamification system with the appropriate tools.

Another commonly used framework is called Octalysis (Chou, Fuqua, & Yuan, 2015). In this framework, the design process is viewed from a “human-focused” lens as opposed to “function-focused” points of view. Its author proposes that normally design processes concentrate on optimizing efficiency, getting the job done, rather than on human motivation. Octalysis derives its name on an octagonal structure that arranges concepts into eight ‘gameful’ shapes (see Figure 6): 1) epic meaning and calling, 2) development and accomplishment, 3) creativity and feedback, 4) ownership and possession, 5) social influence and relatedness, 6) scarcity and impatience, 7) unpredictability and curiosity, and 8) loss and avoidance.
Even if these gamification models exist, it is important to keep in mind that one cannot expect that they perfectly translate to health scenarios. In generic gamification models the goal is usually to increase a certain task efficiency or improve user retention (Mora et al., 2017); and while these may look appropriate on a surface level, there are hidden dangers inherent to healthcare. In a business case, getting a user to continuously repeat a desired action over and over thanks to a point system may be considered a success. However, what happens if that action is administering an insulin injection? Generic gamification models often do not contemplate these kind of negative consequences. Ethics should guide the design of health technologies and recognized principles of bioethics play an important role in this process (Meslin & Schwartz, 2015). It is because of these issues that specific conceptual frameworks for gamification in health are being developed.

The Wheel of Sukr is a health-specific gamification framework for assisting diabetic patients to self-manage and reinforce positive behaviors (Al Marshedi, Wills, & Ranchhod, 2015). Diabetes Mellitus is a chronic disease that requires a high degree of adherence to the medical treatment plan through self-management (Ahmann, 2007). The Wheel of Sukr framework (Figure 7) uses reward systems to
motivate users towards healthy behaviors and its theoretical basis lies in reaching the state of flow and motivation as understood by SDT.

Another health oriented gamification framework is PACT (People, Aesthetics, Context, and Technology) (Charles & Mcdonough, 2014); a participatory design framework for the gamification of rehabilitation systems that looks to involve all of the relevant stakeholders from the beginning of a rehabilitation design process. This framework, however, does not use any behavioral change theory as foundation. Despite the existence of some health gamification frameworks, a systematic review (Mora et al., 2017) found that as far as gamification design frameworks are concerned, the health sector is the least developed.
2.4 Research gaps summary

There are several gamification approaches to implement gamification techniques but it remains unclear which approach would be better suited for health scenarios. Likewise, many BCM exist for modeling health behavioral changes but there is insufficient evidence as to how these can be used effectively in combination of gamification techniques.

The scientific literature (Kroeze, Werkman, & Brug, 2006; Noar, Benac, & Harris, 2007; K. C. Richards et al., 2007; Sohl & Moyer, 2007) report benefits from tailored interventions versus non-tailored as a whole. These kinds of tailored interventions can evoke favorable perceptions from individuals (A. Oenema, Tan, & Brug, 2005; Rimer & Kreuter, 2006; Skinner, Campbell, Rimer, Curry, & Prochaska, 1999) and allow for personalized content presentation leading to positive outcomes for a variety of conditions (Brug, Steenhuis, van Assema, & de Vries, 1996; Chiauzzi, Green, Lord, Thum, & Goldstein, 2009; a. Oenema, Brug, & Lechner, 2001; Strecher, Shiffman, & West, 2005). The current landscape of mHealth apps shows a lack of condition-specific solutions, likely due to the fact that wellness solutions may appear to outsiders to the healthcare sector as a “safer bet”. However, the particular needs of chronic patients requires for these health apps to start being designed with their specific needs in mind.

As mHealth continues to mature, it is reasonable to assume that generic health apps will simply not fare well as they will likely fail to engage and deliver relevant and actionable information. As previously stated, not all health apps involve relevant stakeholders in the design process and this disconnect seems quite odd in an inherently interdisciplinary field. Finding ways for designers to approach the healthcare sector and use condition-specific know-how they can use in their design process is a necessity for the survival of digital health interventions.
3 Research approach

This section provides an overview of the research methods and strategies used in this doctoral thesis. It first offers information regarding where the work of this thesis is located; then reviews the selected methods; the process of data collection and analysis; and disclaims ethical and funding considerations.

3.1 Research domain

As the application of informatics in the health domain, Medical Informatics intersects between many disciplines. Medical Informatics stands at the crossroads of a range of disciplines, such as public health, health promotion, health education, human computer interaction and information systems among many others. Figure 8 shows where the work of this research is located.

![Research work and related domains.](image-url)
3.2 Embedded case study methodology

The nature of Medical Informatics is very complex, its research field is focused on realizing the potential to use computer and information technologies in health care and draws on theories and methods developed in other disciplines (Chiasson, Reddy, Kaplan, & Davidson, 2007). As such, it is a complex phenomenon that benefits from complex analysis.

The study of complex phenomenon can often improve with the use of methodological triangulation to generate more thorough results (Bekhet & Zauszniewski, 2012). Methodological triangulation has been found to be beneficial in providing confirmation of findings, more comprehensive data, increased validity and enhanced understanding of the studied phenomenon (Bekhet & Zauszniewski, 2012; Jones & Bugge, 2006). The combination of different research methods tends to decrease the weaknesses of an individual method and strengthen the outcome of the study.

According to Yin (Yin, 1994, 2012), a “case” is a bounded entity such as a person, an organization, an event or other phenomenon, but the boundary between the case and its context may be blurry. The case itself serves as the main unit of analysis in a case study. The case study methodology allows for a single case or multiple cases; these cases can be holistic or have nested units as “embedded” subcases.

An embedded case study is a case study containing more than one sub-unit of analysis (Yin, 1994). The embedded case study methodology provides the means of integrating quantitative and qualitative methods into a single research study (Scholz & Tietje, 2002). For complex, real-world problems, no single unifying theory or model exists to explain everything simultaneously. The problem is usually multifaceted and composed of mutually related subsystems and elements. Embedded case studies are considered an appropriate approach to real, complex, current problems that cannot be treated simply by one of the known analytic methods. The problem is then explored in terms of subunits, each focusing on different features.

In an embedded case study, the starting and ending points are the comprehension of the case as a whole in its real-world context (Scholz & Tietje, 2002). Embedded case studies bridge the gap between the two camps: quantitative and qualitative methods. A process based on experiential understanding and formative synthesis derives the global statements and conclusions of the study. The data obtained from the cases is interpreted in a transformational process that relies
on different methods to arrive at a perception, judgment, or evaluation (Scholz & Tietje, 2002). In this way a synthesis is created, resulting in new knowledge or an insight. As a whole, the research question is approached following an embedded case study research methodology.

3.2.1 Setting

The present doctoral thesis is the result of an industrial PhD experience. The work took place in Salumedia Tecnologias, a digital health company in Spain, over the span of my Marie Skłodowska-Curie fellowship (see Research funding). Salumedia is a spin-off of the University of Seville, Spain that provides technological solutions for the health domain. The company is specialized in the application of social media, games and mobile technologies for healthcare scenarios.

As part of Salumedia, I was involved in several mHealth projects and product development processes. The different design projects were looking at mHealth solutions in complex real-world situations with different stakeholders and many facets of the healthcare system and technology. Using a single analytical method would not cover the spectrum of the phenomenon, so this made the use of embedded case study as an appropriate method of exploration.

3.2.2 Study case

In order to explore design factors for mHealth solutions for chronic patients, different disease courses, management and symptomatology had to be taken into consideration. Two very different chronic conditions were selected because they represent different models of chronic conditions and provide a rich area of analysis that is useful to prevent the results from being overly specific to one condition paradigm. MS represents a chronic condition that manifests itself in the life of a patient as they become young adults (Browne et al., 2014); while BC represents an acute condition that becomes chronic thanks to improved treatments and care (Bedard & Siu, 2014; Weingart et al., 2008).

The way embedded case study methodology was used in this research is through a single embedded case with 4 embedded units as illustrated in Figure 9. The dashed lines represent the blurred boundary between a case and its context.
Fig. 9. Embedded case study used in this research.

The design of mHealth solutions within Salumedia was used as an instrumental case study. Instrumental case studies differ in that the case itself is secondary to gaining understanding on a particular phenomenon (Lapadat J C, 2010). As described by Stake (Stake, 1995), the philosophical underpinnings of the instrumental case make it so that researcher, participants, and readers play a role in reconstructing experience. What each embedded unit was and how it was explored is explained in the following section.

3.3 Data collection

Keeping in mind the goal and research questions of this thesis, it was evident that there were distinct areas of knowledge that I needed to understand. This need guided my selection of embedded units described below.
3.3.1 Embedded unit 1: breast cancer and multiple sclerosis mHealth apps review

To understand what kind of mHealth solutions were available for my selected chronic conditions I decided to embark in an exploration of the current landscape of BC and MS apps.

Working with my colleagues, I led two cross-sectional studies (Turner, 2013), one for BC (Study I) and one for MS (Study II) health apps, in the two major smartphone app stores: iTunes App and Google Play Store. Cross-sectional studies are used to describe a group of subjects at one particular point in time (Turner, 2013), they provide a picture of a certain population in a specific time to describe a situation. In our case, the subject population that we were interested in were BC and MS apps. These two stores represent more than 98.9% of the smartphone app market share (Statistica, 2016) which is why we considered them more than suitable to provide a representative picture.

We defined a selection criteria that would allow us to include and identify all relevant applications and proceeded to systematically explore each of them. Almost 600 BC apps and 25 MS apps were analyzed and categorized by their intended purpose, the reliability of their contents and who were their intended audiences. We were also interested in finding out the composition of the mHealth ecosystem so we assessed what kind of entity was behind each application. Finally, an in line with current gamification trends in mHealth, we assessed how many of these health apps had gamification elements.

There was a clear difference between MS and BC apps not only in features but also in other aspects such as their intended audiences. Study I and Study II allowed me to comprehend what is the state of the practice of mHealth solutions for chronic conditions and get a sense of what kind of design factors such as features and characteristics available mHealth solutions offer for these conditions.

3.3.2 Embedded unit 2: gamification presence in mHealth apps

Given that the use of game elements in health apps is on the rise (Lister et al., 2014) and it was also significantly present in the previous two studies, we continued to explore the phenomena of gamification. There was a larger amount of BC apps than MS apps so our attention turned to them.

Based on the scientific literature on gamification and game elements and with the help of a panel of experts, we were able to generate a catalogue of gamification
concepts and constructs. In Study III, I directed the efforts to use these constructs to empirically study the presence of gamification in BC apps and develop a predictive model to automatically detect the presence of gamification in large samples of breast cancer health apps using only the title and description text of the application.

Our study provided researchers and designers an effective gamification screening tool with the ability to correctly predict the presence of gamification in BC apps in over 85% of the cases. This tool facilitates the identification of gamified health apps so that further analysis can be undertaken.

The steps involved in the construction of this gamification screening tool nurtured my understanding of gamification techniques and how they can be applied in the design of health apps.

3.3.3 Embedded unit 3: understanding the needs and barriers of stakeholders in chronic conditions

One of the main aspects of UCD as a design philosophy is setting the needs of intended users and relevant stakeholders as a priority and involving them as much as possible in the design process (Dabbs et al., 2009; ISO, 2010; Pruitt & Adlin, 2005). In order to see how UCD could be applied to the design of behavioral change mHealth solutions I conducted a mixed methods design study with qualitative and quantitative components in a clinic specializing in neurological, musculoskeletal, and geriatric rehabilitation called Kliniken Valens in Switzerland. In this study we explored persons with MS and the healthcare professionals who work with them (Study IV).

The aim of this study was to generate insights as to persons with chronic conditions’ specific needs and characteristics for mHealth solutions; detect perceived obstacles and facilitators, and motivational aspects for the adoption of mobile technologies from the perspectives of both patients and healthcare professionals.

The study had a qualitative part comprised of focus groups and interviews to persons with MS and healthcare professionals; and a quantitative part composed of structured surveys and standardized tools like satisfaction with life scale (SWLS) (Diener, Emmons, Larsen, & Griffin, 1985) and eHealth literacy scales (eHEALS) (Norman & Skinner, 2006). Participants in this study were coded as PWMS for persons with MS and HP for healthcare professionals ranging from 1 to 12, e.g.: PWMS11 or HP02.
The work in this study was used to inform on the design factors specific to living with and managing chronic conditions, as well as the overall care process involved.

**3.3.4 Embedded unit 4: design of a gamified mHealth solution for chronic patients**

Now, since the intention of my research was to generate something that would be of use to future mHealth designers, it became clear that first-hand experience designing a mHealth solution would provide beneficial insight.

In order to design mHealth solutions, practitioners and researchers draw from innovation, best practices, theory, and evidence (Gonçalves, Cardoso, & Badke-Schaub, 2014). There is a research approach known as research through design that employs methods and processes from design practice as a legitimate method of inquiry (Koskinen, Zimmerman, Binder, Redstrom, & Wensveen, 2011). In this method, design activities play a formative role in the generation of knowledge, so I found it fitting to my research needs.

Taking into consideration users and other stakeholders’ requirements obtained from my previous works and the available scientific literature; we used design through research to design a mHealth solution called *More Stamina* (Study V). *More Stamina* is a fatigue management app for persons with MS. As *More Stamina* attempts to create a health behavioral change, relevant models and theories were explored and understood for their use. Additionally, MS patients and healthcare professionals had expressed their desire for more gameful experiences for condition management, so the design of this new mHealth solution would make use of gamification elements.

The design process for *More Stamina* required deep explorations of both behavioral change models and the use of gameful design. The interplay between these two areas of knowledge and the users’ needs were key during requirement negotiations that shaped the final design. The work involved in this research was very valuable to my understanding of what factors would mHealth design for chronic conditions require.

**3.4 Data analysis**

A broad range of analysis methods was used on the collected data from both quantitative and qualitative approaches.
3.4.1 Embedded unit 1: breast cancer and multiple sclerosis mHealth apps review

The work in Embedded unit 1 used a descriptive quantitative study approach to show the composition of the mHealth solutions ecosystem and what kind of tools and features are available for persons with the selected chronic conditions. For each individual study, two reviewers independently reviewed app information using structured forms and going over the app store descriptions to classify and categorize each app. Fleiss-Cohen’s coefficient was used to assess inter-rater reliability according to Landis & Koch’s standards (Landis & Koch, 1977). The classification schemes are described below.

**mHealth apps origins**

Entities that were responsible for the development of the apps were coded into one of the following categories:

- **Healthcare related agency**: hospitals, clinics or governmental organizations directly related to healthcare (i.e. public health branches).
- **Governmental agency**: any kind of governmental agency or organization not directly involved in healthcare (i.e. IT departments).
- **Non-governmental agency**: any kind of organization that is neither a part of a government nor a conventional for-profit business such as societies or organizations that specialize both in general health improvement as well as illness-specific objectives and offer support groups (i.e. patient empowerment organizations).
- **Educational organization**: any kind of educational organization such as universities, colleges, libraries or schools not directly related to healthcare (i.e. science school projects).
- **Conferences and journals**: scientific journals, patient and/or medical conferences.
- **Small and medium-sized enterprises**: startups, software developing companies or any other private organizations that identified themselves as an enterprise and not individuals (i.e. digital health startups).
- **Individuals**: developers or uploader entities who are listed as individuals or have not identified themselves as enterprises (i.e. John Smith).
**mHealth apps purpose**

The intended use of the apps was classified following a scheme similar to that of Bender et al (Bender et al., 2013).

- **Awareness-raising**: tools to raise public recognition of the condition as a societal problem.
- **Fundraising**: tools to attract financial resources for the condition.
- **Promoting an organization**: apps that encourage awareness about an organization that supports people affected by the condition.
- **Disease and treatment information**: tools that provide general information about the condition (e.g., disease or treatment options).
- **Prevention**: apps that provide information and practical tools to avoid the condition.
- **Early detection**: tools that provide information and tools to assist in the identification of the condition before the emergence of symptoms or signs.
- **Disease management**: apps that provide information and practical tools to deal with the medical, behavioral, or emotional aspects of the condition.
- **Physical rehabilitation**: tools that help remediate impairments and promotes mobility and function for the condition.
- **Support**: apps that provide access to peer or professional assistance.

**mHealth apps target audience**

The apps were also assessed and coded depending on the intended target audience.

- **Patient-oriented**: to be used by the general public, patients and/or their family members.
- **Physician-oriented**: to be used by healthcare professionals or students from health related fields.

### 3.4.2 Embedded unit 2: gamification presence in mHealth apps

In Embedded unit 2, the process of creating the gamification detection algorithm used multivariate logistic regression where significant and relevant variables were incorporated into the algorithm. The reliability of the algorithm was evaluated using receiver operating characteristic (ROC) curves for the predicted values of gamification presence. Several iterations of the logistic model were compared to
and the one with the largest area under the ROC curve and the lowest AIC was selected.

### 3.4.3 Embedded unit 3: understanding the needs and barriers of stakeholders in chronic conditions

**Embedded unit 3** used two methods simultaneously: a qualitative exploration of the different stakeholders in a chronic condition, and standardized structured questionnaires to complement each other. Among the stakeholders explored were persons with MS, physiotherapists, occupational therapists, sport therapists and physicians.

The focus groups and interviews in the qualitative part were audio-recorded, transcribed verbatim and coded using the qualitative data analysis management program NVivo 11 (QSR International, Melbourne, Australia). The transcripts were independently analyzed first and then jointly during meetings to consolidate concepts. Recurring themes and subthemes were identified and coded during a deductive phase; thematic analysis was performed during an inductive phase (Braun & Clarke, 2006). The results of the quantitative standardized structured questionnaires were analyzed according to their own evaluation matrices.

### 3.4.4 Embedded unit 4: design of a gamified mHealth solution for chronic patients

The **Embedded unit 4** used design practice as a way of generating knowledge in an iterative and reflective manner through the practice of hands on design work. The findings from **Embedded unit 3** were used as user requirements, behavioral change models and gamification concepts were considered during requirement negotiations. We used Nielsen’s heuristics (Nielsen, 1994) as design guidelines and evaluation methods for the usability of the resulting prototype. The evaluator team independently examined each heuristic for all prototype screens. Notes were taken on major and minor issues discovered to be later contrasted amongst them. After each heuristic evaluation, the prototype was modified and assessed again. This process was iterated until all usability issues were deemed to be addressed.
3.4.5 Overall analysis

The data obtained from the different embedded units and relevant related research was then gathered for analysis. The objective of this analysis was to generate an abstraction of concepts that could be extrapolated and extracted into a series of high level illustrative design questions. The collection of design questions was then subject to a thematic content analysis (Braun & Clarke, 2006) in which recurring themes and subthemes were sought. This followed an inductive approach where the themes identified were data-driven. The exploration and definition of themes and subthemes focused on aspects which would be relevant in finding out how to design mHealth solutions for persons with chronic conditions which would be valuable and meaningful for all stakeholders in the healthcare context, and could fulfill the needs of the stakeholders. Aspects which are obvious for any ICT based solution were not incorporated; for example, the fact that the solution should be error free, that it should follow relevant laws and regulations, that cost should be within the designer’s limitations, etc.

In order to help ensure the integrity of the content analyses I followed the guidelines recommended by Shenton (Shenton, 2004) which include collecting and analyzing data in an iterative process to identify themes and generating an audit trail among others. The use of methodological triangulation allowed complementary findings to converge creating greater understanding from different parts of the different concepts.

The iterative process of grouping and subgrouping illustrative design questions led to a series of abstract constructs that were used to create a model that can be useful to guide the design process of condition-oriented gamified behavioral change mHealth solutions.

3.5 Ethical considerations

The ethical guidelines of the University of Oulu (Finnish Advisory Board on Research Ethics, 2009) were followed for all studies that included human participants. In all the studies, voluntary participation was required. The ethical approval for studies involving participants was obtained from the Swiss Ethics Committee on Research Involving Humans ID #2016-00529. The participants were informed about the nature of the research project; the reasons for their subjectability; risks, benefits, and alternatives associated with the research; and their rights as research subjects before agreeing to participate. Steps were taken to ensure that
data gathered from participants was kept under strict security, anonymity, and privacy.

3.6 Research funding

This doctoral thesis is part of the Connected Health Early Stage Researcher Support System Initial Training Network (CHESS ITN) program who provided funding for the research project. CHESS ITN is a European Union Horizon 2020 Framework Program under the Marie Skłodowska-Curie grant agreement No. 676201 (CHESS ITN, 2015).

The goal of the CHESS ITN program is to develop connected health scientists and champions who have a broad understanding of multiple domains, who can communicate in an interdisciplinary world and who can operate across the education, industry, health and policy sectors. CHESS ITN includes inter-sectoral secondments, interdisciplinary communication skills, public engagement and outreach with particular focus on patient, clinician and policy-maker audiences. This builds on a program of interrelated core research projects which address gaps in the knowledge and evidence base for Connected Health in terms of health economics, use of big data, personal sensing, business modeling, navigating markets and ecosystems, change management and user-led design.

Additionally, while working on this thesis I was a part of several research and training activities funded by the European Network for the Joint Evaluation of Connected Health Technology (ENJECT) under grant TD1405 from the European Cooperation in Science and Technology (COST) action (ENJECT, 2014). COST is a European Union Horizon 2020 Framework Program. ENJECT brings together an international network, including business and revenue modellers, clinicians, technologists, engineers, economists, ethnographers and health researchers, to help society to understand how to connect therapies, patients and care-givers to deliver optimum health results in an era of stretched resources and increasing demands.
4 3MD for Chronic conditions: a condition-oriented model for designing gamified behavioral change mHealth solutions

This section presents the main findings from the embedded units, as they were found in Studies I–V, and combines them with information presented in the Related research to contribute to the construction of the Model for Motivational Mobile-health Design for Chronic conditions (3MD for Chronic conditions or 3MD for short).

4.1 Research questions

The main RQ was answered by providing the 3MD for Chronic conditions. The secondary research questions were explored in the embedded units that contain Studies I–V and the literature presented in the Related research.

The work done in Study I and Study II answers RQ1 as new knowledge about the state of the practice of current mHealth solutions for the selected chronic conditions is provided. Through these studies the intended purposes, content reliability and involved stakeholders in the development of these health apps is now known. These studies also hinted at the current gamification trend in mHealth for motivating users which was explored in the following research question.

In regards to RQ2, the scientific literature in the Related research showed several different theories and models to create health behavioral change; different behavioral change models were examined in greater details in Study V. The work in Study IV shows what persons with chronic conditions and relevant stakeholders consider relevant for motivation. There was evidence in Study I and Study IV that the use of gamification could be used as motivational tactic, and further exploration of gamification in mHealth solutions was done in Study III.

Finally, RQ3 is answered through the design of the More Stamina mHealth solution, which follows a user-centered design process that started in Study IV; and that in Study V shows how the negotiation between the medical knowledge, behavioral change models and gamification present in the Related research can be integrated.

Table 1 shows a summary connecting the different research questions and studies.
Table 1. Research questions and studies summary

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<tr>
<th>Research questions</th>
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<tbody>
<tr>
<td>RQ1. What is the state of the practice in mHealth solutions for chronic conditions?</td>
<td>Study I</td>
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<td>Study II</td>
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<tr>
<td>RQ2. What motivational approaches can be used in mHealth solutions for health behavioral change in chronic conditions?</td>
<td>Study III</td>
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<tr>
<td>Study V</td>
<td>Related Research</td>
</tr>
<tr>
<td>RQ3. How can mHealth solutions for health behavioral change in chronic conditions be designed in a way that integrates different motivational approaches such as behavioral change theories, gamification techniques and design principles?</td>
<td>Study IV</td>
</tr>
<tr>
<td>Study V</td>
<td>Related Research</td>
</tr>
</tbody>
</table>

4.2 Overview

The embedded units were used to extract valuable insight for the study case. Data from the different Studies and the Related research was integrated and is presented in the sections below to provide traceability and facilitate the thematic trail. As a result of the thematic analysis, design factors emerged from the data and are grouped in the form of the components for the proposed conceptual model. A conceptual model is a high-level description of how a system is organized and operates (J. Johnson & Henderson, 2002). According to Storrs (Storrs, 1989) models are “frameworks for understanding” a subject, they are representations which are used to help people know, understand, or simulate a subject the model represents.

The main components of the 3MD for Chronic conditions model are: Condition specific, Motivation related and Technology based (see Figure 10). A general overview of the model is presented in Table 2.
Table 2. Model components overview.

<table>
<thead>
<tr>
<th>3MD for Chronic conditions model component overview</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Condition specific</strong></td>
</tr>
<tr>
<td>Factors that act as the foundation of the design process since they provide direct and indirect knowledge about our intended users, relevant stakeholders and their characteristics.</td>
</tr>
<tr>
<td>Common condition problems</td>
</tr>
<tr>
<td>Patient self-narrative</td>
</tr>
<tr>
<td>Care process</td>
</tr>
<tr>
<td><strong>Motivation related</strong></td>
</tr>
<tr>
<td>Factors that nourish our understanding in regards to the type of intervention and experience that we are building.</td>
</tr>
<tr>
<td>Behavioral change aspects</td>
</tr>
<tr>
<td>Gameful aspects</td>
</tr>
<tr>
<td><strong>Technology based</strong></td>
</tr>
<tr>
<td>The different technological factors that can be used to mold and craft the particular mHealth solution.</td>
</tr>
<tr>
<td>Quantification</td>
</tr>
<tr>
<td>Tailoring</td>
</tr>
<tr>
<td>Representation</td>
</tr>
</tbody>
</table>
The 3MD model is aimed at designers of mHealth solutions and, it is because of this and the fact that said ecosystem largely consists of start-ups and individual entrepreneurs; that the overall language and approach was chosen. The model proposes illustrative design questions expressed in layman’s terms, minimizing academic terminology. These questions are not definitive ones, rather they work as a means to illustrate how to approach each component to guide the design process. Designers are encouraged to explore and expand them, creating more subsets that fit their purposes.

A description of each component and their respective factors can be found in the following subsections along with their respective series of illustrative design questions. The design questions are displayed in tables at the end of the description along with a summary of their audit trail.

4.3 Condition specific

Although chronic conditions share similar overall needs, each condition has inherent differences and idiosyncrasies according as presented in the Medical Considerations section. These differences require special fine tuning during design. In Study IV and Study V, the relevance of centering the design of mHealth solutions around identified patient needs and characteristics was highlighted.

The Condition specific component describes factors that need to be adjusted and adapted for the chronic condition in question. Further thematic analysis grouped these factors into subgroups which are detailed below:

- Common condition problems
- Patient self-narrative
- Care process

4.3.1 Common condition problems

Persons with chronic conditions are affected by a myriad of problems that alter the way they live their lives. As was mentioned in the Chronic conditions section, some conditions require patients to spend a significant amount of time dealing with their symptoms and disease management but these are not the only issues that ails them. Study IV showed how persons with chronic conditions can be concerned or even afraid of issues that the healthcare team may disregard, such was the case where one healthcare professional claimed:
**HP11:** If you ask them ‘how do you feel’, they will always say "I don't feel good". Interestingly, this feeling doesn't change, they may train over three, four or five weeks and they will feel the same. However, if you look at the parameters that you normally assess, you will see that they have improved. VO2, oxygen uptake or maximum heart rate will have gone up. They objectively improve but subjectively still feel bad.

In this example, one can see that the subjective experiences of persons with MS were placed in an inferior condition than the “objective” physiological parameters.

Clinical symptoms can affect patients with chronic conditions physically, emotionally and even cognitively; and while some symptoms may be a direct manifestation of their condition, others may be brought upon the patient as a consequence of the treatments. No treatment is, in of itself, without side effects. Figure 11 shows the findings of **Study I** and **Study II** where disease management (symptom management) and disease information were greatly represented among the available mHealth solutions.
We need to also consider that not only pharmacological treatments will alter the day to day life of the patient. The prescription of a new diet, exercise or rehabilitation routine, changes day to day life and how these issues can be approached were discussed in the sections on Empowering patients and the Patient journey. There are lifestyle changes that persons with chronic conditions adopt that can cause sometimes even more resistance and problems than simple medication adherence. In Study IV, MS conditioned the way persons with MS lived their life; seeing their physical energy as a resource that needs to be managed and in many other subtler ways. Simple weather conditions like warmer
temperatures worsened MS symptoms according to some of the interviewees. In some cases, chronic conditions can diminish the sense of self-efficacy, PWMS02 claimed that there are times when “you don’t know how much confidence to have in yourself”.

Having a social circle of family and friends who provide support was a determining factor for motivating persons with chronic conditions in Study IV, friends and family reminded them that:

**PWMS08: We’re not alone with our MS. There are people thinking about what they can do to help us**

The way others who were not part of the close social circle behaved and reacted also determined their actions. It stands to reason that if a person used to socialize with their coworkers during leisure jogging sessions, this relationship will be affected when their condition affects their mobility. Simultaneously, how would a recommendation for daily exercise affect the lives of someone whose quiet time included spending time watching movies with their partner? What will going for a run represent in this established social dynamic? Relationship and priorities may suffer from this agenda tension. Designers would benefit from understanding how patients deal with these changes and how it affects them as human beings.

The illustrative design questions for this section and their audit trail summary are presented in Table 3.

**Table 3. Common condition problems illustrative questions.**

<table>
<thead>
<tr>
<th>Input</th>
<th>Illustrative questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptom and treatment related</td>
<td>What does the medical literature says are the main symptoms of the condition? What kind of treatment are people with the condition receiving? What are common side effects for these treatments? What do people with the condition feel about their treatments? How much do people with the condition feel they understand their condition?</td>
</tr>
<tr>
<td>Study I and Study II in regards to condition and symptom management tools. Study IV and how possible motivational aspects of MS patients were assessed.</td>
<td></td>
</tr>
<tr>
<td>Related research on Chronic conditions</td>
<td></td>
</tr>
<tr>
<td>Condition-driven lifestyle changes</td>
<td>How much has the lives of people with the condition changed because of the condition?</td>
</tr>
<tr>
<td>Study I and Study II in regards to condition and symptom management tools.</td>
<td></td>
</tr>
</tbody>
</table>
Study IV on how the exploration of physical activity barriers and facilitators was done.
Study IV on how possible motivational aspects of MS patients were assessed.
Related research on Empowering patients.

<table>
<thead>
<tr>
<th>Input</th>
<th>Illustrative questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study IV on how the exploration of physical activity barriers and facilitators was done.</td>
<td>What kind of things does a person with the condition “have to do” now?</td>
</tr>
<tr>
<td>Study IV on how possible motivational aspects of MS patients were assessed.</td>
<td>How has routine been disrupted for those with the condition?</td>
</tr>
<tr>
<td>Related research on Empowering patients.</td>
<td>What strategies have people with the condition developed to cope?</td>
</tr>
<tr>
<td></td>
<td>How can our design make people with the condition feel more in control?</td>
</tr>
</tbody>
</table>

Social impact

<table>
<thead>
<tr>
<th>Input</th>
<th>Illustrative questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study IV and how possible motivational aspects of MS patients were assessed.</td>
<td>How has the condition changed the way people with the condition relate to others?</td>
</tr>
<tr>
<td>Study IV on how the exploration of physical activity barriers and facilitators was done.</td>
<td>Are there things that someone with the condition feels they have to hide?</td>
</tr>
<tr>
<td>Related research on Patient journey.</td>
<td>How are the individual and social circle adapting to the changes brought on by the condition?</td>
</tr>
<tr>
<td></td>
<td>In what way are people with the condition involving others in condition-related issues?</td>
</tr>
<tr>
<td></td>
<td>Has living with the condition affected the relationship with significant others?</td>
</tr>
</tbody>
</table>

4.3.2 Patient self-narrative

In the section on Patient journey, it was shown how the story that patients tell themselves about living with a particular condition affects how they relate to it. The moment in life that the condition was diagnosed and the manner in which it first appeared impacts the way the condition is perceived. Someone who has been diagnosed as an adult will interpret things different than if they’ve had it diagnosed at an early age. A person living with a condition since childhood is more likely to see it as part of themselves as opposed to thinking it is something that happened to them. Additionally, the way the condition manifested also plays a role, as receiving the diagnosis due to an emergency situation or routine study changes perspectives and expectations. Contrast that versus a heredity condition that presents itself slowly and over time, giving the person and their social circle to adjust and prepare.

In Study IV, healthcare professionals and persons with MS commented on the different strategies that the chronic condition forced patients to undergo to appear “normal”, for example one patient referred to strategies to cover up symptoms from others:
**PWMS02**: I use one trick, I move all my appointments to the morning so people around me don’t realize that I’m not well. I then take a break in the afternoon and if someone wants to do something, I just say that my calendar will free up again in the evening.

The concept of “normalcy” is very important to persons with chronic conditions. As shown in Study IV, persons with MS experience fatigue to a degree that can prevent them from doing day to day activities. Similarly, treatment of BC may include chemotherapy which carries hair loss and can affect their self-image as is presented in the **Chronic conditions** section. Some conditions require almost constant care; the level of disruption to normal life determines the burden of the condition.

The healthcare professionals in Study IV often recommended understanding the emotional and psychological mindsets that the special circumstances of living with a particular chronic condition places on patients. The loss of perceived autonomy seemed to play an important role as it was present as both barrier and facilitator for physical activity. PWMS04 said he needed to find a way in which doing health-related tasks was his decision:

“[I am doing it] not because I have to do it, but because I want to do it. And [only] then I can do it.”

Another aspect to consider is what views the larger society and culture hold towards the condition in particular. Persons with MS are known to modify their social relationships and free-time activities as a result of their diagnosis, switching from group activities to individual exercises, resulting in worsening of their social life. A fact commented in **Medical Considerations** and Study IV. The way strangers looked at persons with MS had a big effect on participants in Study IV, to the point that some of them try not to move just to limit what can be seen and criticized.

**PWMS10**: If I’m not having a good day, I won’t leave the house. I’d know early on in the morning. [I know that] I’ll have balance problems... I’ve been told a few times by strangers that “I should drink less”. If I’m really having a bad [symptoms] day and someone comes and says something like that, it gets to me.

A special kind of health app was present in Study I: those for condition awareness raising. Some diseases have different status within the collective mind. People with cancer are a good example: as they get better they become survivors and command
a certain level of respect because they have “beaten” the condition. However, not all cancers are treated the same way: while breast cancer, perhaps due to awareness campaigns or the target population, is perceived as something that “happens to” women; whereas lung cancer, due to its association with tobacco and smoking, is seen as something that the individuals “brought upon themselves”. As such, the need for contextualization of socialization features was emphasized in Study IV and Study V, since not all individuals or all conditions may benefit from social media sharing and interaction.

The illustrative design questions for this section and their audit trail summary are presented in Table 4.

Table 4. Patient self-narrative illustrative questions.

<table>
<thead>
<tr>
<th>Input</th>
<th>Illustrative questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socio-cultural perspectives</td>
<td></td>
</tr>
<tr>
<td>Study I on condition awareness raising tools.</td>
<td>How is the condition perceived by society?</td>
</tr>
<tr>
<td>Study IV in regards to how persons with MS</td>
<td>Do people with the condition carry any social stigma?</td>
</tr>
<tr>
<td>perceived themselves and the way they saw</td>
<td>How is society working to help people with this condition?</td>
</tr>
<tr>
<td>society.</td>
<td>How much condition awareness exists in society?</td>
</tr>
<tr>
<td>Related research on Chronic conditions.</td>
<td>Are there special accommodations required for people with the condition?</td>
</tr>
<tr>
<td>Living with the condition</td>
<td></td>
</tr>
<tr>
<td>Study IV in regards to how the condition was</td>
<td>At what age is the condition usually diagnosed?</td>
</tr>
<tr>
<td>lived by persons with MS.</td>
<td>How does the condition manifests for the first time?</td>
</tr>
<tr>
<td>Study V about fatigue management for persons</td>
<td>Do the condition and treatment regimens change over time?</td>
</tr>
<tr>
<td>with MS.</td>
<td>Are there different phases or stages to the condition?</td>
</tr>
<tr>
<td>Related research on Chronic conditions and</td>
<td>How long has the target population been living with the condition?</td>
</tr>
<tr>
<td>Patient journey.</td>
<td></td>
</tr>
<tr>
<td>Condition burden</td>
<td></td>
</tr>
<tr>
<td>Study IV with a focus on disease and symptom</td>
<td>How much time per day does someone with the condition has to invest in symptom</td>
</tr>
<tr>
<td>management by persons with MS.</td>
<td>management?</td>
</tr>
<tr>
<td>Study V about fatigue management for persons</td>
<td>Do people with the condition have other chronic conditions to manage as well?</td>
</tr>
<tr>
<td>with MS.</td>
<td>How much skill does disease management requires?</td>
</tr>
<tr>
<td>Related research on Empowering patients and</td>
<td></td>
</tr>
<tr>
<td>Patient journey.</td>
<td></td>
</tr>
</tbody>
</table>
### Illustrative questions

<table>
<thead>
<tr>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are there things that someone with the condition could do before and now they cannot do anymore? How do they feel about these changes?</td>
</tr>
<tr>
<td>In what ways does people with the condition feel that the condition disrupts their normal life?</td>
</tr>
</tbody>
</table>

#### 4.3.3 Care process

In order to prevent that digital health interventions are seen as an obstacle or harmful to the care process, according to the findings of Study IV, designers should acknowledge the intricacies of each condition and find its place within the accepted care flow.

A visit to our primary care provider involves many more stakeholders than just the attending doctor. For one thing, it is very common that administrative staff deal with scheduling issues such as setting the appointment, verifying health insurance information, getting the right medical records and even greeting us when we enter the building. Nursing personnel are often present to assist the physician examine us, find the diagnosis and create an adequate plan of care. Should a lab or radiology test be ordered, technicians get involved to perform the test and maybe consult on the results. If medications are prescribed, a pharmacist fills the prescription and may discuss how to take it with us. Healthcare is a team effort, each healthcare provider is a member with a special role to play, as emerges from Study IV and the section on the Patient journey.

In Study I and Study II the absence of healthcare professionals involved in health app development was evident. The concerns around app design and app content are well recognized and it is possible that this lack of involvement from healthcare professionals is responsible for the fact that the majority of health apps are aimed at patients and do not offer a support role for the healthcare team.

Chronic conditions present scenarios that require joint collaboration from many disciplines and agents which increases the complexity and the amount of stakeholders involved. The sections on Chronic conditions and Patient journey comment on the fact that as persons with MS go through their lives, they need to find ways to juggle their own needs and wants with having to see an array of healthcare providers: physicians, neurologists, physiotherapists, rehabilitation experts, nurses, psychologists, and many more. In the same way, BC patients have to undergo chemotherapy sessions and invasive procedures that introduce more
actors and alter the dynamics of their condition. Depending on the stage or moment in the condition, some of these stakeholders require patients to meet with them on a monthly, weekly or even daily basis and how they relate with each other is fundamental as seen in the section on Empowering patients. A shared view among healthcare professionals in Study IV was that digital health solutions should not get in the way of standard care, rather they should act as additional support tools that could let professionals guide patients from the distance.

Each and every healthcare provider carries their own agenda, their own goals and expectations and it is important to keep this in mind or the healthcare team can become a barrier as seen in Study IV:

**HP05:** It’s maybe true that we [healthcare professionals] are not likely to recommend or suggest technology-based solutions. I never thought about it. Maybe because there is still no clear answer as to how apps can help. Perhaps we feel that the personal relationship that we form with our patients is not something we can replace with technology.

The illustrative design questions for this section and their audit trail summary are presented in Table 5.

**Table 5. Care process illustrative questions.**

<table>
<thead>
<tr>
<th>Input</th>
<th>Illustrative questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthcare team composition</td>
<td></td>
</tr>
<tr>
<td>Study IV on how healthcare professionals’ views were explored.</td>
<td>What kind of healthcare professionals are involved in the treatment of this condition?</td>
</tr>
<tr>
<td>Study IV in regards of how persons with MS felt about the different stakeholders.</td>
<td>Who is the healthcare professional responsible for the overall treatment?</td>
</tr>
<tr>
<td>Related research on Patient journey.</td>
<td>How are other professionals brought into the process?</td>
</tr>
<tr>
<td></td>
<td>Are there non-medical professionals involved?</td>
</tr>
<tr>
<td></td>
<td>What is the involvement of informal care givers?</td>
</tr>
<tr>
<td>Stakeholder dynamics</td>
<td></td>
</tr>
<tr>
<td>Study I regarding the different stakeholders involved in the development of BC mHealth solutions.</td>
<td>What is the role of each stakeholder in the process?</td>
</tr>
<tr>
<td>Study II regarding the different stakeholders involved in the development of MS mHealth solutions.</td>
<td>How do healthcare professionals relate with each other?</td>
</tr>
<tr>
<td>Study IV on how healthcare professionals’ views were explored.</td>
<td>Do healthcare professionals feel that there is an overlap in activities?</td>
</tr>
<tr>
<td></td>
<td>What do informal caregivers think of the care process?</td>
</tr>
<tr>
<td>Input</td>
<td>Illustrative questions</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Related research on Empowering patients and Patient journey.</td>
<td>How is the care process established?</td>
</tr>
<tr>
<td>Healthcare system use</td>
<td>How often do people with this condition need to interact with the healthcare system? How long are these interactions?</td>
</tr>
<tr>
<td>Study IV on how the care process and medical situations were handled.</td>
<td>What are the different steps required for each interaction with the healthcare system? Are visits to the emergency room an expected occurrence for people with the condition? Do medical interventions require rehabilitation periods? Are surgical interventions required?</td>
</tr>
<tr>
<td>Related research on Chronic conditions and Patient journey.</td>
<td></td>
</tr>
</tbody>
</table>

4.4 Motivation related

Motivation derives from the French word “motive” which points to the concept of needs, desires, wants or drives that we as humans may have. According to the findings of the Studies and Related research, when we attempt to create a behavioral change mHealth intervention, we aim to design a solution that can motivate people to enact our intended action.

The Motivation related component describes factors that address how to influence behaviors in an engaging manner. As a result of thematic analysis, these factors were clustered as detailed below:

- Behavioral change aspects
- Gameful aspects

4.4.1 Behavioral change aspects

Designing a successful behavioral change intervention requires that we take into account several factors since not all interventions are created equal. Depending on the objective of our intervention it is very likely that our behavioral change approach will be different. From the section on Behavioral Change we can understand that if the intervention is aimed at an individual who is unaware of the harm certain actions causes them, tactics that rely and depend on their ability to
recognize the harm or potential harm will not be possible. In a similar manner, creating a new behavior is not the same as reinforcing an existing one.

The way information is presented to users influences the emotional response and this has implications to the design of our behavioral change mHealth solution as seen in Study V and the Behavioral Change section. We should also consider that not all interventions carry the same expectations in regards to the duration of their effects. Learning to cope with the side effects of chemotherapy and channel that into a positive outlet may be desirable at one point in time but not so at a later stage. A person with MS may need continuous reinforcing of his determination to do rehabilitation exercises while a BC survivor who needed to deal with chemotherapy side effects does not. Some behavioral change interventions may have specific goals for specific moments in time or do not expect that the behavior remains after a certain period.

The level of personalization is another factor that plays a role since a population scale action will presumably be less specific than a solution tailored for one person or small group. Personalization and customization was regarded highly in Study IV and PWMS07 warned that it is important to remember that:

“everyone is as active as they want to be. The app is of no use if the person doesn’t want to do things.”

The related research on Behavioral Change states that single theory approaches are not recommended. A certain level of requirement negotiations between existing behavioral change models and our mHealth solution is necessary. In Study V, BCM were key during design negotiations. Each design concept was deconstructed to find matches with current behavioral change models; when a specific part of a BCM was not addressed by a design concept, the concept was explored further until integration with the behavioral change models felt natural or the concept was discarded. To facilitate this process, an ad-hoc diagram representing the constructs from the BCMs we considered was created in Study V (see Figure 12).
Behavioral change factors demand careful thought during the design phases to understand which behavioral change model or models to select and combine. The illustrative design questions for this section and their audit trail summary are presented in Table 6.

### Table 6. Behavioral change aspects illustrative questions.

<table>
<thead>
<tr>
<th>Input</th>
<th>Illustrative questions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of behavior</strong></td>
<td></td>
</tr>
<tr>
<td>Study I and Study II for available mHealth solutions.</td>
<td>What kind of behavior change are we as designers trying to achieve?</td>
</tr>
<tr>
<td>Study V for behavioral change model negotiations.</td>
<td>What models have been successfully used for this condition before?</td>
</tr>
<tr>
<td>Related research on Behavioral change.</td>
<td>Is the behavior an existing behavior or a new one? Does the condition go through stages? Is our intended intervention ethical?</td>
</tr>
<tr>
<td><strong>Behavior over time</strong></td>
<td></td>
</tr>
<tr>
<td>Study V for behavioral change model negotiations</td>
<td>How complex is the behavior that our intervention is trying to establish? Can the intended behavior be broken down into smaller or shorter behavioral components? What is the estimated duration of the intended behavioral change?</td>
</tr>
<tr>
<td>Related research on Behavioral change.</td>
<td></td>
</tr>
<tr>
<td>Input</td>
<td>Illustrative questions</td>
</tr>
<tr>
<td>-------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Intervention scale</td>
<td>What evidence is available for the intended behavior change?</td>
</tr>
<tr>
<td>Study V for behavioral change model negotiations.</td>
<td>What is the size of our intended population?</td>
</tr>
<tr>
<td>Study V for design decisions.</td>
<td>Are there models that fit the size of our intervention better?</td>
</tr>
<tr>
<td>Related research on Behavioral change</td>
<td>Are there proven ways to reach our target audience?</td>
</tr>
<tr>
<td></td>
<td>How are we measuring the effectiveness of our intervention?</td>
</tr>
<tr>
<td></td>
<td>Which are the most cost-effective ways for the size of our intervention?</td>
</tr>
</tbody>
</table>

### 4.4.2 Gameful aspects

The needs for a more enjoyable experience was present in Study IV. Game-like features were desired by persons with MS like PWMS02 who was expressing, for example:

**PWMS02**: [an app could present something like] an obstacle course that you have to get through. [Something] that you tackle daily. The app would have to give you an alert that says you have to walk 2km today, for example. And you have to be able to set [your own] goals. The patient should try how long he or she can walk and then perhaps increase the amount. That would maybe make people use it more. In a game, there are also tasks that you have to do. If you finish them, you get something.

This game-like attitude heavily resonated in several other persons with MS and even some healthcare professionals:

**HP03**: For me, it’s important that (the app) is playful. We all remain children deep down. It should have colors, some music and be attractive.

The findings of Study I and Study III tell us that the trend of gamification in health apps was present in our other studies as well. From the related research on Gamification we understand that the creation of a gamified system is synonymous to crafting an experience that attempts to transport users to a different, more playful mindset.

From the work done in Study V it became clear that depending on the objective of our intervention, it might be better to use different types and layers of
gamefulness. As designers of a gamified system, it is important that we consider what style of experience we want our users to go through. The task of constructing a gameful experience requires that we acknowledge that not all systems require or even benefit from the same features or elements. An awareness raising system could benefit from using metaphors so that the point is emphasized and made in a more relatable manner; or it could just rely on game mechanics to stimulate use. This use of metaphor was implemented in Study V through the design of a fatigue management tool in which a patient’s physical energy was represented as Stamina Credits. These credits were used to help persons with MS visualize and engage in playful attitudes by trying to optimize their use. The unit “credits” was chosen versus “coins” or “points” because points are usually considered as something you gain, while a credit is a form of deferred payment which was more in line with the overarching metaphor. The importance of stories and narrative in the section on Patient journey is something that we can apply to other mHealth tools. A more immersive system might make a symptom management app take the form of monsters invading us unless we warn them off through “rituals of prevention” that cast them off; while a less immersive system might only require that we check the tasks as done.

In order to conduct Study III a panel of gamification specialists was assembled and with them a list of gamification concepts and keywords was constructed. These elements included self-representation with avatars; narrative contexts; feedback; reputations, point systems and levels, in line with the research on the Elements in gamification. From this we learn that the use of the proper game elements for the experience we are trying to create is fundamental in gameful systems design. In Study V “medals” were given for completing fixed in-app objectives such as completing all daily tasks three days in a row; always responding effort assessments or continuously assessing correctly one task, among other specific objectives or “challenges”. Granting users points for doing some activities conveys the unspoken message that such action is “the right one”, having an activity be “worth” less points than another one signals that it is less desirable and no points may indirectly discourage users to undertake a third action. Similarly, not all game mechanics may apply to our specific mHealth solution. In Study IV participants commented on the advantages of social interaction among peers but the idea of competing with each other was not appreciated:

PWMS07: it’s important to distinguish how you’re connected. I don’t want to compete [with other persons with MS].
An important takeaway message from **Study V** was to use positive messages, so as designers it is important to understand that not all conditions may benefit from the same elements in the same way. The game element of progress when used to represent a degenerative condition like MS (see **Multiple sclerosis**) can have a negative effect as it could act as a reminder of how much the condition is worsening every day.

The illustrative design questions for this section and their audit trail summary are presented in Table 7.

**Table 7. Gameful aspects illustrative questions.**

<table>
<thead>
<tr>
<th>Input</th>
<th>Illustrative questions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experience style</strong></td>
<td></td>
</tr>
<tr>
<td>Study I and Study II for the presence of gamification in mHealth solutions.</td>
<td>What opportunities are we as designers offering for socialization?</td>
</tr>
<tr>
<td>Study IV for gameful experience preferences</td>
<td>Does our design provides challenging opportunities for our intended users?</td>
</tr>
<tr>
<td>Study V for gameful design</td>
<td>Does our experience or intervention benefit from having a narrative?</td>
</tr>
<tr>
<td>Related research on Elements in gamification.</td>
<td>How are we as designers providing our intended users with clear objectives?</td>
</tr>
<tr>
<td></td>
<td>How rich and complex is the game world of our design?</td>
</tr>
<tr>
<td><strong>Immersion density</strong></td>
<td></td>
</tr>
<tr>
<td>Study V for the use of gamefulness in different layers</td>
<td>How deep of a gameful experience does our intervention requires?</td>
</tr>
<tr>
<td>Related research on Users and player types.</td>
<td>Are there metaphors that can help tell a story within our design?</td>
</tr>
<tr>
<td></td>
<td>How does our gameful system fit our intended target population?</td>
</tr>
<tr>
<td></td>
<td>Is the tone of our message coherent with our design?</td>
</tr>
<tr>
<td><strong>Intervention scale</strong></td>
<td></td>
</tr>
<tr>
<td>Study III for presence of gamification in mHealth solutions</td>
<td>What kind of game elements can we as designers use for this design?</td>
</tr>
<tr>
<td>Study V for gameful element design</td>
<td>Which elements seem appropriate for the type of experience that we as designers are building?</td>
</tr>
<tr>
<td>Related research on Gameful design models.</td>
<td>Are virtual self-representations needed in our design?</td>
</tr>
<tr>
<td></td>
<td>How can we as designers transmit the feeling of progress?</td>
</tr>
<tr>
<td></td>
<td>Is social comparison useful to our design?</td>
</tr>
</tbody>
</table>
4.5 Technology based

Mobile technologies offer a wide variety of features that can be used to help chronic patients improve their quality of life and manage their condition. However, it is important to keep in mind that services destined to this end should be designed in a way that provides value to the different stakeholders. Technology should work together with the condition specific needs and engagement aspects to find a solution that fully benefits all stakeholders. In Study V we centered the design of a mHealth solution on the intended users, following personas that we created in Study IV as user representations. Design features for mHealth solutions for persons with MS were found in Study IV and are represented in Table 8.

Table 8. Sample of features and characteristics for a mHealth solution for persons with MS extracted from Study IV.

<table>
<thead>
<tr>
<th>Desired features and characteristics for a mHealth solution for persons with MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customizable goal setting</td>
</tr>
<tr>
<td>Challenges need to be tailored to the specific person with MS characteristics</td>
</tr>
<tr>
<td>Energy profiles and fatigue management</td>
</tr>
<tr>
<td>Information and tools that help users in managing their day to day activities</td>
</tr>
<tr>
<td>Patient education</td>
</tr>
<tr>
<td>Offer verified information that’s helpful and reliable</td>
</tr>
<tr>
<td>Data visualization</td>
</tr>
<tr>
<td>Information must be presented in a way that is meaningful to persons with MS</td>
</tr>
<tr>
<td>Positive feedback system</td>
</tr>
<tr>
<td>Rewards and incentives for completing tasks and objectives</td>
</tr>
<tr>
<td>Activity tracking</td>
</tr>
<tr>
<td>Register metrics such as distance walked or run, calorie consumption, heartbeat and quality of sleep among others</td>
</tr>
<tr>
<td>Exercise library</td>
</tr>
<tr>
<td>A collection of different activities beneficial to persons with MS like fitness or relaxation techniques that can be selected</td>
</tr>
<tr>
<td>Game-like attitude</td>
</tr>
<tr>
<td>Playfulness is a mindset whereby people approach activities as something not serious, in a way that is highly pleasurable and motivating</td>
</tr>
<tr>
<td>Strong evidence base</td>
</tr>
<tr>
<td>Features and information offered should have a solid scientific foundation</td>
</tr>
<tr>
<td>Remote monitoring</td>
</tr>
<tr>
<td>Healthcare providers can follow persons with MS progress and give feedback</td>
</tr>
<tr>
<td>Optional Sociability</td>
</tr>
<tr>
<td>Ability to opt-out of social media features like messaging, feeds and/or other kinds of social comparisons</td>
</tr>
</tbody>
</table>
Desired features and characteristics for a mHealth solution for persons with MS

<table>
<thead>
<tr>
<th>Reminders system</th>
<th>Notifications that remind persons with MS to engage in activities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Personal data management</td>
</tr>
<tr>
<td></td>
<td>Access to personal information and data defined by the user case by case</td>
</tr>
</tbody>
</table>

The **Technology based** component describes factors that are directly connected to the technical capabilities that mobile technologies offer that could be used in behavioral change mHealth interventions. Using thematic analysis these factors were sub grouped as characterized below:

- **Quantification**
- **Tailoring**
- **Representation**

### 4.5.1 Quantification

To make something quantifiable means to make it measurable, to give it with a clear numerical value that we can later use. We understand that numbers provide an objective reference point that is useful for us to make decisions in our daily life: when we manage budgets, buy a car, or search for recipes online. Thanks to technology we are able to find hard numbers for facets of our lives that before the advent of mobile and wearable devices was not possible.

Related research on **Chronic conditions** speaks highly of different variable tracking during the course of a disease. This was in line with what we found in **Study I** and **Study II**, where a large percentage of health apps dealt with disease management. Keeping track of physical activity, nutrition, medication regimes or even sleep patterns are good examples of what mHealth solutions can do. These features work not only as ways of creating a log or record for the person but also as a way of generating relevant data.

Gathering data can help empower people with chronic conditions and allow them to take more control over their lives, the need for this design feature was mentioned in Textbox 2. The mHealth tool called *More Stamina* we designed in **Study V** had the purpose of tracking and monitoring fatigue in persons with MS. mHealth solutions can propose systems that provide information for decision-making and feedback on how they are doing and what to do. With the right tools and the right data as input, figuring out the next move for our intended users is more accessible.
The illustrative design questions for this section and their audit trail summary are presented in Table 9.

**Table 9. Quantification illustrative questions.**

<table>
<thead>
<tr>
<th>Input</th>
<th>Illustrative questions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tracking</strong></td>
<td></td>
</tr>
<tr>
<td>Study I and Study II examples of mHealth solutions used for tracking</td>
<td>Does the condition have parameters that need to be tracked?</td>
</tr>
<tr>
<td>Study IV on the desired features for mHealth solutions by persons with MS</td>
<td>What kind of parameters are we as mHealth designers interested in following?</td>
</tr>
<tr>
<td>Study V on fatigue management features</td>
<td>Do the technological capabilities allow for direct tracking?</td>
</tr>
<tr>
<td>Related research on Chronic conditions</td>
<td>How accurate are the devices we will use for keeping track?</td>
</tr>
<tr>
<td></td>
<td>How reliable are the device tracking capabilities?</td>
</tr>
<tr>
<td><strong>Monitoring</strong></td>
<td></td>
</tr>
<tr>
<td>Study IV on the desired features for mHealth solutions by persons with MS</td>
<td>Does remote monitoring help the care process?</td>
</tr>
<tr>
<td>Study IV on the role patients with MS see for the different stakeholders.</td>
<td>How can we as mHealth designers enable healthcare professionals to follow the target population?</td>
</tr>
<tr>
<td>Study V on fatigue management features</td>
<td>Are intended users able to control what is being monitored?</td>
</tr>
<tr>
<td>Related research on Chronic conditions and Empowering patients.</td>
<td>Are communication channels offered to healthcare professionals to contact the intended users?</td>
</tr>
<tr>
<td></td>
<td>What role are we offering for the social circle within our design?</td>
</tr>
<tr>
<td><strong>Feedback</strong></td>
<td></td>
</tr>
<tr>
<td>Study I and Study II for examples of mHealth solutions.</td>
<td>How are we as designers letting intended users know of their progress?</td>
</tr>
<tr>
<td>Study IV on the desired features for mHealth solutions by persons with MS</td>
<td>In what ways does our designed system notifies intended users about corrective actions?</td>
</tr>
<tr>
<td>Study V on fatigue management features</td>
<td>How are we as mHealth designers encouraging intended users to perform the desired actions?</td>
</tr>
<tr>
<td></td>
<td>What metrics are we as mHealth designers providing the intended users?</td>
</tr>
</tbody>
</table>

**4.5.2 Tailoring**

Few devices know more about us than our mobile devices, not only because of the information that we freely enter into them but also thanks to the myriad of sensors they carry. The majority of smartphones are sold with embedded accelerometers,
gyroscopes and GPS chips. It is because of these features that they know where we have been, who we have met, what kind of presents we buy, and how often we really go to the gym. The related research on Behavioral change in mHealth shows that with some additional processing and analysis, they can also figure out our mood and current way of thinking through who we text and what we post on social media. There is probably more about us on our mobile phones than there is in our houses.

However, not everyone relates to their mobile devices in the same way. One person may feel completely lost without technology while the next may rely on their phone solely for calling their granddaughter. The degree to which people obtain, communicate, process, understand and deal with electronic resources such as the internet and other technologies, or technological literacy, plays a big role in consumer health informatics. One person with MS from Study IV phrased this as follows:

“those who are not interested in technology would never use an app”.

In Study IV, we found that the main deterrents for installing, and most influential factors preventing healthcare professionals from recommending mHealth solutions, were the presence of false or inaccurate content and negative experiences from acquaintances. Other barriers and facilitators for mHealth solutions for persons with MS were discovered in said study. When creating mHealth solutions for behavioral change, it is important that we keep these items in mind since they can go a long way into crafting the experience for our chronic condition users. Crosschecking the fact that a cancer patient is in a specific GPS position every Thursday at 2 PM for four hours with the fact that this location is the oncology department of the local hospital, we could infer that they are undergoing chemotherapy. Knowing this could prove useful for recommending suitable actions for this context and patient, perhaps offering educational reading material during this period or even withholding suggestions for physical activity immediately after. Having a personalized experience reportedly helps persons with chronic conditions feel that a given solution is right for them; this was felt so in Study IV and it was also present in the Related research.

In Study V we took advantage of the capabilities that mHealth solutions offer in the design of More Stamina. Our mHealth solution learnt about the user’s habits and once sufficient information was gathered, a personalized recommendation system took over.
The technological capabilities at our disposal are also susceptible of tailoring efforts. In Study V we explored the implementation of voice commanded interfaces to prevent the problems that typing in a small screen represents for people with advanced stages of MS. The technical complications exceeded our reach and we needed to resort to a more frugal engineering approach.

The illustrative design questions for this section and their audit trail summary are presented in Table 10.

**Table 10. Tailoring illustrative questions.**

<table>
<thead>
<tr>
<th>Input</th>
<th>Illustrative questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context awareness</td>
<td></td>
</tr>
<tr>
<td>Study I on how BC apps take advantage of</td>
<td>How are we as designers using the technological capabilities to learn about our intended users?</td>
</tr>
<tr>
<td>technological capabilities.</td>
<td></td>
</tr>
<tr>
<td>Study II on the different approaches in MS apps.</td>
<td></td>
</tr>
<tr>
<td>Study V on the design of a mHealth solution.</td>
<td></td>
</tr>
<tr>
<td>Related research on Behavioral change in mHealth.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>What kind of information can we as designers learn directly through the device? Are there ways to indirectly gain more information?</td>
</tr>
<tr>
<td></td>
<td>Does the use of geo-localization provides us as mHealth designers with useful insights?</td>
</tr>
<tr>
<td></td>
<td>Would using social media information benefit our understanding of the situation of the intended users?</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Just in time recommendations</td>
<td></td>
</tr>
<tr>
<td>Study I for BC using recommendation systems.</td>
<td>How can we as designers find the right moment for making a recommendation through technology?</td>
</tr>
<tr>
<td>Study II how MS patients are prompted by health apps.</td>
<td>Are there different levels or types of actions that we as designers want the intended users to take?</td>
</tr>
<tr>
<td>Study V on the design of a mHealth solution.</td>
<td>What kind of prompting do we as designers want to provide our intended users?</td>
</tr>
<tr>
<td>Related research on Behavioral change in mHealth.</td>
<td>How do we as designers evaluate the validity of our suggestions to intended users?</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>eHealth relationship</td>
<td></td>
</tr>
<tr>
<td>Study IV on exploring perceived obstacles and facilitators for use of mHealth solutions.</td>
<td>What do intended users feel about technology in general?</td>
</tr>
<tr>
<td>Related research on Empowering patients.</td>
<td>Do intended users seek out online health information?</td>
</tr>
<tr>
<td></td>
<td>How likely are our intended users to use technology to help them with their condition?</td>
</tr>
<tr>
<td></td>
<td>Do intended users feel they have enough skills to use the technology?</td>
</tr>
<tr>
<td></td>
<td>What causes our intended users to start and stop using a technological solution?</td>
</tr>
</tbody>
</table>
4.5.3 Representation

According to Related research, vast amounts of health related data is being generated constantly, from electronic health records, consumer health electronics and mobile devices among others. As methods for tracking all sorts of patient-related data are continuously being developed, we need to find ways in which this information is presented in a meaningful and relevant way to patients. Cleaning it up and using it to identify potential interventions can lead to cost-saving and life-saving opportunities.

Data by itself does not provide with valuable insights on its own. It must be gathered, organized, made interpretable, and then analyzed to be of any use. Knowing that I have ingested over two thousand calories today or that I am beneath the average sugar intake is not the same as understanding what that means. Is it too much? Too little? The related research on Empowering patients shows that turning these statistics into actionable information is what makes a difference. In Study IV, the healthcare professionals who worked with persons with MS said that it was often helpful to have some sort of visual representation to aid in the educational and rehabilitation. The patients themselves also view this as important, for instance PWMS06 felt that:

PWMS06: [In general, if you want] to convince people that physical activity is the key; we need to give them targets. Having feedback to how you are doing is good. We need to know we are doing something right.

Representing information in didactic ways allows persons with chronic conditions to see connections with their actions and better interpret data. The mHealth solution designed in Study V represented the patient’s overall energy is through a progress bar composed of Stamina Credits, a unit we devised to quantify the estimated effort an activity might take. In this manner, persons with MS had a more tangible notion bridging the gap between the abstract concept of “energy” to a representation of the actual experience at the end of the day. The significance of having meaningful and clear representations for the users was an important takeaway lesson from Study V and is in line with what was stated in Behavioral change in mHealth and Related research in general. In this way, the Condition specific and Motivation related components informed and built upon each other to guide Technology based components

The illustrative design questions for this section and their audit trail summary are presented in Table 11.
Table 11. Representation illustrative questions.

<table>
<thead>
<tr>
<th>Input</th>
<th>Illustrative questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Didactic</td>
<td></td>
</tr>
<tr>
<td>Study IV on the needs and desired features of mHealth solutions.</td>
<td>Are we as designers expressing the information in a friendly manner?</td>
</tr>
<tr>
<td>Study V on mHealth design.</td>
<td>How are we making the call to action clear to our intended users?</td>
</tr>
<tr>
<td>Related research on Empowering patients.</td>
<td>Are we as designers presenting easy to follow steps for the intended users?</td>
</tr>
<tr>
<td></td>
<td>Can we as designers break down the information in smaller and easier to comprehend segments?</td>
</tr>
<tr>
<td>Dynamic</td>
<td></td>
</tr>
<tr>
<td>Study IV on the needs and desired features of mHealth solutions.</td>
<td>How are we as designers taking advantage of the mHealth technological capabilities to communicate our meaning to our intended users?</td>
</tr>
<tr>
<td>Study V on mHealth design.</td>
<td>How are we accounting for different learning styles in our intended users?</td>
</tr>
<tr>
<td>Related research on Empowering patients and Behavioral change in mHealth.</td>
<td>What kind of metaphors or analogies can we as designers use to facilitate comprehension?</td>
</tr>
<tr>
<td></td>
<td>Can we as designers use animations or simulations to represent key concepts?</td>
</tr>
<tr>
<td>Meaningful</td>
<td></td>
</tr>
<tr>
<td>Study IV on the needs and desired features of mHealth solutions.</td>
<td>Are we as designers giving the intended users meaningful choices within our design?</td>
</tr>
<tr>
<td>Study V on mHealth design.</td>
<td>Can we as designers show how each action is personally connected to our intended users?</td>
</tr>
<tr>
<td>Related research on Empowering patients.</td>
<td>Does our design highlight the benefits for the intended users?</td>
</tr>
<tr>
<td></td>
<td>Are we as designers setting realistic expectations for the intended users?</td>
</tr>
<tr>
<td></td>
<td>How can we as designers make the experience more relevant to our intended users?</td>
</tr>
</tbody>
</table>

4.6 Model summary

The 3MD for Chronic conditions model follows user-centered philosophy in line with Study IV and Study V to take into account the perspectives from the different stakeholders involved in the care of a chronic condition as well as the dynamics and elements that can create behavioral change. It has been intentionally developed in a way that allows it to be used simultaneously with other existing frameworks for design and analysis.
Figure 13 shows the design factors of the 3MD model. Designers are suggested to use the different groups of illustrative questions for inspiration and to make sure that no key element is left behind in their design.

![3MD model's factors](image_url)

**Fig. 13. 3MD model's factors.**

The components of the 3MD for Chronic conditions model nurture and build on top of each other, they are interconnected and interdependent. A Condition specific issue can affect our choice of behavioral change model in the same way that the selection of Technology based issue can alter the overall experience. A negotiation between all components must happen so that these factors properly align to produce our mHealth solution. Designers are to view this model as a tool that helps guide how to approach the problem of designing behavioral change mHealth solutions for chronic conditions.
5 Discussion

The goal of this section is to discuss the contributions of the present work, address how the different research questions were answered, provide context by comparison with previous work, and to discuss the limitations of this research project.

5.1 Contribution

The main contribution of this work lies in Consumer Health Informatics within the field of Medical Informatics research, as it proposes a model which is unique in how it demonstrates the way different disciplines can be combined in a meaningful manner to address a gap in the current body of knowledge; it also provides help in the understanding of what to consider and to explore in the design of new behavioral change mHealth solutions.

This doctoral thesis makes a Research contribution addressing the gap in the current body of knowledge regarding the combination of condition-specific knowledge with the understanding of technological opportunities and human factors. The research contribution of the thesis combines these three factors which have been studied as separate elements in previous research, and shows how this integration reveals new and meaningful aspects about designing mHealth solutions for chronic conditions. Behavior change support systems are a relatively new area of research therefore theoretical efforts made for promoting scientific research in the area are valuable.

There is a Practical contribution in the proposed model as it can help designers to understand factors for the design of mHealth solutions and it offers illustrative design questions that can be used by mHealth designers from different disciplines to recognize and integrate factors relevant in designing mHealth solutions for chronic conditions.

Finally, this thesis also provides a Methodological contribution in the form of a new method developed for automatic detection of gamification features in mHealth apps in Study III. The proposed detection method can help researchers in analysis of large numbers of apps in a systematic and efficient manner. An online tool using the automatic gamification screening method was made available for other researchers to use and test to find gamification in other mHealth solutions. The method itself can be fine-tuned for many different conditions allowing for further understanding of gamification in mHealth solutions.
5.2 Research questions

The proposal of the 3MD for Chronic conditions model attempts to answer this research project’s main RQ. How the model fits in relation with the current context and prior work will be discussed separately and in more detail in the following section; the way each of the secondary research questions were answered is discussed below.

The work done in Study I and Study II answered RQ1 as it provided a clearer picture of the current landscape for mHealth solutions for chronic conditions. Study I and Study II are the first systematic reviews to provide an in-depth analysis of health apps available for consumers of their respective conditions. These studies described the apps’ features, purpose, as well as the ecosystem and active stakeholders behind it. The absence of healthcare professionals involvement in app development has been raised many times (Connor et al., 2014; Hamilton & Brady, 2012; O’Neill & Brady, 2012; Ventola, 2014; Wong et al., 2015) and the and the results of these studies highlight that the case is also so for BC and MS. The value of including relevant stakeholders and users as part of the design team is also well recognized for health IT (Clemensen & Larsen, 2007; Forducey, Glueckauf, Bergquist, Maheu, & Yutsis, 2012; Pilemalm & Timpka, 2008; Ruland, Starren, & Vatne, 2008; Sjoberg & Timpka, 1998). Additionally, the presence of gamification in BC health apps was also previously unknown.

In regards to RQ2, a thorough review of the literature on health behavioral change is presented in the Related research section and the work in Study IV explored the motivations of persons with chronic conditions and relevant stakeholders. Issues with self-management adoption have been brought up in the past (Anderson & Funnell, 2010; Jallinoja et al., 2007; Richard & Shea, 2011; Schroeder, 2007) and the general lack of enjoyment was expressed as one of the probable causes in Study IV. The presence of gamification in health apps as seen in Study I and Study III shows consistency for the selected conditions with the overall trend (Cugelman, 2013; Lister et al., 2014). Reviews on gamification in mHealth apps report low use of theoretical models, both for game elements and the use of health-behavior-theory constructs (Lister et al., 2014).

To conclude, the issue raised in RQ3 is answered through the design process that started in Study IV and Study V. Current trends of health IT interventions point out that solutions should be designed not only to be effective, acceptable, and non-harmful, but also pleasant and engaging (Ludden et al., 2015; Mirkovic et al., 2016). The use of multi-theory approaches for improved results (Schaalma & Kok,
was considered in this process: BCM, gamification principles and medical knowledge presented in the Related research played a great part in the requirement negotiations.

5.3 Comparison with prior work

Health IT for the promotion of healthier lifestyles seems to be one of the most prominent areas for the future of healthcare (Kraft, Drozd, & Olsen, 2009) with this area receiving more and more attention from the technological sector and investors (Jain & Zweig, 2018; Sung Kim, 2015). The need for health IT solutions to be engaging has been repeatedly highlighted in the literature (Ludden et al., 2015; Mirkovic et al., 2016) as it has the fact that evidence-based interventions are significantly more impactful (Webb et al., 2010). Behavioral theory and user-centered design have widely acknowledged merits in their application to digital health interventions. Many have underscored the need for digital health interventions to be grounded in behavioral theory (Azar et al., 2013; Pagoto, Schneider, Jojic, Debiasse, & Mann, 2013; Riley et al., 2011), designed with in-depth understanding of the target population (Yardley, Morrison, Bradbury, & Muller, 2015), and developed involving the relevant stakeholders (Hekler et al., 2011; Tate et al., 2013). The 3MD for Chronic conditions model presented in this doctoral thesis is the first to identify how health behavioral change theories and gamification can be used for user-centric design of mHealth solutions for persons with chronic conditions. The components and themes presented in this model emerged from explorations of the mHealth state of the practice, frequently used behavioral change models and interactions with persons with chronic conditions and their care givers.

3MD for Chronic conditions was intentionally designed to be agnostic to specific behavioral change models making it easier to adapt to different theories as needed. There are many recommendations to use multiple theories for health behavioral change (Schaalma & Kok, 2009); by prompting reflection on the intended behavioral intervention aspect, the model favors an integrative approach. The model places a strong focus in understanding the context of the target population and the intended intervention, this is in line with what has been stated in the literature as fundamental in the development of behavioral change digital health interventions (Oinas-Kukkonen, 2013; Oinas-kukkonen & Harjumaa, 2009a, 2009b). Other design models such as the Persuasive Systems Design (PSD) (Oinas-kukkonen & Harjumaa, 2009b) and the IDEAS model (Mummah et al., 2016) agree
on the importance of fully understanding contextual factors but are not specific for mHealth solutions or chronic conditions.

As a model for mHealth solutions design, **3MD for Chronic conditions** places particular considerations on the capabilities and challenges that mobile technologies offer. When building mHealth solutions there is a variety of settings and possibilities that need to be accounted for. For example, a solution that supports an existing chronic disease management program differs from a standalone app in many ways (Wilhide III et al., 2016). The Chronic Disease mHealth App Intervention Design Framework (Wilhide III et al., 2016) integrates clinical and behavioral change evidence for intervention and feature design but is not focused on the users and their needs. In the same manner, it does not address the issue of engagement.

In many behavior change interventions, technology is still used as a passive medium that mostly serves to expedite the process of communication with the user. Behavioral change interventions that take advantage of the mobile capabilities can rapidly adapt based on the individual’s current and past behavior and situational context (Riley et al., 2011). The concept of “just-in-time” of Intille et al. is used to characterize interventions that adjust based on data obtained during the course of the intervention (Intille, Kukla, Farzangfar, & Bakr, 2003). Additionally, standard health interventions have to consider the capacity of the intended users to process and understand basic health information, called health literacy (Nutbeam, 2008); mHealth designers need to also consider how technologically literate their users will be (Norman & Skinner, 2006). **3MD for Chronic conditions** acknowledges the importance of these issues and specifically presents aspects to address them in a manner that can provide valuable insight for designers.

Behavioral change interventions have been identified as potential areas for the application of gamification (Alahäiväälä & Oinas-Kukkonen, 2015; Oinas-Kukkonen, 2013). The **3MD** model considers gameful design as an engagement tactic that can be tailored for the target population, the intended intervention and the type of experience we are trying to achieve. Gamified systems have been described as complex interventions on themselves, the over reliance on points systems and disregarding contextual factors have led to unsuccessful gamification (Al Marshedi et al., 2015; Hamari, Koivisto, & Sarsa, 2014). Thorough analysis of the content, structure, and delivery of the intervention and its components is needed for a desirable outcome (C. Richards, Thompson, & Graham, 2014; Rojas, Kapralos, & Dubrowski, 2013). Gamification design frameworks like Kevin Werbach’s (Werbach & Hunter, 2012) or the Octalysis (Chou et al., 2015) provide
notions that can be helpful for designers but were not created with healthcare scenarios in mind. Health oriented gamification frameworks like The Wheel of Sukr (Al Marshedi et al., 2015) or PACT (Charles & Mcdonough, 2014) exist and while useful, they focus on diabetes care and rehabilitation systems respectively. The **3MD for Chronic conditions** model aims to go beyond one particular condition and into chronic condition care. The components presented in this model provide a conceptual way to help approach the challenges that designing an engaging behavioral change mHealth solution for chronic conditions poses.

Unlike other available design frameworks that are used to explain or describe how mHealth design should be embarked on, the proposed model also offers a series of illustrative design questions that can be used by designers to better understand the problem at hand and how to address it. The need for more concrete guidance in mHealth design has been highlighted often (Mummah et al., 2016; Sharp & O’Sullivan, 2017) and can be particularly important, keeping in mind that the bulk of consumer health informatics mHealth solutions seem to be designed by small companies and entrepreneurs (G. Giunti, Giunta, Guisado-Fernandez, Bender, & Fernandez-Luque, 2018; Guido Giunti, Guisado-Fernandez, & Caulfield, 2017).

Finally, the absence of healthcare provider involvement in the design of health IT has been raised in many occasions (Connor et al., 2014; Hamilton & Brady, 2012; O’Neill & Brady, 2012; Ventola, 2014; Wong et al., 2015) is addressed within this model. Active involvement and participation from relevant stakeholders is contemplated in the design process through the use of **3MD for Chronic conditions** model.

### 5.4 Limitations

The work presented on this thesis should be interpreted in the context of its limitations which are discussed below:

There are inherent limitations to the embedded case study methodology. The features that case study methodology offers that provided the rationale for its selection, also present certain limitations in its usage. Some authors (Hamel, Dufour, & Fortin, 1993) have commented how case study methodology may lack of representativeness, rigor in data collection, construction, and analysis of the empirical materials. Since myself as the investigator am the primary instrument of data collection and analysis, my subjectivity is vulnerable to the problem of biases. However, the issues often raised against qualitative studies are so only in light of certain epistemological views. Qualitative approaches take into account and
include differences; they do not attempt to eliminate what is inherent to being human and cannot be discounted (Hamel et al., 1993; Yin, 1994, 2011). During idea generation, designers also use their background experiences and skills, as well as different types of internal and external stimuli they might have access to (Gonçalves et al., 2014). Further, the audit trail is provided to help increase transparency.

The use of methodological triangulation opens the possibility of disharmony based on conflicts of theoretical frameworks and differences in the epistemologies of each method used in sub-cases (Thurmond, 2001). However, the findings from these methods were considered as different parts of a knowledge continuum in line with Foss and Ellefsen (Foss & Ellefsen, 2002), aiming to improve the accuracy of my findings and to increase their scope (Bekhet & Zauszniewski, 2012; Jones & Bugge, 2006).

An important aspect is that the model does not consider the fact that there are chronic patients who live with more than one chronic condition. Multimorbidity, as this phenomena is called, is known to impact on health care costs and resources across health systems, regions, disease combinations, and person-specific factors (including social disadvantage and age) (McPhail, 2016). Additionally, this model is the outcome of mHealth design exploration where only two conditions were considered, which leaves room to question the generalizability of its results. However, this was so because the creation of the model was driven by the different cases that I had the opportunity to work on and there was no mention of other concurrent conditions. Even so, the way the model is conceived allows for the generation of further subthemes within the components that could accommodate multiple conditions.

From a design perspective, the proposed model uses experiences that stem from a single design case in which the design evaluation did not involve the intended end users. This was due to the context of the research project which influenced the actions that could be embarked on within the overall project scope. However, the model was systematically constructed based on the different studies and related work and, as it follows empirical evidence, its results still are valid.

Finally, as this model uses gamification in one of its factors, it is possible that in the future the use of game elements in health trend turns out to be just a fad (Lister et al., 2014), and said subcomponent could lose its relevancy. Notwithstanding this, the 3MD for Chronic conditions model uses gamification as a way to further explore and enhance motivational aspects; this subcomponent could be adjusted and amended in light of future findings.
6 Conclusions and future work

Looking at the way things are evolving, it would seem that both chronic conditions and technology are here to stay. The need to understand then how to use the one to support the other in a meaningful way can only become more and more important as time goes by. The results of this thesis address a recognized gap in research and practice on how medical, design and technology factors can guide the creation of mHealth solutions to face the global challenge that chronic conditions pose. Further, this thesis explores the design of behavioral change mHealth solutions for chronic conditions and proposes a model that could be of use in the generation of new tools to help chronic patients.

Future research is necessary to validate the kinds of conclusions that can be drawn from the model proposed in this thesis dissertation. More empirical design studies are needed to validate the 3MD for Chronic conditions model and assess its usability. This provides a good starting point for further research regarding the use of the model in different phases of the design cycle and how it can be approached by different stakeholders. The exploration of multimorbidity in the context of the proposed model may also constitute the object of future studies.

Taking into consideration all the advances and progress that science has brought us so far, every once in a while it is very tempting for humankind to want to claim that we have reached the edge of knowledge, since we cannot imagine what could be next. In a similar way, Robert Frost’s poem “Stopping by Woods on a Snowy Evening” (Frost & Jeffers, 2001) tells the story of a man traveling through the forest on the darkest night of the year, and falling in love with what surrounds him. The road still forges ahead but he cannot quite tear himself away from the sight, and yet in the end the poem concludes:

*The woods are lovely, dark and deep,*
*but I have promises to keep,*
*and miles to go before I sleep,*
*and miles to go before I sleep.*

As technologies continue to emerge and adapt, healthcare will transform into something very different from what we have now. The journey healthcare systems are on goes some place as of yet unknown, but it is the hope of the present work to help the path be treaded in a way that technology, medicine and the good for all
involved leads to a bright new future. There is a much left to be done, so we should get working. We too have promises to keep.


103


116


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<table>
<thead>
<tr>
<th>Book No.</th>
<th>Author(s)</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>706</td>
<td>Mononen, Jukka</td>
<td>Korkeaasti koulutettujen vammaisten integroituminen ICT-älille heidän itsensä kokemana: “Älä anna muille etumatkaa!”</td>
</tr>
<tr>
<td>707</td>
<td>Tolonen, Katri</td>
<td>Taxonomic and functional organization of macroinvertebrate communities in subarctic streams</td>
</tr>
<tr>
<td>708</td>
<td>Turunen, Jarno</td>
<td>Responses of biodiversity and ecosystem functions to land use disturbances and restoration in boreal stream ecosystems</td>
</tr>
<tr>
<td>709</td>
<td>Huuskö, Riina</td>
<td>Downstream migration of salmon smolts in regulated rivers: factors affecting survival and behaviour</td>
</tr>
<tr>
<td>710</td>
<td>Huuskö, Karolina</td>
<td>Dynamics of root-associated fungal communities in relation to disturbance in boreal and subarctic forests</td>
</tr>
<tr>
<td>711</td>
<td>Lehosmaa, Kaisa</td>
<td>Anthropogenic impacts and restoration of boreal spring ecosystems</td>
</tr>
<tr>
<td>712</td>
<td>Sarreméjane, Romain</td>
<td>Community assembly mechanisms in river networks: exploring the effect of connectivity and disturbances on the assembly of stream communities</td>
</tr>
<tr>
<td>713</td>
<td>Oduor, Michael</td>
<td>Persuasive software design patterns and user perceptions of behaviour change support systems</td>
</tr>
<tr>
<td>714</td>
<td>Tolvanen, Jere</td>
<td>Informed habitat choice in the heterogeneous world: ecological implications and evolutionary potential</td>
</tr>
<tr>
<td>715</td>
<td>Häimälä, Tuomas</td>
<td>Ecological genomics in Arabidopsis lyrata: local adaptation, phenotypic differentiation and reproductive isolation</td>
</tr>
<tr>
<td>716</td>
<td>Edesi, Jaanika</td>
<td>The effect of light spectral quality on cryopreservation success of potato (Solanum tuberosum L.) shoot tips in vitro</td>
</tr>
<tr>
<td>717</td>
<td>Seppänen, Pertti</td>
<td>Balanced initial teams in early-stage software startups: building a team fitting to the problems and challenges</td>
</tr>
<tr>
<td>718</td>
<td>Kinunen, Sanni</td>
<td>Molecular mechanisms in energy metabolism during seasonal adaptation: aspects relating to AMP-activated protein kinase, key regulator of energy homeostasis</td>
</tr>
<tr>
<td>719</td>
<td>Flyktman, Antti</td>
<td>Effects of transcranial light on molecules regulating circadian rhythm</td>
</tr>
<tr>
<td>720</td>
<td>Maliniemi, Tuja</td>
<td>Decadal time-scale vegetation changes at high latitudes: Responses to climatic and non-climatic drivers</td>
</tr>
</tbody>
</table>

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Guido Giunti

3MD FOR CHRONIC CONDITIONS

A MODEL FOR MOTIVATIONAL mHEALTH DESIGN