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BEYOND THE NUMBERS

BEYOND THE NUMBERS

A user-centered design approach
for personal reflective healthcare technologies

Juan Jiménez Garcia

Juan Jiménez Garcia



Sensing Systems for Interactive
Home-Based Healthcare and Rehabilitation



Smart Reasoning Systems
for Well-being at Work and at Home



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A user-centered design approach for personal reflective healthcare technology

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Printed by

ISBN:

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BEYOND THE NUMBERS

A user-centered design approach for personal reflective
healthcare technology

Proefschrift

ter verkrijging van de graad van doctor
aan de Technische Universiteit Delft,
op gezag van de Rector Magnificus prof. ir. K.C.A.M. Luyben,
voorzitter van het College voor Promoties,
in het openbaar te verdedigen op woensdag 17 december 2014 om
10:00 uur

door

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Dit onderzoek is mogelijk gemaakt door steun van het SENIOR project (Sensing Systems for Interactive Healthcare and Rehabilitation), een initiatief binnen het programma van economische innovatie Pieken in de Delta Oost-Nederland, en SWELL/COMMIT project (User Centric Reasoning for Well Being at Work).

“By three methods we may learn wisdom: First, by reflection, which is noblest; second, by imitation, which is easiest; and third by experience, which is the bitterest”

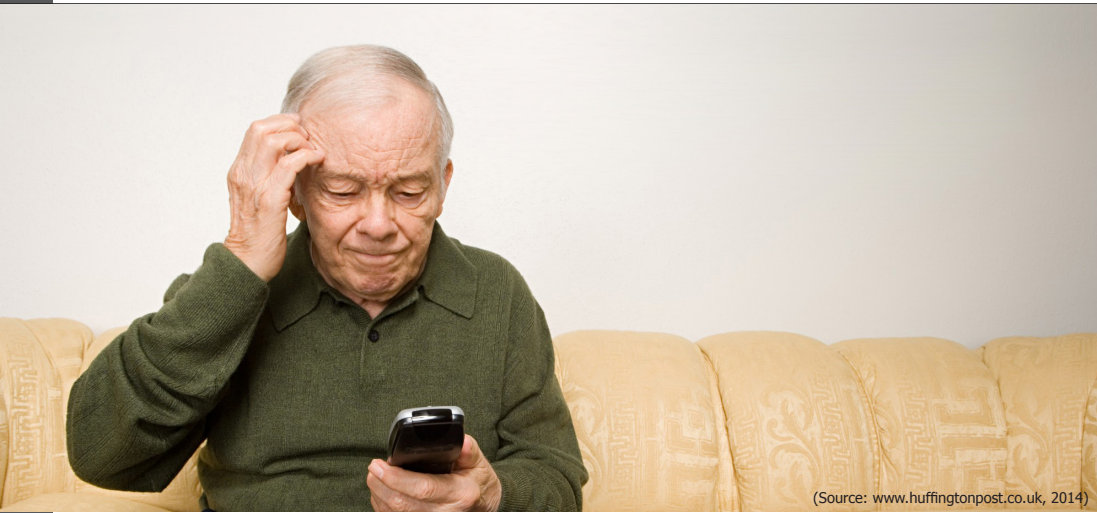
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1 INTRODUCTION



(Source: www.huffingtonpost.co.uk, 2014)

Let us imagine the following scenario: Bob is 70 years old and has osteoarthritis in his hip joint. The last 1.5 years, he complains of pain and a somewhat stiff joint. Normal level walking, walking the stairs, and bending over becomes more and more difficult and pain and stiffness are increasing. Therefore, Bob is scheduled to have a cemented total hip prosthesis. Two days following surgery he is discharged from the hospital. When Bob is in his second day at home after surgery, the homecare system detects that he has done too little physical activity that day and sends him a reminder to his mobile phone advising to perform the prescribed exercises for today. He does not understand why he gets a reminder as he considers that he has moved enough today and feels very tired and even with some pain. But the system persists with reminders and notifications making Bob feel increasingly more anxious and stressed.

This scenario illustrates the common approach to develop user centered assistive tools for daily life health care. Assistive technologies commonly assume a more persuasive approach, in which the system takes a prominent role by nudging people towards a goal (Munson, 2012). In this thesis it is argued that this approach is insufficient to support end-users during their daily life health experiences. Then, what should the system present to Bob so he could be better informed of what is best to do at that moment? How could the system incorporate Bob's feelings and emotional state to better support him?

In order to design supportive system technologies that are integrated into people's daily life we need to know how to design for user empowerment. Providing Bob with control over his own data may empower him to play an active role, contributing and deciding what is important to take from the big amount of data that is collected by these systems. This is a design research challenge that requires more than an understanding of the functional characteristics of a system. It requires an understanding about what users need to use technology that aims to support their physical status. Supportive homecare technologies can provide a reflective approach by providing users with relevant information in which they can reflect upon so that they can become self-managers of their own care (Hassling et al., 2005). The shift from assistive to supportive technology is considered a relevant research direction to avoid scenarios like the one described above.

1.1 Outlook

This thesis is positioned in relation to today's healthcare strategy, which is focused on shorter hospitalization times to solve the problem of high demand for hospitalization under conditions of insufficient resources and funding. Consequently, homecare is thought to alleviate the care responsibilities that professionals and health institutions are facing due to increasing need for care that our current society demands. Additionally, given the rapid expansion of mobile devices and applications based on in-built sensors, wearable monitoring devices and context-aware systems, the extent of access for personal health data for patients and health professionals have increased while at the same time posing new challenges for Human Computer Interaction (HCI) design.

With the increasing amount of personal data offered by technologies such as smart phones or wrist devices with embedded sensors, the line that separates lifestyle and healthcare is rapidly dissolving. Consequently, patients are gradually changing from passive health consumers to pro-active choice-makers (Sergio, 2013). Health practices are therefore experiencing a paradigm shift from being solely delivered by professionals in hospitals to considering the home and every-day contexts as a self-care environment and patients as active responsible of their own care, monitoring and reflecting over their own data. Given the increased direct access to health care data by patients it is evident that developments in health technology need to work towards an improvement in users' perception and care results in an effective and meaningful way. But then, how can personal technology be implemented in a way that supports users' responsibility to reflect?

1.2 Problem definition

The impact of new technology advances and personal data on people's life is rapidly increasing. In a multitude of technological systems, the design of technology for healthcare has become a priority for both governments and research institutions alike to bring care services closer to the end-user. Recent advances in wireless sensing technology offer innovative ways to deliver healthcare services to the patient's home serving as a self-care environment. In recent years, miniaturized inertial sensors have become an increasingly popular solution for ambulatory physical human monitoring. Furthermore, recent advances in wireless communication and miniaturization stimulate the development of pervasive technologies, such as wireless sensor and Body Sensor Networks (BSN), foreseen to have a high impact in the wellness and healthcare domains.

This potential matches with the growing need for new healthcare service systems for supporting specific user groups in their everyday lives. Additionally, there is an opportunity for explorative research in healthcare given by the World Health Organization that considers empowerment as a fundamental element in disease prevention and health promotion (WHO, 2010). The European Strategy for the Prevention and Control of Non-communicable Diseases extends this view by stating: "people should be empowered to promote their own health, interact effectively with health services and be active partners in managing disease".

However, designers of pervasive health technologies are confronted with two main challenges:

- The lack of proper tools to reach a holistic understanding of the user's situation in context.
- Once this understanding is reached, the lack of mechanisms to implement user empowerment in pervasive healthcare technologies.

1.3 Understanding users and user empowerment as the cornerstones of this thesis

A new personal information ecosystem in HCI is emerging. It is organized on one side by designers developing systems and mobile applications for individuals to collect, store, use and share their own personal data; on the other side, it is the users interpreting this data and making sense of it, so that they can use it to for their own purposes. Between them, the technology system and the data it generates. Nowadays, developments in pervasive technology move our society into a transformative era where data is constantly generated, distributed and shared with the power to change users' daily practices. The users are surrounded by a huge amount of data that can be used to nudge users to interact and behave in certain ways. This data reveals opportunities that HCI research can respond to this emerging ecosystems. The core purpose of building upon these technological developments of the last few years is to help individuals manage their own personal data as an asset and resource, which they can use to organize and manage their lives better (Mydex, 2010).

The first participant in this ecosystem – the designer – dedicates most of his efforts on defining the functional requirements of technology systems, making these systems technically reliable. This task requires a methodological exploration on what are the wishes and desires of the users towards the functional design of a system. With an increasing user group diversity appropriating new technologies, along with an over-saturated market with mobile applications and devices, it has become more and more important for designers to adopt an approach that brings users closer to research practices. For designers this is a matter of understanding, enabling them to grasp and perceive holistically the health experiences of users and the potential of providing data to support the users' daily life. If we are designing for daily life of people taken into context, we need first to assume an understanding approach to inform solutions that elicit more meaningful and distinctive experiences of users with this technology. Designers face practical issues with research procedures in the design and evaluation of information systems in the field (Harjumaa and Isomursu 2012), The authors expose that the explorative nature of field studies, the difficulty of working with a specific target user with physical conditions (e.g. elderly), recruiting users, collecting data about subjective experiences and the integration of current data collection instruments into the everyday lives of users are common obstacles to explore users' daily life. But, if users' experiences are not fully understood the result could bear no relation to their real needs in context. This challenge contributes to align and ground design research practices towards the same common point: the user. Therefore, understanding users is the first cornerstone of this thesis and it proposes a research shift to entitle how technology systems can support them.

The second participant of this ecosystem – the user – dedicates his effort and daily lifetime on interacting with these systems. With the rise of social media and the expanding use of mobile devices, an interesting development that is partially blurring the boundaries between lifestyle and life care is getting stronger: the so-called 'self-quantified movement' and Personal Informatics systems. Smartphones are becoming more powerful and able to measure and track user's physiological aspects and activities, often with the extension of additional measurement accessories. For example, with Nike+, Fitbit and more recently Samsung Gear Fit wrist devices and mobile applications people are being persuaded to achieve programmed goals and to connect with each other with access to sources of physical activity information any time or place, regardless the physical distance. Although these solutions use persuasion mechanisms towards behavior modification, for users this is a matter of empowerment. When the system extends its persuasive elements to empowerment capabilities, it enables users to contribute to and explore their own daily life experiences through meaningful data. These actions provide

insightful material to self-reflect and self-learn towards better-informed actions. Therefore, empowerment is the second cornerstone of this thesis and it requires a design shift to entitle how to provide meaningful information for long-last behavior modification, and this one comes from personal reflection.

Research and design shifting requires re-thinking traditional paradigms in Human Computer Interaction (HCI) by means of new approaches and frameworks that integrate new types of methods, tools and data types. Here is when understanding as an element for the designer to dive in, and empowerment as an available component for the user to acquire become the new agenda in Human Computer Interaction for the design and research of technology systems and services.

1.4 Goals

The primary goals of this thesis are 1) to build on understanding-user in the design research methods and practices by means of in-situ tools and methods, and 2) to build on user-empowerment in the design of supportive systems by means of tools and applications that explore the integration of sensed with self-reported data.

1.5 Research questions

As developed further in the subsequent chapter, current solutions in pervasive healthcare are more assistive (data-centric) than supportive (user-centric). But the question is then, how can a system be designed to be more supportive? This thesis discusses that understanding-user and user-empowerment are fundamental aspects in the design of supportive pervasive healthcare systems but they have not been deeply synchronized and applied. The value of technologies to support patients becomes important when user experience is considered of prime focus for research exploration. A proposed translation of user experience in this context relates to how awareness and reflection could become an important step in designing appropriate mechanisms that fit patients' needs. However, with the open gap for tools that facilitates this exploration, the approach to address understanding and empowerment in the design of pervasive solutions is highly needed.

This lead to the following main question: How can supportive personal systems be designed? For this purpose, two sub-questions are derived:

R.Q. 1: How a better understanding of users' situation in context can be reached to support the design research of supportive technology systems?

R.Q. 2: How can user empowerment be facilitated through designs that encourage users to have a more active role in the use of personal informatics systems?

1.6 Research approach

Derived from these research questions two hypotheses are formulated. The first one states that an in-situ tool is a research resource that provides a holistic view of patients care experiences in context. This hypothesis serves as contribution to the research implications in ecological and in-situ studies. The second hypothesis states that the integration of subjective and sensed data in personal technology systems enhances self-reflection and self-awareness. This hypothesis contributes to the design implications in the design of pervasive healthcare systems.

An integrated user-centric approach has been constructed to provide insights that help uncover the aforementioned research questions (Figure 1). They are supported by specific methods that were gradually introduced to address the need to cover from general to more centralized focus on the user. User Centered Design Methods (UCD), Experience Sampling Method (ESM) and Personal Informatics (PI) framed a different stage of an iterative design and implementation of several prototypes. This approach differs from previous attempts to reach the user in that it assumes the challenges of considering users' personal experiences and social context, collected in-situ, as crucial aspects when providing care support, which makes the research process more representative on real users' daily life needs and desires.

1.7 Contributions and relevance

The research work presented in this dissertation has been conducted around two specific healthcare scenarios, namely Total Hip Replacement (THR) and physical activity in Knowledge Workers. The outcomes discuss the value, challenges and contributions that understanding-the-user makes to the current available methods to reach the user in context, and user-empowerment makes to the methods currently available for the design of supportive healthcare technologies. The assumed approach considers as essential the elements in the design of supportive healthcare technologies that embrace a more active role of patients. Additionally, this thesis aims to contribute to the existing research approaches of design research practices and the design of Personal Informatics based on its staged-model. This thesis is particularly directed at researchers and designers of personal health technologies aiming for an integrated approach that points out why and how innovations should address the patient experience early in their design process in order to guarantee the acceptance and adoption of innovations that are designed to support home care.

1.8 Structure of this thesis

The chapters of this thesis are built upon a combination of published or submitted papers. In total, eight chapters compose it. Chapter 2 discusses the two cornerstones of this thesis and the research scope. Chapter 3 presents the background and healthcare scenarios that frame this thesis. Two case studies, Total Hip Replacement (THR) and physical activity in Knowledge Workers (KW) are examined presenting the state of the art of current technology system solutions, as well as the design opportunities they are providing.

Then, the thesis is divided in two main sections. Section A tackles the first cornerstone of this thesis, understanding users in context. This section unfolds two chapters that answer the first main question of this thesis describing why a holistic understanding was needed and how it was reached: Chapter 4 presents the design and implementation of a situated research tool for Total Hip Replacement patients based on Experience Sampling Method (ESM) called ESTHER. A field study with ESTHER (1.0) illustrated the value of this tool to facilitate reflective mechanisms to support patients. Chapter 5 presents an iteration of ESTHER (1.2) tested in the field providing insights on the technical challenges of integrating self-report and sensed data.

Later, Section B tackles the second cornerstone: empowering users mechanisms. This section also unfolds two chapters that answer the second main question of this thesis: Chapter 6 introduces the micro-Cycles of Self-reflection (mCR), an extended stage-model of Personal Informatics that frames the integration of sensed and subjective data. The mCR is applied in a new iteration of ESTHER (1.3) with the purpose to explore strategies of dynamic prompts and understand the impact of visualization that integrates objective and subjective data to empower

users. Chapter 7 presents an analysis of three parallel design explorations that opened other kind of mCR mechanisms to empower users.

Finally, conclusions and a discussion on the experiences developing and implementing a situated in-situ research tool are presented in Chapter 8. This chapter also discusses the challenges of an initially explorative research to a more integral focus with ESTHER as a vehicle to explain a user-centric approach.

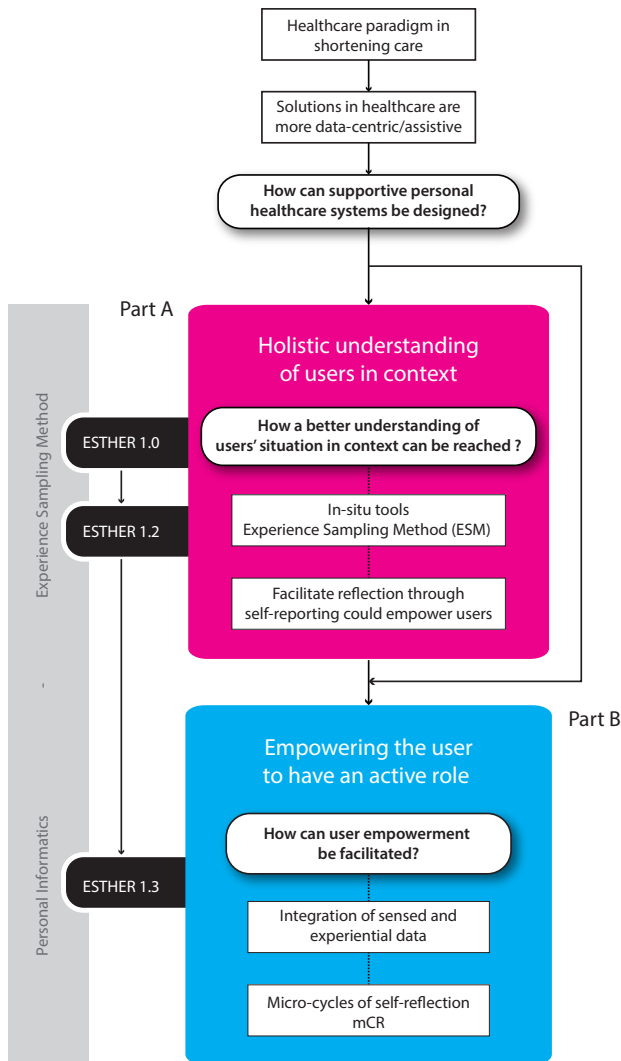
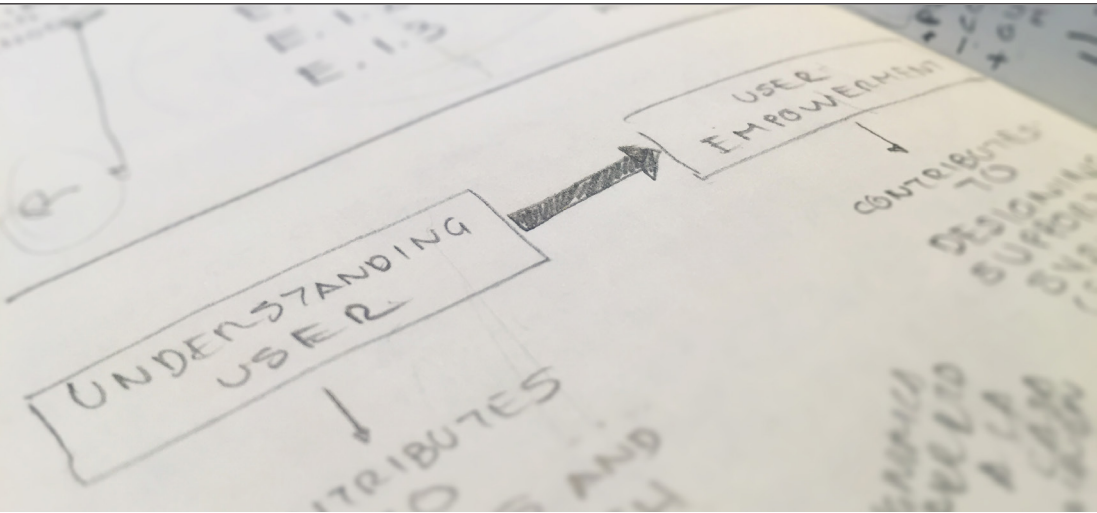


Figure 1. Thesis outline. Main research and design steps.

2 THE CORNERSTONES



This chapter describes the concepts of understanding and empowerment and their relevance in Human Computer Interaction practice. The scope of this dissertation within two healthcare scenarios will be presented: Total Hip Replacement home recovery and physical activity in knowledge workers. Later, the main challenges to address understanding and empowerment in healthcare design are developed unveiling research opportunities.

2.1 Understanding: the initial stage in the development of Human Computer Interaction systems

Kelley, CEO at IDEO, states: “All clients, all organizations and companies could benefit by trying to understand humans more deeply: their employees, their customers, the people in the community around them. I have hundreds of examples of how understanding people better than the competition understands them unlocks tremendous value” (Making sense of big Data, 2012). We all can see how understanding touches our daily life at work, family or friends and how the lack of this element may affect these relationships. Imagine if we approach our most precious relationship without first a sense of understanding when a situation arises. We will be struggling in finding appropriate solutions that suit that particular individual at that moment in time. Understanding allows us to be open, to learn and to make the ball rolling towards shared agreements and meaningful relationships. We particularly see this translated into the design of technology systems. Designers of systems that deal with people and their daily life can have a meaningful relationship with the users in order to find solutions that suit them better. In order to outline new future developments designers should contemplate new methods and tools to support a better understanding of the user. To this end, designers need to understand the situation from the user’s perspective since the very beginning. However, this shift in focus demands time and resources. But the gained information is valuable by any measure.

Up to 20 years ago the Human Computer Interaction (HCI) community started with a growing interest to appropriate a User-Centered approach. It came from embracing cognitive science and human factor engineering in software development to later incorporating usability in the design of these solutions. Later, the development of mobile devices puts technology at the hands of the user. With the quick advent of these mobile devices, technology started to be present everywhere, it moved from being fixed on a desk to be pervasive, mobile, and more specific: personal. Consequently, HCI is facing new questions and problems to solve, some of them with regards to the experiential aspects of the user towards these pervasive solutions. Then, the HCI community starts to think differently, putting special attention on how the user uses and experiences technology. Modern HCI realizes that technology solutions are to be used by users, so it is suitable that the design process has to be centered on the user.

Both Human Computer Interaction community and Experience-Driven design practitioners claim that understanding the user and his experiences in context is a new step towards the creation of products, systems, applications and services that truly represent an individual, to gradually reach later to a group. HCI currently uses a conventional four-stage design/research model (Harper et al., 2008). This model involves 4 consecutive steps, study, design, build, and evaluate that follows an iterative process. But there is a new proposal in the design of technology systems in HCI. Microsoft, in its report “Being Humans, HCI in the year of 2020” (2008), proposes an extension of this model by adding a new explicit step called “understand” (Figure 2). This new step aims to enrich the study of people’s experiences beyond the usability.

The addition of “understanding” in this cycle will in turn provide better insights towards tailored design objectives. For example by considering which functions should be provided from a supportive technology solution or to define the research focus based on what users are concerned or interested about. With “understanding” as an explorative process with the user at the central element of exploration, the HCI community is looking for new methods to help designers to capture the user’s experiences in context. Currently, the HCI community commonly uses User-Centered Design Methods such as in-depth interviews, diaries, personas and scenarios (Putman et al., 2009) to obtain tacit knowledge about the user by encouraging the user to document part of their lives and their experiences.

In the case of Experience-Driven Design, an emerging design practice with a strong interest in the experiential or emotional consequences of product use (Hekkert et al., 2006), it involves “understanding” as a set of activities that helps designers to grasp better knowledge about the user and his situation (Figure 3). Acknowledging that different users have different experiences, the design of system technologies first requires an understanding of their goals, needs, values, expectations and context. For them this is also an explorative stage in which designers can qualify and quantify what influence certain experiences. While the initial step towards the design of a supportive system use to be a quick exploration of functional and non-functional aspects of the system, it has been found that a deeper look is necessary if the system is addressed to be supportive, and the case of designing for healthcare is eager to include this characteristic in new developments. Understanding is a step that strengthens the knowledge around the user in order to take both research and design choices.

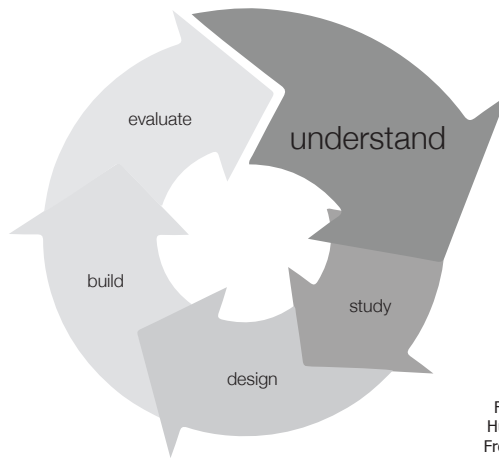


Figure 2. Graphic representation of the Human Computer Interaction approach. From: Being Humans, HCI in the year of 2020, Microsoft, 2008.

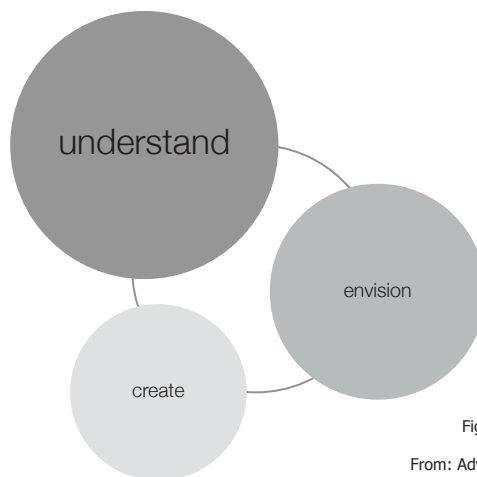


Figure 3. Graphic representation of the Experience Driven Design model. From: Advance Design Methods for Successful Innovation, Design United, 2013.

2.2 Empowerment: the new agenda in HCI to support users

Although traditional Human Computer Interaction aims to know how efficient or useful a system might be, rather usefulness and functionality in the design of new supportive technology should be harmonized with the properties of user empowerment. New trends in HCI aim to know much more than merely ask the user about the effectiveness of a system. It aims also to address how to support deeper and more meaningful experiences with this technology in specific using situations and user behaviors.

When HCI looks beyond the functionality of a system to a deeper view into the underlying reasons of behavior, this has profound implications for the design of meaningful experiences that can be delivered to the user. Because people are often unaware of the aspects that influence their behaviors, designers should fulfill the existing gap of applications that solely inform and persuade the user about their physical performance. A way to do this is by looking into a more experiential and empowered support in which users have a more active role in the creation of their own data, giving them the chance to dive and explore the causes and consequences of their own behavior.

Empowerment is a process that enables people to gain power and self-influence towards a better control over their own lives. It is not a one-time process. It is a constant process of self-understanding about how we all work, what are the elements that play a role in our daily life situations, how do they affect them and acting on issues that are considered as important. The first step towards gaining empowerment involves gaining Knowledge. This requires having access to information, resources and a range of options that are self-determined so that people are able to take proper informed decisions in the future (World Health Organization, 2012). Then, the next stage leads to Awareness when people are able to ground themselves in the present, finding out where beliefs and actions come from providing understanding. Once we understand the elements that run our lives, we reflect within ourselves. This is a self-reflection process that requires thinking or analyzing one's behaviors in meaningful moments over a long period of time (Pommeranz et al., 2011). Self-reflection points us in the direction that we must move to, it provides the path, but in knowing where we are going we can proceed step by step. It provides vision. A self-empowered person is an expert about his own life. This theoretical grounding on empowerment is hereafter defined as KARA and it is described in Figure 4.

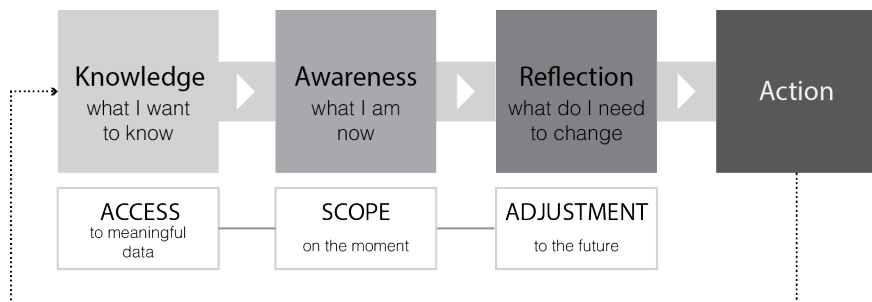


Figure 4. KARA. Empowerment process.
Diagram based on Perkins and Zimmerman (1995), World Health Organization (2010) and U-Yah-tal empowerment organization (2013).

The most important characteristic of the empowerment process is the high involvement and active participation of the individual. Tengelnd (2010), states that this approach promotes self-determination, autonomy and fully respects the individual since he has the control over the process, from the problem formulation, the decision process, and the actions undertaken. This will lead to the development of knowledge closing the loop. Empowerment is, therefore, an iterative process with a strong bidirectional link between the Knowing and the Action and self-Awareness and self-Reflection as the elements to support this link. However, one of the essential and fundamental reasons causing the low degree of self-awareness and self-reflection is the absence of a strategy and planning which can provide the individuals with meaningful information.

Tengelnd (2010) also identifies that the major advantage of an empowerment process over a behavioral change approach, i.e. transtheoretical model, is that the first one avoids the ethical problems often found in a more coercitive approach. The author describes that although both of these approaches pursue people to modify their behavior towards better actions, it is defined that the more people are manipulated, the less autonomous they will become. This, in turn, reduces knowledge and makes the individual less inclined to reflect deeply on the options available, compromising the loop between Knowledge and Action.

It is suggested that HCI community should place more emphasis on designing technology systems that include the principle of user empowerment. In particular, the field of health persuasion raises many ethical questions about how the data and the feedback are used to influence the user. On the other hand, and as pointed by Müller et al. (2013), designing for empowerment is all about providing the user with the necessary information for self-reflection with less ethical issues because the user has control to make conscious and insightful decisions.

In the design of personal interactive systems empowerment is about a shared understanding between the system and the user. It is about self-awareness. It is about facilitating the user to take decisions and actions that support self-planned goals. The technology should support these goals, measure, and provide resources in an environment of trust and open feedback.

2.3 Scope: two healthcare scenarios

This thesis embraces two different healthcare situations that involve direct patient engagement, namely (a) Total Hip Replacement home recovery (THR), and (b) physical activity in knowledge workers (KW). With the paradigm in healthcare, shifting the responsibility on users for care, the emergence of technological homecare innovations could empower patients to undertake a more active role in the care practice.

The first scenario, THR recovery, was provided by the project SENIOR (Sensing Systems for Interactive Home-based Healthcare and Rehabilitation). This project had the objective to deliver a platform to explore wireless sensors for monitoring and supporting the wellbeing and health of elderly, in their everyday life. The research work performed with THR tackled the first cornerstone of this thesis – understanding- reaching the user in context by exploring self-reporting methods and its technical challenges. Later, SWELL project (Smart Reasoning Systems for Well-being at Work and at home) had the goal to explore design interventions to support physical activity in knowledge workers. This new scenario served as exploration and implementation of empowering mechanisms. The following two subsections will briefly introduce these scenarios, presenting their main challenges and design research opportunities.

2.3.1 Home recovery in Total Hip Replacement

THR is an effective and conventional solution for moderate or severe osteoarthritis, the prevalence of joint disorders that affect the older population (Arden et al., 2006). This procedure improves the quality of life of people that suffer from this condition enabling them to return to their daily life (Wong et al., 1999). Due to the high demand for this surgery and the scarcity of medical resources, Total Hip Replacement procedure has adopted an early discharge strategy resulting in a quick transition from surgery to post-operative home recovery. Wong et al., (1999) state that in early discharge, hospital staff limits their effort to support the functional recovery, with little attention to the psychological needs of patients living with a new hip. This situation creates an environment of fear and uncertainty for the patients by not getting adequate educational preparation to manage their recovery (Fielden et al., 2003; Fortina et al., 2005). The existing educational programs and the physiotherapist's verbal instructions that patients get before discharge are reported as insufficient in helping them and their families to make adequate decisions about recovery at home (Williams et al., 1996). Patients might forget or misunderstand spoken information, or they might not get all their questions answered. As a consequence they do not know the rules they have to follow during rehabilitation (Stevens et al., 2004) and make uninformed decisions (Macario et al., 2003).

Once at home, the recovery is monitored on the basis of sporadic weekly or bi-weekly check ups between the professional and the patient, which take place at home or in the hospital. In between these meetings the patient is left with a list of home assignments, which he should perform daily without supervision. This creates a communicational gap between health professional and patient, leading to insufficient information on the progress of recovery (van den Akker-Sheek, et al., 2007). Given the lack of frequent monitoring and feedback during the recovery may severely aggravate the emotional state of the patient and that emotional and psychological problems have a direct effect on the recovery process (Jimenez Garcia et al., 2010), homecare technologies may open an opportunity to provide more frequent guidance and to extend the support beyond the functional.

For surgeries like THR, current technology developments aim to primarily assist homecare practices with the possibility to automatically and even remotely monitor patients' functional performance. The challenge in this case study is to shift from an assistive technology focus to a supportive one. The focus on assistance implies a passive role of the patient since all the responsibility lies on the judgments and advices processed by the system. Relying entirely on the system, current developments are primarily focused on the technical challenges to capture functional aspects such as foot pressure, balance and movement in an accurate and efficient way. However, as pointed by Grönvall and Lundberg (2014) the challenges of implementing pervasive healthcare solutions go beyond functional-related aspects. Despite its relevance, these innovations are not considering in their approach an understanding of the complexity of patients' home, their lifestyle, attitudes and preferences.

2.3.2 Physical activity in knowledge workers

Knowledge Workers is a target group that could be benefited from pervasive health technology and mobile applications. In the current market, most of these solutions focus on functional aspects of physical activity, keeping a balance between unobtrusiveness and rapid access to feedback, and data accuracy. Nike+, FitBit and DirectLife are some examples that intent to shape behavior with analysis, assessment and visualization of physical performance. However, the data-centric focus of these mobile applications is often missing the user's contribution in the process of supporting behavioral change that can be seen, in contrast, with other mobile

applications. MoodPanda, Moody, and more recently Reporter, are mobile applications that mainly focus on self-reporting as a mean to engage users to understand the sources and consequences of behavior overtime. The latter example points: “It’s good for a lot more than rendering nifty visualizations. Reporter can create a truer self portrait of your otherwise intangible human metrics -nuanced ideas like your mood, your real friends, and your diet-that modern sensors just can’t track very well” (Fastcodesign, 2014).

As demonstrated by Groot (2010) and Wichers et al., (2011), self-assessment mechanisms provide elements of daily life behavior that users may learn from and adjust to influence their behavior. When the design of pervasive health technology mainly focuses on functional rather than extending to the experiential aspects of the user limits the opportunity to incorporate the empowerment that the user needs when using these systems. Therefore, the challenge in this case study is to emphasizing self-reporting as main mechanism to shape behavior, balancing how the existing mobile applications assist and support users.

As explained in Chapter 2, in the particular case of physical activity and knowledge workers, there are little initiatives supporting knowledge workers implementing physical activity as part of their work routines. Due to the sedentary nature of their work, knowledge workers have little opportunities to engage in physical activities during the working hours. In addition, physical activity is not a priority in their busy agenda, which results in knowledge workers been unaware of their physical behavior at work. Considering self-reporting as the mean to achieve self-awareness, the design of pervasive technologies for physical activity can be benefited by going beyond the support of the automation of data collection and visualization of physical behavior to actively support the process of self-reflection.

2.4 Research opportunities

This thesis encounters two main challenges that are related to the limited user-centered design focus in the design of pervasive healthcare systems. Although the agenda for establishing an “understanding” stage in design research has been proposed, there is a lack of proper tools to reach the user and gain a holistic understanding of the user’s situation in context. Moreover, once this understanding has been reached, there is a lack of strategies to implement user empowerment in pervasive healthcare technologies.

2.4.1 The lack of proper tools to reach a holistic understanding of the user’s situation in context

In developing a new system, one of the main difficulties is to identify and meet the particular user needs and consequently this is where systems can result in a failure: due to the technology driven way of development, instead of user needs driven (De Rouck et al., 2008). The potential of a supportive technology can be only achieved if the entire functional components offer an unobtrusive and adequate user interaction, tailored feedback interface and they are more adaptive to the user’s preferences (Baldauf et al., 2007; Kleinberger et al., 2007). Most studies about activity monitoring systems reflect technological principles such as system architecture, sensor technology, measurement outcomes or data analysis techniques, and it is unknown if these activity monitoring systems actually comply with what the users need. Working fluently and seamlessly with the patient’s individual situation in an early phase of development, technology can be fitted to their daily practice and environment of use (Fowler, 2004; T. Broens, 2007).

The traditional approaches of HCI, such as User Centered Design (UCD) are essential to address the above circumstances, but they are unable to go fine-grained into the complexity of users' experiences in the healthcare context. The principle of "know the user" in Human Computer Interaction makes obvious that it is not possible to design something for people without a deep, detailed knowledge of the users. However, developing technology for healthcare faces substantial considerations to deliver meaningful possibilities to the user that are currently not being addressed with the tools and methods used by HCI. UCD needs to be re-examined, in particular to be clear about the difference between using its methods, which may not suit special needs, and achieving its objectives (Thimblely et al., 2008). Interestingly, there are no tools that address a deeper look on users' experiences that support designers in the design of personal healthcare technologies, a tool that can be used in-situ, providing sensitive, granular, as well as information of the user experiences overtime.

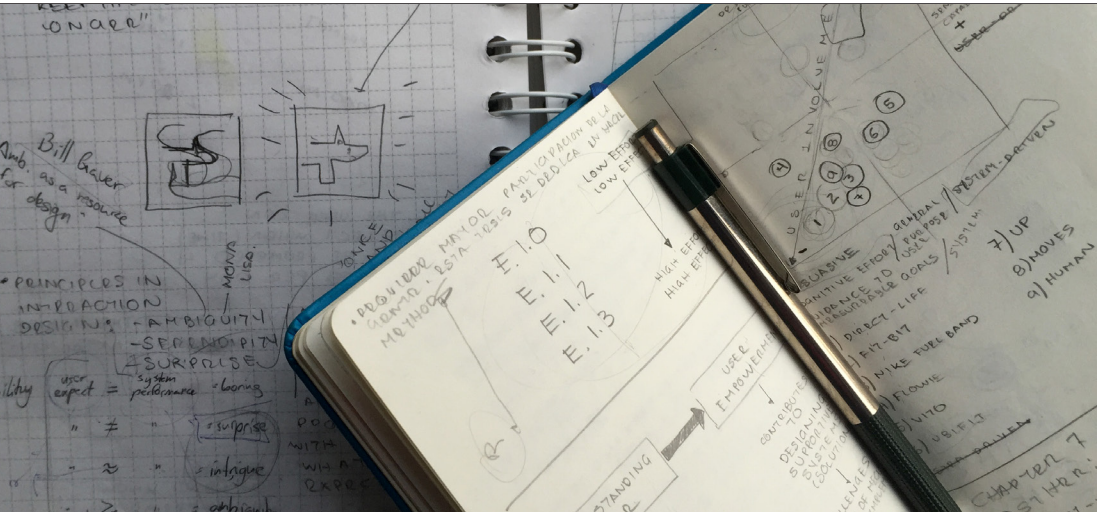
2.4.2 The lack of mechanisms to implement user empowerment in pervasive healthcare technologies

New developments in Human Computer Interaction and personal technology, such as mobile applications and wearable sensing monitoring devices are promising developments in the definition of the future of healthcare supporting physical conditions, chronic diseases and recovery processes. However, Human Computer Interaction mainly focuses on the efficiency, effectiveness and satisfaction of usability aspects of a system but the concentration on pragmatic aspects of the system falls short (Ziefle and Jakobs 2010). As mentioned by Ziefle (2010), a long time HCI has been discussed from a dominantly functional perspective considering that HCI requires a broadening of the focus to include emotional or affective aspects of the user. The authors extend their claim considering that HCI should involve attributes that emphasize the fulfillment of the individual productivity.

Advances in sensor capabilities are helping the collection of data to be more pervasive and accurate. With these data-centric solutions it is possible to collect huge amount of data such as physical activity tracking providing calorie consumption, count of steps, active-inactive time or steps climbed. This information helps researchers and health professionals to access users' data, make decisions and advise based on evidence. The latest challenge is, however, not only about providing huge amount of data but also giving to the patient more insight, control and reflection in their personal data. Health professionals are experts in clinical care while patients are experts in their daily experiences and how they make them feel. The integration of automated sources of health information into patients' self-generated data can help to bridge the gap of health delivery focusing on care rather than on the disease. However, crafting data into information to facilitate the process of user empowerment in healthcare is an area of research that is in need of attention.

Being data-centric means these applications can collect a wide and extended variety of functional values, such as calories, steps, hear rate, distance, as well as contextual information, such as location, weather, temperature, even moods can be collected. But are these systems with this amount of data revealing ways to help users to self-reflect on their own behavior? Or, on the contrary, are these systems persuading people, unaware, towards goals that the system intends? Sometimes more is not enough. Sometimes nudging only is not enough. Besides the fragmented aspect of this data, it is usually not of any meaning to the user. Also, the user is not able to add any information to existing personal data collections. This aspect could improve how the user understands his data to better-informed actions, enhancing the feeling that the data belongs to him. Hence, it is important to support user's empowerment to facilitate what and how users can do with their own data collected by these applications.

3 BACKGROUND



This chapter presents an overview of the domains and contexts in which the proposed research approach is developed, gives a glimpse of the challenges ahead and provides an analysis of current approaches to patient care during home recovery and of technological solutions to monitor physical activity. Following this, a review of methods to support user-centered design research is provided.

As described in this chapter, current solutions are typically more data-centric rather than user-centric, reflecting upon the opportunity for user-centered research and design approaches. In order to design for supportive technologies that remotely support patients in their rehabilitation process and help users in identifying opportunities to change behavior, the major challenge ahead lies in designing technologies such that they become part of the users' daily life activities. Therefore, methods are needed to capture requirements that go beyond understanding not only functional aspects but also to include and focus on users' experiences during home recovery and daily life practices.

3.1 Treating osteoarthritis at home following total Hip Replacement surgery (THR)

Osteoarthritis (OA) is the most common joint disorder and affects a large population, primarily in the later stages of life (Arden and Nevitt 2006). Patients with OA of the hip joint experience pain, stiffness and loss of joint function. Total Hip Replacement (THR) is an effective and common solution for moderate or severe osteoarthritis. This procedure reduces considerably pain and enables patients to function in terms of hip movement (Wong et al., 1999; Ethgen et al., 2004). Several studies indicate an increasing prevalence and incidence of THR procedure in The Netherlands and other Western countries (Ostendorf et al., 2002; Robertsson et al., 2000). The number of THR performed in The Netherlands from 1996 to 2005 increased by 17.1%, and is expected to increase along the same lines in the coming decades (Ostendorf et al., 2002).

The number of THR interventions increase with age: starting at around 55 and peaking at age 75; and sharply decreasing after age 75. After age 75, the ability to fulfill the surgery requirements and rehabilitation capacities decrease, making this population less suitable for THR surgery. The third type of intervention (besides Total Knee Replacement) shown in Figure 5 is 'other hip arthroplasty', with a total of 6,369 in 2008. This type of intervention is often needed after a fall. The number of 'other hip arthroplasty' increases gradually with age, starting at about age 55.

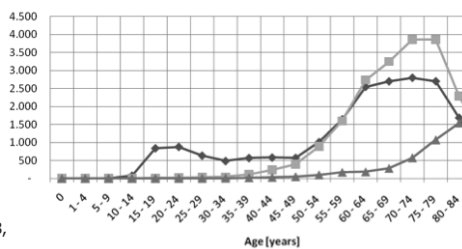


Figure 5. Number of medical interventions in The Netherlands in 2008, (Ziekenhuisstatistieken, Prisma™).

Although the number of THR surgical procedures is rather high (e.g., in the Netherlands 20,551 annually), the rehabilitation process is not sufficiently standardized. Oosting et al., (2009) analyzed the content and quality of protocols for the perioperative physiotherapy management by collecting 10 protocols at hospitals in the Netherlands. All these protocols described equivalent interventions, which were mainly aimed at training both function and activities. Although discharge criteria were present in 6 of the 10 protocols, they were not uniform. The discharge criteria are: no wound drainage; extension-flexion 0 to 90 degrees; patient can lift the leg in extension; no nursing necessary; patient can make safe transfers (e.g. from sitting to standing); patient knows behavioral advice; patient can walk level and stairs safely with crutches; patient is ADL-independent (Activities of daily living). When discharging to home, skilled nursing or in-patient rehabilitation must be arranged. Each protocol contains a subset of these discharge criteria, resulting in a non-uniform level of patient status at discharge in the Netherlands.

In the last decade we have observed several technical innovations and societal transformation processes that have had direct consequences on the design of pervasive healthcare systems (Zieffle et al., 2014). In the context of hospital post-surgery care, the growing demand of hospital resources and the advances in surgery technology have led to a reduction of in-patient

care and shorter hospitalization times (Fortina et al., 2005). In response the healthcare system is adopting e-health solutions leading to new approaches in care practices. These solutions embrace a variety of online communities and health services with the purpose of facilitating connectivity between patient and medical staff.

Nowadays, medical and economic developments allow more people to undergo Total Hip Replacement surgery with the aim of improving quality of life. As a result of this high demand, over one million of total hip arthroplasties are implanted every year in the world. The healthcare system is facing a paradigm shift in shortening hospitalization time (Fortina et al., 2005). Consequently, there is limited time for clinicians to educate patients and to follow-up their progress during the early stages of recovery. This creates problems for patients and physiotherapists. Wong et al. (1999) states that in early discharge, hospital staff limits their effort to support the functional recovery, with little attention to the psychological needs of patients living with a new hip. This situation creates an environment of fear and uncertainty for the patients who are not getting adequate educational preparation to manage their recovery (Fielden et al., 2005; Fortina et al., 2005). The existing educational programs and the physiotherapist's verbal instructions to the patients before discharge are reported as insufficient in helping them and their families to make adequate decisions about recovery at home (Williams et al., 1996). Patients might forget or misunderstand spoken information, or they might not get all their questions answered. In consequence, they do not know the rules they have to follow during rehabilitation at home (Stevens et al., 2004) and they make uninformed decisions (Macario et al., 2003). Physiotherapists also face difficulties in their daily practice to predict short and long-term outcomes and to define rehabilitation trajectories (van den Akker-Scheek, 2007). With an existing lack of tools to measure beyond the functional recovery of patients, care practitioners are faced with an incomplete assessment of patients' health status during the recovery process. This, in consequence, generates an atmosphere of misinformation and uncertainty about patients' recovery outcomes and leads to demands for resources that they cannot provide.

The home-based recovery management of THR patients is even less standardized than the clinical procedures, resulting in a wide range of rehabilitation strategies in a non-uniform patient population. When treatments and post-surgery recovery of THR is taking place at the patient's home this situation has a direct impact in the frequency and quality of communication and follow-up programs between the patient and the physiotherapists. Research has found that less frequent contact negatively affects the patient's experiences during the recovery at home (Wong et al., 1999).

As a consequence, physiotherapists may find it difficult to follow how patients deal with the recovery as soon as they are discharged, the individual's process of recovery or health status, due to limited meetings and out of context observations of patient's activities. Also, patients feel an atmosphere of anxiety as they perceive that they are poorly informed about what is normal or what to expect during recovery (State of Health Care, 2006). This results in an increased burden on patients in terms of achieving expected improvements in physical condition and increases the patients' responsibility for the rehabilitation (Fielden et al., 2003).

3.1.1 State of the art in mechanisms to reach the patient after surgery

Self-report measures

Clinicians are constantly seeking better ways to coordinate care and ensure people undergoing THR surgery receive personal and tailored therapy (Stevens et al. 2004). In determining short-term recovery, measuring both patients' health perceptions in surgical recovery and how their experiences differ during recovery has become an important element in the evaluation of

THR post-surgery. Furthermore, such analysis can assist in the prediction of recovery times (Wong et al. 1999; Salmon et al. 2001). In order to collect this information, medical teams are using standardized techniques in stages of the recovery to measure functional progress. For example, the Western Ontario and McMaster Universities osteoarthritis index (WOMAC) and the multi-purpose health survey questionnaire (SF 36), in combination with several physical performance measurements (e.g. Six Minute Walk Test, Time Up & Go) are widely used prior and several months after surgery (Stratford et al. 2003; Maly, Costigan, and Olney 2006; Dohnke, Knäuper, B., and Müller-Fahrnow 2005).

Although these questionnaires have been widely used to evaluate THR outcomes and they have been reported extensively in the literature, THR recovery is strongly related to the individual experiences of the patient, which are left unobserved by these methods. Several limitations have been documented. First, these questionnaires are usually used as pre-operative and post-operative measurements (usually several months after surgery), resulting in an incomplete data collection during the initial and critical weeks of recovery at home. These self-report scores relied on the ability of patients to recall past events and experiences (Cole et al., 1994; Intille et al., 2003). Kennedy et al. (2006) and Parent & Moffet (2002) describe the weak longitudinal ability of these questionnaires to follow-up on patients during their recovery process, in particular during the early period after surgery. Grant et al. (2009) emphasize the importance to consider the changes of patients' needs over time, however the identification of these patterns has not yet been deeply explored. Second, questionnaires created by health professionals often fail to elicit more constructive critical responses from patients' points of view overlooking their emotional responses (Fielden et al., 2003).

One more important limitation of these questionnaires is that although they take into account patients' perspectives of their own level of health and mobility, the results only reflect cross-population health outcomes. Busija et al., (2008) and Ostendorf et al., (2002) indicated low sensitivity of SF-36 questionnaires to assess individual change for THR patients following surgery. Busija continued their study suggesting to not use SF-36 questionnaire for monitoring individual patients for orthopedic purposes. One effort from clinicians to create a patient-based score to overcome the limitations of related measurements was the Oxford Hip Score (Dawson et al., 1996). This score assesses the level and changes in pain and function of the hip function from the viewpoint of the patient. However, McMurray et al., (1999) showed that this measurement lacks clarity, thus patients find it difficult to understand. It was found that these repertoires of questionnaires are not designed to simply sample patients' individual issues during the recovery process; neither do they measure how they vary over time.

Performance-related measures

Apart from self-report questionnaires, clinicians may evaluate outcomes after surgery by means of observed physical performance, such as the six-minute walk test (6MWT) (Enright, 2003), and Timed UP & GO (TUG) (Podsiadlo & Richardson, 1991). It has been found that a moderate relation exists between self-report questionnaires and performance measures. Performance scores are designed to assess a single physical attribute (Maly et al., 2006) while self-reports are capable to collect information of a higher number of aspects over physical function (Kennedy, 2006). Therefore the combination of questionnaires and performance measures is highly recommended in order to assess mobility. In practice, however, clinicians examine recovery mobility either with one or the other method. It is interesting to note that a low relationship has been found between physical performance measures and real physical demands in daily activities. These measurements are not integrated into the flow of daily living and they are seen as not relevant by the patient (Maly et al., 2006).

Other techniques

Woolhead, Donovan and Dieppe (2005) reported that only after complementary in-depth interviews it was possible to get a more global reflection on the recovery process, where patients admitted that they still perceived limitations during their process. Additionally, Grant, St. John, and Patterson (2009) emphasize the importance to consider the evolution of patients' needs, when standardized methods capture snapshots situations overlooking meaningful changes over time (Busija et al., 2008).

A few studies have explored different aspects of recovery beyond the functional rehabilitation. Fielden et al., (2003) and Grant et al., (2009) used in-depth interviews to investigate patient's perspectives about surgery service and their satisfaction after discharge. These studies opened new insights about the psychosocial determinants involved in THR. However, these studies did not capture the dynamic of the identified determinants and the patients' experiences over time since the information was collected in two pre-defined periods, one just after discharge and another several weeks later. Akker et al., (2007) and Fortina et al., (2005) identified the importance of educating patients and assist them in their recovery process after discharge. These studies evaluated the use and effectiveness of the designed material (e.g. videos, newsletters and guide books) during the patient's recovery process. Customized guides were well accepted, and perceived as satisfactory in providing useful information. However, a low effect of the intervention was observed which was linked to the lack of feedback patients received on their personal experience and progress during recovery.

With a closer view on patients' individual psychosocial experiences, Hassling et al., (2005) used cultural probes as a method for elicitation of requirements for the design of supportive technologies including emotional aspects. They implemented a self-documentary media kit for the collection of data to capture patients' experiences from living with a chronic disease. Although participants were able to capture interesting family and personal activities around the disease, it was still challenging to express emotions and to provide more reflective thoughts on what they reported. The authors suggest that explicit mechanisms need to be developed to motivate emotional reports.

3.2 Physical activity of Knowledge workers

Physical activity plays a very important role in people's life (Chan et al., 2009, Bosems, 2012). The lack of physical activity can have a negative influence on physical and mental wellbeing, thereby affecting daily life at home and work, and the quality of life in general. The importance and urgency of providing health and lifestyle guidance is evident from the fact that according to the Dutch Labor Inspectorate, 50% of the Dutch employees exercise too little; Dutch employees have an unhealthy lifestyle, such that 50% of them do very little exercise besides other unhealthy behaviors such as smoking, drinking too much alcohol, and skipping breakfast (Hoofman et al., 2011). Other studies also emphasize the need to motivate people to be more physically active (e.g., Chan et al., 2009). Therefore, there is a need for health and lifestyle support that detects user state and context in real time and provides effective motivational feedback to increase physical activity. Such motivational mechanisms can help reduce the overall cost caused by people's ill health and unhealthy lifestyle, and at the same time it can help improve wellbeing (Kraaij, 2011).

The concept of knowledge workers as a target group is relatively new. Wellbeing at work has become particularly important in the context of knowledge workers, as the stress and sedentary work associated to office work leads to unhealthy work practices characterized by insufficient physical activity, which increases the risk of numerous diseases (Boerema et al., 2012; Brownson et al., 2005). More than a quarter of all employees in The Netherlands have

sedentary work and sit on average 4 hours per day while being at work and travelling to and from work (Boerema et al., 2012). Knowledge workers' agenda is driven by task completion, scheduling and planning what activities have to be done on daily basis. Knowledge workers are unaware about how (in)active they are at work (Corder et al., 2010) easily adopting sedentary behaviors due to the nature of their work with prolonged sitting over 4 hours (Hooper & Bull, 2009). Their work is characterized by the ease at which task switching occurs, making their daily work life very fragmented (Koldijk, Saskia, et al., 2011) and by the urgency to accomplish tasks getting totally engrossed during a three-hour time frame (managermechanics.com).

When confronted to such intense work habits, knowledge workers put their health at risk. Although there is a substantial body of literature confirming the need of at least 30 minutes of physical activity at work and hourly breaks of five minutes, the level of sedentary behavior is increasing (Commissaris et al., 2006). The lack of self-awareness makes it difficult for knowledge workers to implement health-related solutions into their daily schedule, as well as limiting the effectiveness of physical activity interventions (Corder et al., 2010). Implementing breaks that involve walking for at least five minutes requires knowledge workers to reflect on their work routines without affecting their current work responsibilities.

3.2.1 State of the art in technological solutions for physical activity monitoring

Being physically active is highly recommended by health institutions, especially for groups at risk such as the elderly or patients with chronic conditions (Pate et al., 1995). In Total Hip Replacement and other physical conditions (i.e. Chronic Obtrusive Pulmonary Disease - COPD), traditional physical interventions such as home-based, group-based, and educational physical activity interventions may not always fulfill the expectations at promoting health since they may not be completely successful in keeping patients motivated in the long term and typically they do not include behavioral support (Van der Bij et al., 2002). The introduction of technology-based products, such as wearable and non-wearable sensor systems to motivate physical activity for these risk groups has become a promising medical solution. It assists physicians in providing tailored physical treatments with personalized feedback mechanisms that result in higher engagement of patients. However, the involvement of a new technology into people's daily life implies an ongoing challenge to encourage users to adopt and use this technology. This challenge is of particular importance in the context of designing technologies to support users during home recovery.

There is a range of systems from mobile devices to more context-aware systems that apply different persuasive strategies to engage people in increasing physical activity. Several examples are described below. The current market of products that support detection and monitoring of user's physical activity builds on a variety of technological developments. For example, it can be seen that commercial devices such as Nike+ Fuelband (Nike.com/nikeplus/nikefuel), Fitbit (Fitbit.com) and DirectLife (directlife.phillips.com) are based on a single on-body sensor to assess energy expenditure by means of an accelerometer to detect the number of steps. Some other commercial devices such as Polar and Garmin Forerunner use simultaneously a wider range of sensors to monitor user's physical activity by detecting heart rate. These devices provide information through smartphones or web applications allowing people to review their data. Additionally in this spectrum of solutions, design concepts such as UbiFit (Consolvo, et al., 2008), Flowie (Albaina, et al., 2009) and ViTo (Nawyn, et al., 2006) not only assess user's physical activity and track user's location, but also sense the context and the user's behavior.

DirectLife (Phillips)

Phillips, 2010) is an activity monitor device that encourages people to be more active in their daily life. By previously setting the user's age, gender, height and weight, the device uses a Tri-Axial accelerometer to measure all the performed movements along the day. By combining this information the measurements are converted to caloric expenditure in different activities. With a personal coach on a web-based service, the device allows users to set personal goals and monitor their physical progress. DirectLife is focused on embedding a persuasive technology in user's daily life in an unobtrusive and simple way of use for non-professional athletes. Rather than measure activity on sports and dedicated exercises, DirectLife measures activity levels throughout the day.



Figure 6. DirectLife provides physical activity performance by means of indicator lights. (source: <http://www.directlife.phillips.com>).



Figure 7. DirectLife. Web-based personal plan and goals achievement.

Nike +



Figure 8. Nike+ iPod System (source: <http://www.nikeplus.com>).

Nike Plus is a pedometer-based device that allows runners to track their progress of distance, time, and calories. This device focuses on recreational or competitive athletes. The way this product stimulate usage engagement is based on its capabilities of “building virtual communities”, along with the iPhone™ features. The community helps to build motivation to play sports (Kurdyukova, 2009). The user can upload and exchange training data, participate in virtual competitions and interact with others on the website (www.nikeplus.com).

com). For instance, the “Human Race 10 K” is a Nike’s Brand competition in which athletes can participate in a virtual race and be ranked worldwide. It works as a reward for good performance, encouraging users to keep on improving and using the device. Physical activity monitoring and goal-achievement has been largely implemented in other dedicated products such as Fitbit, Polar and Garmin’s Forerunner devices. They are designed to perform a specific pre-planned physical activity goal.

ViTo system

ViTo (Nawyn, 2005) is a system that uses a residential sensing infrastructure to recognize user’s TV viewing habits with a PDA-based interface aimed at decreasing the daily television usage while increasing the physical activity as a means to prevent obesity. It explores the possibilities and efficacy of embedding behavior modification strategies into ubiquitous computing technology. At the first level, the PDA serves as a universal TV and home theatre remote control with a graphical-touch based screen. It provides information about user’s viewing practices, as well as providing value-added features not present in current TV-remote controls, such as accessing a media library or interactive games. Such features have been included to encourage users to adopt the device in their TV viewing routines. This PDA device, which can be connected to wearable accelerometers, creates a personal training system which can persuade the user to watch less TV. The device is intended to deliver persuasive content in a way that is always available but not disruptive to other activities with tailored information, and timely to the situation, so that the user reacts positively towards modifying activity behavior. A single test was conducted at PlaceLab, a living lab apartment to study and evaluate the ViTo system. The participant reacted positively to the design, including perceived ease of integration, ease of use, and adoption of the new TV control. Although there are still questions about the long-term impact of behavior modification techniques on the user’s daily life, the study with ViTo demonstrates the viability of integrating persuasive strategies into every-day devices.

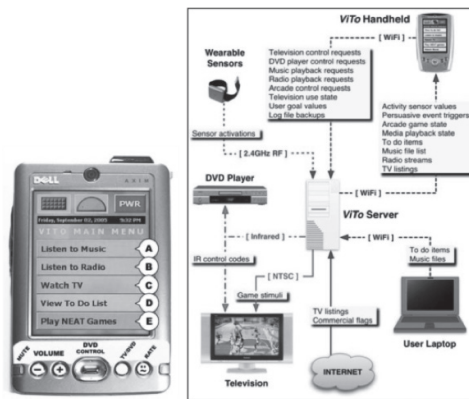


Figure 9. ViTo system (Nawyn, 2005).

UbiFit Garden

UbiFit (Consolvo et al., 2008) is a research prototype that aims to encourage physical activity engaging users with an awareness mobile display. The UbiFit System includes a fitness device, an interactive mobile phone application and a glanceable mobile feedback display. The fitness device uses a Mobile Sensing Platform (MSP; tri-axial accelerometer, barometer, humidity, visible and infrared light, temperature, microphone and compass) (Figure 11) to infer wider

physical activities in real time, such as walking, running or cycling. The data is sent via Bluetooth to a mobile phone, which presents the information of daily activity and goal progress on an interactive application. The key feature of this prototype is the use of a “glanceable” display on the screen background of the user’s mobile phone (Figure 10). This display uses a metaphor to motivate behavioral change, showing the user’s physical activity in a form of a garden that blooms throughout the week. Different butterflies of varying sizes are used to depict the goal attainment for the current week, while different types of flowers represent cardio training, resistance training, flexibility training and walking.

Based on a three-week field trial with users the UbiFit Garden was well received, in particular the glanceable display with the interactive garden. This study also showed the challenges of user’s acceptability for on-body activity sensing when incorporated into mobile devices or to be worn during daily life activities. The size, weight and placement of the device are issues to consider for further development. The authors emphasized that letting the users add, edit or delete inferred data is important to encourage physical activity. This can also improve the possible flaws with the system’s activity inference, which in turn increases the user’s credibility with the system. As a future work, it was recommended to allow the user to set one’s individual interests and adapt to changes in goals and abilities.



Figure 10. UbiFit Garden. The glanceable display shows user’s information in a form of a blooming garden. (Consolvo, et al, 2008).



Figure 11. UbiFit fitness device-the MSP. (Consolvo, et al, 2008).

Flowie

Flowie (Merino, et al., 2009) is a virtual coach to motivate elderly to walk more, and thus, improve their health status. The prototype consists of a pedometer with wireless connectivity with a touch-screen photo frame. The pedometer aims to measure the ambulatory level of the users. When the data is assessed, it is then displayed in a small touch screen photo-frame. The main objective of this prototype is to evaluate the acceptance of persuasive systems for elderly people. The prototype combines a set of persuasive principles adapted to the target group and the application. To engage users to modify behavior, the prototype uses an animated flower that changes its appearance according to the user’s performance (Figure 12). This metaphor aims to provide a more pleasurable abstract feedback for evoking curiosity and empathy with elderly users. Besides this, the graphical interface shows a general, day and week overview of user performance levels (Figure 13).

Figure 12. Left: Touch-screen display embedded in a wooden frame. Right: Flowie's different status. It provides user's progress, encouraging users to improve walking performance. (Merino, et al. 2009).

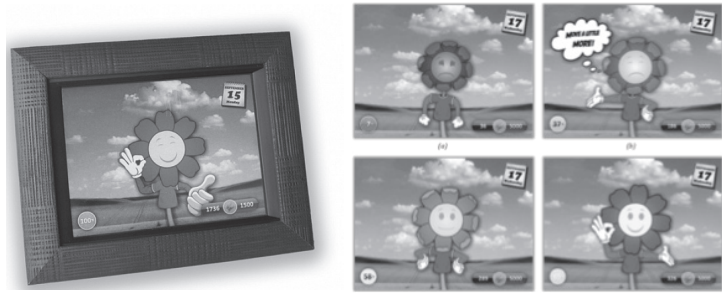
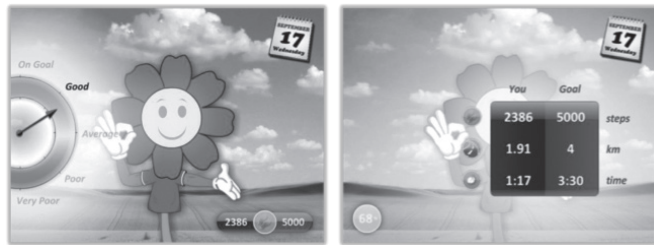


Figure 13. Flowie's Graphical User Interface. Progress status (left) and detailed information (right). (Merino, et al., 2009).



An 11-day evaluation plan was conducted with two senior participants. This study included a pre-intervention to define the baseline activity level, an intervention in which participants could monitor their activity by interacting with the Flowie, and a post-intervention to evaluate the acceptability of Flowie as a persuasive technology application. To do this evaluation, the Pervasive Technology Acceptance Model, PTAM (Connelly, 2007) was adopted.

In spite of the small scale of the test, the study showed a positive impact. The two participants viewed Flowie on a regular basis. They remarked that the system increased their as a motivation to walk more frequently. While the Graphical User Interface was able to show both numerical and graphical information, the participants appreciated Flowie as a constant stimulus to keep them on walking more. The success of the acceptability of Flowie relied on a close end-user involvement through the design process. The study also showed that the limited sensing capabilities of the prototype limited the provision of information surrounding the user such as the climatology or the fatigue caused by other activities. This factor can influence negatively the user's perception of Flowie, since it would encourage the user to walk more even when it is raining or in case of illness. For this reason, the authors recommended developing a more context-aware system to register and monitor the actual condition of the user and her environment, providing more accurate and tailored feedback. In short, the Flowie virtual coach appears to be a promising persuasive system to support elderly to increase physical activity.

Pavlok

Advertised as “the first wristband designed to actually change your habits, and not just measure what you already do (pavlok.com), Pavlok is a physical activity tracker device that coaches by providing mild electrical shocks if the user fails, for instance, to wake up on time or a fitness goal. In contrast to fitness bands such as Fitbit and Nike or Polar (polar.com) that are built around positive reinforcement, Pavlok uses negative reinforcement to form new habits. Users can set new goals and depending on the performance assessed by an accelerometer, they

receive from a text message, an electric “zap” or a small fee charged to the users’ bank account. Pavlok also uses positive reinforcement if users are successful in achieving their goals. They will receive, for instance, a small reward such as money or lottery tickets. It also involves social elements like Nike+ or Fitbit. It is possible to create teams so fitness partners can review if a specific goal was achieved or not, so that they can “zap” the user. Although Pavlok may not be a proper tracker for everyone, it looks as a promising device for those who require more coercion than support to form and modify habits.



Figure 14. Pavlok – A “habit-forming” wristband system (source: <http://pavlok.com>).

3.3 User Centered Design Methods (UCD)

Around 75% of the technological initiatives in healthcare fail during the operational phase after a pilot (Berg, 1999). Furthermore, according to the review by Broens et al., (2007), determinants of success depends in 29% of the cases on technical reasons for failure, as opposed to 37% of user acceptance as reason for failure. This review also shows that technology acceptance is influenced by the users’ attitude towards the technology. Thus by involving users in an early phase of development, technology can be fitted to their daily practice and environment of use (Brones et al., 2007, van Helvert and Fowler 2004). In developing a new system, one of the main difficulties is to identify and meet the user needs and consequently this is where systems can result in a failure. There is a tendency towards a technology-driven way of development, instead of user needs driven (De Rouck et al., 2008). As technology should not be a mere focus in the design process, needs of users should first be clear and form the onset for design (Esser and Goossens, 2009). An approach that goes into more detail and puts users in a center stage is the User-Centred Design (UCD). User-Centered Design takes the user as onset for design and involves them in the evaluation of design choices (Kinzie et al., 2002). It aims at improved communication between designers, engineers and users in order to enhance user acceptance and fewer failures in technological design (De Rouck et al., 2008).

An important goal of User-Centered Design is to overcome the translational gap between what users need and to actually design the technology (Sutcliffe, 2002). Two types of requirements can be distinguished: functional requirements and non-functional requirements. Functional requirements describe the functions of the system in terms of the input, behavior and output. Non-functional requirements, or quality requirements, specify criteria to judge the system and are not descriptive of the behavior for the system: they create boundaries set by the environment (e.g. users, context of use) and it is useful to define a design concept. Examples of non-functional requirements are security, reliability, privacy or usability (Gross and Yu, 2001). Requirements elicitation can be achieved by different techniques such as document reading, questionnaires, interviews, protocol analysis, video and audio transcripts, use cases and scenarios or observations (Cysneiros, 2002). The challenge is to proceed from individual,

fuzzy statements of needs to a formal specification that is understood and agreed upon by all stakeholders involved in the design process. However, stakeholders such as technicians and users all have their own vocabulary, complicating communication throughout the design process (Hagglund, 2010).

In the context of healthcare, Berg (1999) has defined healthcare work as a multidisciplinary environment of “disciplines, tools, ICT and routines in an environment of unpredictable events and distributed decision making”. Therefore Berg states that a sociotechnical approach for system development should consider the underlining interrelationship of social features and technical features of the system. The sociotechnical approach of Berg is merely a higher-level perspective of how to design systems for healthcare, but it does not give answers on how to involve users (Scandurra et al., 2008). A key question is thus, how can the design of ICT healthcare solutions assume a more user-centric approach?

3.4 Experience Sampling Method (ESM)

Experience Sampling Method (ESM) (Hektner, Schmidt and Czikszenmihalyi, 2007) has the ability to capture user experiences in-situ, i.e. in time and situation, and for extended period of times to elicit people’s feelings and emotional state. ESM takes advantage of the popularity of mobile devices to ask people for feedback at random times during the day. Via ESM participants can make a quick record close to the moment of interest, providing instant reports on momentary experiences instead of having to recall what they did in the past. The involvement of context-aware technologies in ESM opens the opportunity to automatize the capturing of context around participants’ self-reports (Barren and Barren, 2001; Consolvo et al., 2006; Intille et al., 2003). Furthermore, contextual information could help to adapt the timing and content of the prompts minimizing interruptions as well as tailoring the research questions according to what has been observed (Vastenburg and Romero, 2010). These characteristics allow the researcher to map the users’ experiences providing a closer view of people daily life over time (Vastenburg et al., 2008).

The downside of this method is that participants may perceive the prompts as too frequent and/or repetitive, which could result in undesired interruptions, burden and boredom negatively influencing the participants’ experience. One interesting way to overcome this drawback, is by providing participants visualizations of (part of) their reports which may result in a more positive experience as they become aware of personal situations that other wise would be difficult to envisage (Li 2009; Romero et al., 2013).

3.5 Personal Informatics (PI)

Personal Informatics (PI) is an emerging area in the field of Human-Computer Interaction that facilitates people to collect and visualize personal relevant information for the purpose of supporting self-reflection and action for behavioral change (Li, 2010). While ESM can assist researchers sampling users’ experiences, PI systems go further by supporting users and their behaviors.

3.5.1 Stage-Based Model of PI

The implementation of possible system solutions depend on the roles and applications they can have within a PI product. This is subjective to the structure of PI systems and is often visualized as an iterative, barrier cascading, model with five stages; preparation, collection, integration, reflection and action (Figure 15).

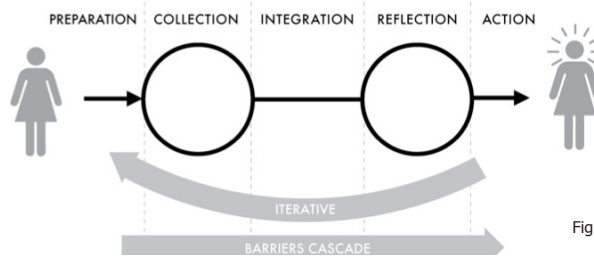


Figure 15. The staged-model of Personal Informatics (Li, 2010).

Preparation

The Preparation stage occurs before any personal data is collected. This stage concerns itself with determining what information will be recorded, how this will be recorded and people's motivation to collect personal information.

Collection

During the Collection stage the previously determined information is collected. This can be done automatically or manually, either way this is dependent on the (technical) properties and qualities of the system.

Integration

In the Integration the gathered data is prepared, combined, transformed and translated for the user to reflect on. The purpose of this information is to increase the self-awareness of the user after which they can reflect on their new knowledge. Because of this the manner in which this information is displayed greatly influences the whole PI system. This is an iterative process that flows through to all the phases of this system, but is most evident in the reflection and action stages.

Reflection

During the Reflection stage the user reflects on their personal information as it is given to them in the integration phase. This can be done by (re)viewing lists of collected personal information or by exploring and interacting with the information through visualizations or other solutions.

Action

The Action stage is where people decide what they are going to do with their newfound understanding of themselves. If the PI process is successful then the user will change their behavior/actions to some degree. If the user continues to use the PI product this will lead to new data being collected that restarts this iterative process.

Despite the importance of self-reflection in PI systems, most of the studies to date have been focused on supporting collection and representation of data with the implementation of new automated sensors, tools and attractive visualizations. In line with Pirzadeh et al., 2006 and Koldijk, 2011, the challenge in PI is the design of meaningful data towards in-depth self-awareness and self-reflection.

3.6 Conclusions

3.6.1 Need for a focus on patients' health experiences

In the clinical scenario, there is an existing lack of tools to remotely follow patients at home and to measure beyond the functional aspects of recovery, leading to an incomplete assessment of patients' health status and current progress. As a consequence, the lack of tools to follow patients generates a common atmosphere of misinformation and uncertainty. Monitoring patients' functional performance in post-surgery recovery and how patients experience recovery during this period is becoming an important element in the evaluation of THR after surgery to predict short-term outcomes (Wong, et al., 1999, Salmon, et al., 2001). There is an increasing body of research reporting that many diseases are related to psychosocial factors, in particular, the significant impact that individual experiences in daily life have on the recovery process play a key role [Salmon, et al., 2001, Yoshiuchi, et al., 2008, Myin-Germeys, et al., 2009]. However, most of the current methods to follow THR recovery focus on functional aspects with few studies exploring different aspects of recovery (Fielden, et al., 2003, Fortina, et al., 2005, Grant, et al., 2009). It is not well known how patients experience the recovery process and how they would experience the use of technology that supports their current situation.

Several considerations co-exist in the development and implementation of a supportive system for healthcare with the home as a main care environment instead of just the clinic. The implications of the aforementioned lack of tools to follow patients are the main reason of the lack of knowledge about the elements of patients' daily life, as well as the lack of practical tools to understand their situation and communicate this information to designers, developers and the medical community. This information can play an important role in developing a tailored system. From the point of view of engineers, as a system with deployment of sensor networks, several challenges arise, namely, managing collected data, ensuring reliability of observations, algorithmic design, and interoperability of architectural components. From the designers' perspective, the challenge is how to identify user requirements, create trust of technology, acceptability of technology, design usability and to create attractive and engaging systems.

3.6.2 The passive role of users in current solutions

Many of the systems to date that promote physical activity are based on using persuasive mechanisms to change user behavior. Vito and Ubit are examples of persuasive tools that provide positive reinforcement, capturing and assessing measurable behavior. Recent commercial products such as DirectLife, Nike+ Fuelband or Fitbit use a single sensing capability to monitor user's physical performance by means of pedometers or accelerometers. These examples use smartphone applications and web-support as engaging mechanisms, providing the user with attractive data visualization and social connectedness features by sharing personal achievements and progress online with other users. They provide guidance to measurable goals (e.g. calories or distance) with reminders, pokes and reinforcement feedback. On the other extreme of persuasive mechanisms, Pavlok involves the new trend of "getting things done" by forcing users to modify behavior by means of electric shocks. Users set a goal and the bracelet will coach you to achieve it. However, while those solutions make certain actions such as monitoring and assessing behavior simpler, they also take the opportunity from people to be more proactively engaged in understanding, reflecting and controlling behavior change. In other words, when these solutions are more focused on efficiency and they guide the user to specific goals, they are in turn reducing the responsibility and effort of users to learn and therefore appropriate a more sustainable behavior.

In line with Müller et al. (2012), there is a difference in user's involvement when the system tends to be more persuasive than reflective. With persuasive technology the data is analyzed by the system and displayed in complex visualizations (i.e. pie charts, histograms, bar or line graphs). As a consequence of deploying persuasive technology, a minimal degree of cognitive effort by the user is required to interpret the information in relation to achieving a specific target behavior. On the other hand, solutions that support a more reflective process demand a higher degree of user involvement and thus increased cognitive load. The way the system collects some of the data and how it is presented to the user leaves the interpretation to the user.

The clear specific goal provided by persuasive technology is replaced by the general goal of more awareness about own behavior (Müller et al. 2012). The challenge of reflective technology is to deal with a higher amount of data coming from different sources. Not only more data must be processed, but also more information should be translated and communicated to the user in a suitable manner. The integration of both objective data (e.g. physical performance) with subjective data (e.g. self-report information) has not been widely explored in home recovery systems. It is also possible to identify that simpler devices are easier to bring to the market due to the user's acceptability tends to be higher (e.g., FitBit), while complex ones stay as experimental prototypes. This reflects an open opportunity to develop solutions that support the user to follow a more reflective process and facilitate user adoption.

3.6.3 Reflective systems to support users

Examining the role of technology in supporting users becomes more and more important that the designer engages the user and his experiences in close settings such as the home or the office. Both ethical and social aspects need to be taken into account as every design intervention implies some change to existing routines and lifestyle. This choice comprises two main possible routes in the design of technology systems that refer to how much persuasive vs. reflective an application could be. A persuasive oriented system can reinforce, change or shape behaviors with persuasive principles, nudging people to specific goals. On the other hand, a reflective system facilitates users to learn more about themselves with meaningful information that can be explored. As examined by Munson (2012), this spectrum confronts two types of technology with different goals. On one side the technology that pushes people to do something without their knowledge and without having behavioral change as explicit goal; on the other side, the technology that supports people in gaining insights into their existing behavior and achieving the behavioral change they desire (Munson, 2012). The latter aims to have the user as an active element in the use of this technology. Reflective technology tends to be less system-driven, therefore the user has actions and control over the collection of data.

Persuasive technology is not a new domain in HCI. Fogg et. al., (2003) mention how persuasive systems were introduced in 1970s and 1980s with a handful of computing systems designed to motivate health behaviors and work productivity. Nowadays, with the advent of mobile technology, people are documenting more about their daily life and Personal Informatics systems (PI) are currently supporting the collection of this data. Although PI considers the process of reflection as its inherent concept, there are a limited number of studies that focus on the process of reflection in designing these systems (Pirzadeh et al., 2013).

Existing research efforts focus on combining different information sources for better understanding user activity and context (physical state and situation) (Consolvo et al. 2008, Li 2009a). However, few studies have been conducted to understand users' state and context in relation to situated support (Grönvall and Verdezoto 2013). Recently, we can see this effort in commercial products such as Nike+ that has started to shift the responsibility on users to re-

cord certain activities. FuelBand with Nike+ app (2013), started to involve self-reporting as a powerful mechanism to engage users and it is read like a major departure from the original design intention of a carefully streamlined user experience (Nike's new fuel SE highlights 2013). This shows a potential for using different sources of information in a complementary way to provide better detection of user state and context to generate right motivational feedback.

In short, looking into the existing technological approaches to health care, it would appear that the approaches are lacking a user centered focus whereby users are able to provide subjective feedback and reflect on their health process related to daily life practices. Although further research is needed to understand self-reporting as a source of meaningful information for the user, these new developments are opening a new channel to investigate how this information can be integrated with automated sensed data to trigger in-situ motivational feedback in relation with the user state and context. It might become a powerful self-reflection tool with a positive impact to the wellbeing of patients. The potential of this can be investigated by means of an integrated patient-centric approach that combines User Centered Design (UCD), Experience Sampling Method (ESM) and Personal Informatics (PI), providing instruments to address the challenges in developing a supportive tool for healthcare.

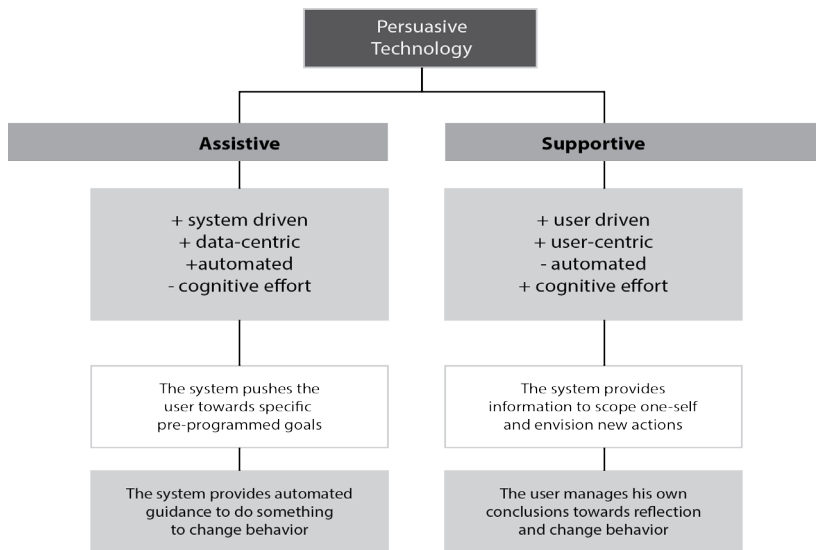


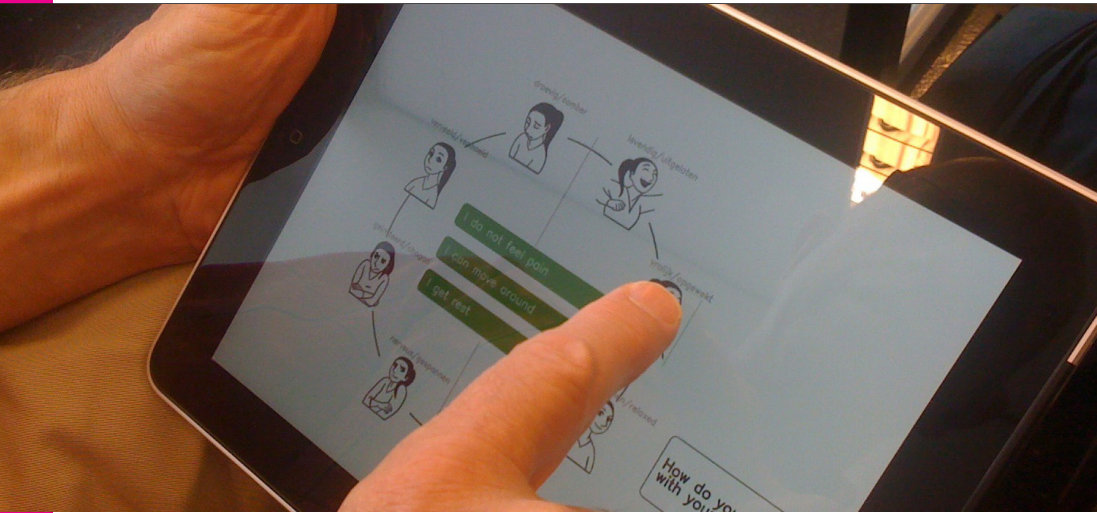
Figure 16. Both assistive and supportive systems pursue a change in behaviour. However, they use different strategies, face different challenges and encourage the user differently.

PART A

A HOLISTIC UNDERSTANDING OF THE USER IN
CONTEXT

4 INVESTIGATING SELF-REPORT WITH IN-SITU RESEARCH TOOLS:

Developing a home based research tool to capture patients experiences during recovery



The previous chapter unveiled how current pervasive healthcare solutions offer a more data-centric approach overlooking the opportunities that the collection of users' experiences provide to define systems that could be more supportive. With the lack of proper tools to explore and understand daily life experiences of users in context, it was concluded that an integrated user-centered approach is needed to identify users' requirements that go beyond the functional aspects of health.

This chapter therefore introduces the first stage towards an integrated user-centered approach. ESTHER, an Experience Sampling tool for Total Hip Replacement addresses the challenge to design tools that fit in the user's home context and recovery process. ESTHER is an in-situ ecological design research tool aims to capture an acute view of the life of THR patients during recovery at home. Based on a Design Inclusive Research framework, several iterations were developed to understand the effect of the tool in the recovery experience. In particular, this chapter presents the first iteration, ESTHER 1.0, how patients experienced it and its potential implications for medical use, physiotherapists' practices and users' motivations. The chapter concludes with the notion that mechanisms used by the ESM tool to capture users' inputs envision a system that could provide support for users reflecting on their own health experiences.

The following chapter is based upon the papers:

Jimenez Garcia, J.C, Romero N, and Keyson, D. (2011) Capturing patients' daily life experiences after Total Hip Replacement. In: 2011 5th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth) and Workshops, 23-26 May 2011, Dublin, Ireland. pp. 226-229. IEEE. ISBN 978-1-61284-767-2

Romero N, Jimenez Garcia, J.C and Keyson, D., Havinga P. (accepted, in revisions 2014) ESTHER 1.0: Experience Sampling Tool for Patients of Total Hip Replacement. in Journal of Ambient Intelligence and Smart Environments, JAISE

Jimenez Garcia J. (2012) Understanding Total Hip Replacement Recovery towards the Design of a Context-Aware System. In: Proceedings of the AmI 2011 Workshops -AmI 2011 Workshops, Constructing Ambient Intelligence book, Amsterdam, The Netherlands. pp. 313-317. November 16-18, 2011

4.1 Introduction

De Rouck et al. (2008) state that one of the main difficulties in developing a supportive system is to identify and meet the user needs. Consequently this is where systems can result in a failure: due to the technology driven way of development, instead of user needs driven. Acknowledging that the definition and implementation of a supportive system for a particular healthcare application entail both technological and usability challenges, issues regarding users' concerns and desires need to be taken into account in the early stages of the system development.

As a first step towards understanding the physical and mental implications of THR surgery and the determinants of the physical function recovery process, a study based on User Centered Design methods (UCD) was conducted (Jimenez et al., 2010). Several UCD methods with stakeholders in small groups and individual sessions, involving engineers, designers, physiotherapists and patients were conducted. The study showed the value of using workshops, scenarios, and individual interviews to uncover different aspects of the recovery procedure. One of the main findings describes the recovery process as a journey in which both functional and emotional aspects are inter-related as they change over time. The THR recovery process implies several stages in which mobility, general health, independency, pain, family, friends, and emotions are involved (Jimenez Garcia et al., 2010). Although this study provided general insights to define functional and non-functional characteristics of a supportive system, the study also revealed the shortcomings of UCD methods in examining in detail the complexity of the recovery process, experiences of patients overtime in a home setting (Jimenez Garcia et al., 2010).

The lack of adequate methods to follow patients during their recovery and to predict outcomes for individual cases, opens the challenge for the design of a homecare system that effectively addresses patients' demands and optimizes medical resources. Therefore, ESTHER (Experience Sampling for Total Hip Replacement) a context and emotional aware system for patients and clinicians in the home recovery of pathophysiology and psychopathology conditions. It aims to be: 1) reflective, enabling meaningful information to activate patients' awareness about the course of their recovery and to help them to cope with the dynamic changes of the recovery; 2) supportive, personalizing and optimizing the quality of communication between the patient and the physiotherapist; and 3) predictive, helping clinicians to get new insights about psychosocial and physical outcomes of THR, complementing the information given by standardized methods. With ESTHER it is acknowledged the need to implement Ambient Intelligence technologies that are defined by their context-aware ability to address users' needs, desires and emotions in particular situations (Alves Lino J. et al., 2010) It aims to recognize and respond to users' preferences and the complexity of their situation (Augusto, 2010) thus implementing a holistic system that addresses the functional as well as psychological, social and emotional needs of THR patients at home. Therefore the success to implement ESTHER requires to first understand the complexity of patients situation during their recovery.

This chapter presents ESTHER 1.0, the first stage of ESTHER development that focuses on the implementation and validation of an ecological research tool based on Experience Sampling Method (ESM) (Hektner et al., 2007) with the purpose to gain information around the patients' recovery by patients themselves who are experiencing such recovery. ESTHER 1.0 aims to provide a description of the situation of the patient, the changes of determinant factors throughout the recovery period, and the influences of issues related to patients' emotional transition and needs over time. With ESTHER 1.0 it is expected to contribute to the design of ESTHER with requirements that go beyond the architectural components of sensing technologies and such. This work expands the limited methods researchers and clinicians have to investigate the daily living of THR patients in their home environment.

An overview of current clinical efforts to assess recovery, and the risen opportunities to apply ESM in this domain is first presented. Then, the design of the proposed tool and its

functional characteristics are described. Next, results of field studies with four THR patients are presented to validate the descriptive feature of ESTHER 1.0. Based on the gained insights, this chapter ends with a discussion around how this research tool leads to the development of ESTHER providing user requirement knowledge for the design of a reflective, supportive and predictive system for patients, physiotherapists and clinicians to include the complexity of daily life practices around home recovery process.

4.2 Research opportunities with Experience Sampling Method

Experience sampling method (ESM), a research methodology developed by Larson and Csikszentmihalyi (1993), was designed to capture user experiences in the field. Initially ESM took advantage of the popularity of earlier mobile devices (e.g. pagers) to ask people for feedback at random times during the day. This configuration aimed to reduce problems that participants might have recalling events, a problem underlying many self-report techniques. With ESM participants make a quick record close to the moment of interest, rather than having to recall what they did in the past. Using current portable and context-aware technologies, latest ESM developments have been envisioned to approach individuals at opportune moments by triggering relevant questions related to a recent event (Vastenburg and Romero, 2010). ESM is increasingly used in behavioural and social studies for the recollection of experiences related to a particular moment in time or a recent event by means of regular self-report entries (Yoshiuchi et al., 2008; Myin-Germeys et al., 2009; Hachizuca et al., 2010; Smyth and Stone, 2003; Groot, 2010; French, 2010; Wichers, et al 2011). Groot (2010) provides a good example on how an ESM tool helped patients to self-assess and recover from a psychological condition by having their own reports at hand. The feedback on participants' inputs and daily life situations helps them to be aware about the subtle variations in behavior over time that can otherwise be overlooked (Wichers, et al 2011).

There are important considerations in the design of ESM studies. As noted by Myin-Germeys (2010) and Scollon, C. et. al (2003), ESM designs should take care of the frequency and time-demanding effort of participants to self-report. On the long term, participants often lose motivation to provide information every time they receive a prompt. Therefore, adaptive sampling rates needs to be designed to avoid annoying interruptions (Vastenburg and Romero, 2010). In addition, engaging strategies such as empathy techniques, self-reflection, etc. could motivate people to self-report.

Table 1 summarizes the characteristics of the three types of measurements (Section 3.1.1). The table classifies the measurements in relation to the sensitivity, longitudinal and granularity to collect information over the recovery process illustrating the current problems of standardized measurements. ESTHER 1.0 bridges this gap by providing information that is sensitive to individual cases, longitudinal to measure changes over time and granular to capture daily nuances during the recovery.

4.3 ESTHER 1.0: Goal and scope

The goal of ESTHER 1.0 is to implement in-situ data collection to capture contextual and experiential variables by patients during their home recovery process. The tool aims to answer the following questions: “what are the experiences of being a THR patient?” and “what are the moods present during this process and what activities are related to them?” This approach will allow prompting concrete questions to patients, investigating their affective states and how they fluctuate and change over time in response to certain situations, something that has not been investigated by traditional methods.

Table 1. Overview of three types of measurements for Total Hip Replacement.

	Patients' assessment of won physical function [WOMAC, SF-36, Oxford Hip Score]	Physiotherapists' observed performance [6MWT, TUG]	Patients' momentary assessment in natural settings [ESM]
Sensitivity: ability to research individual and group effects	Group effects	Group effects	Individual effects
Longitudinal: ability to measure variation over time	Snap-shots prior and after surgery	Snap-shots prior and after surgery	Dynamic intervals of samples overtime
Granularity: ability to detect small changes along the recovery process	Collect functional attributes of the recovery from self-reports over past events	Collect isolated functional attributes of the recovery from single observations	Capture experiential attributes from self-reports over recent events

4.3.1 Description

ESTHER 1.0 provided a fixed interval sampling protocol (see Table 2). The protocol divides the day in 4 recognizable moments: 1) after waking up, 2) right before/after lunch, 3) tea time, and 4) before going to bed. The participants can define a priori the hour around each prompt may occur (e.g. 9, 13, 17, 21). The prompts are then triggered in a ± 30 minutes vicinity of each scheduled hour, minimizing anticipation and therefore undesired influence of the experiences under investigation. In each prompt, an open question is presented 'How are you doing?' (see screens 1 and 2 in Figure 19). The open question is followed by an open/close question that provides a mood diagram (Vastenburger et al., 2011) asking participants to position themselves in the diagram (choosing one or two moods) and to explain their choice (see screens 3 - 4 - 5 in Figure 19).

Table 2. ESTHER 1.0: ESM design features. Based on Conner et al., 2003.

	ESTHER 1.0
Type of control	Interval-contingent protocol (fixed)
Sample period	15 days
Self-reporting platform	Tablet
Data transfer	Transferred to a server
Probing request rate	4 prompts a day
Probing rate time set-up	Defined by each patient

ESTHER 1.0 is targeted to older adults, therefore the design aims to guide the user through these questions in a friendly and familiar way in order to unveil their current mood and relate them to daily life situations. This is achieved by designing a step-by-step interactive questionnaire embedded in a touch-screen device (a tablet). The tool enables a simple input data collection by providing intuitive ways to interact with the questions.

When looking for an easy-to-use way to select specific emotions, the Pictorial Mood Reporting Instrument, PMRI, (see Fig. 18a) (Vastenburger et al., 2011) was chosen, a mood capturing technique that offers a pictorial representation of the Circumplex Model of Affect (Posner et al., 2005) that represents a circular distribution of emotions in two dimensions: arousal and valence.



The design of ESTHER 1.0 was informed by focus groups testing earlier concepts of the tool with a panel of THR patients (Figure 17) (Jimenez et al., 2011). The final set of screens and graphical elements can be seen in Figure 19. To provide a friendly identity to the tool and achieve empathy with the target group, an avatar was designed based on the mood character of PMRI. Seeking for consistency (see Figure 18), permission was asked to the developers of PMRI to design the ESTHER avatar with a similar look that the characters used in PMRI. The avatar is a female personification that welcomes the patient at the initial screen of the prompt, closes the prompt with a grateful greeting at the end (see Fig. 18b) and hosts the patient through out the different questions (see Figure 18c) in a friendly way. This female character is assumed to be familiar to the patient, improving their participation; for instance, she might remind a nurse or a physiotherapist. It also aims to give a stronger sense of being “heard” by someone, adding some human aspect to the tablet. In order to make stronger this feeling of being heard by and provide a “communication window” an idle state was implemented to allow participants to tell whatever they want to say at any time (outside the prompts intervals), whether regarding their daily life, or something they want to ask.

Several graphical elements were included to reinforce the presence of the avatar in the application. In order to reach familiarity for an older population, a coloured dialogue box using a palette of brown-orange colours was designed to connote a more subtle classical style. Finally, voice recording was implemented as an optional alternative to typing the answers (see screens a and b in Figure 19), allowing patients to share their thoughts and experiences in a spoken way if desired.

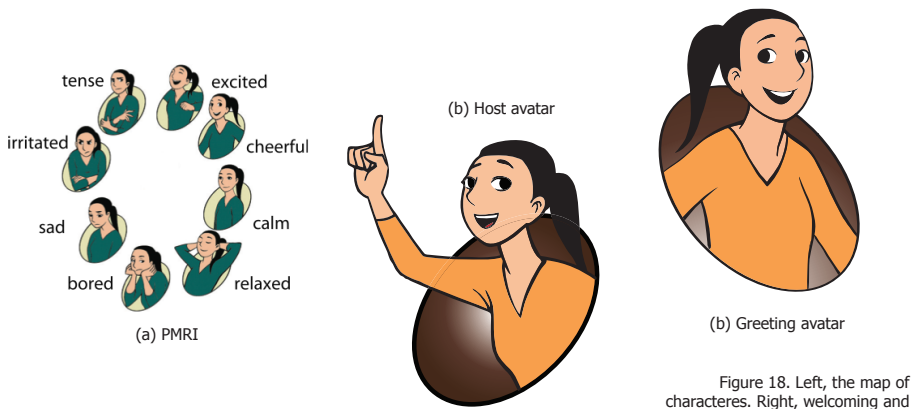


Figure 18. Left, the map of characters. Right, welcoming and asking question characters.

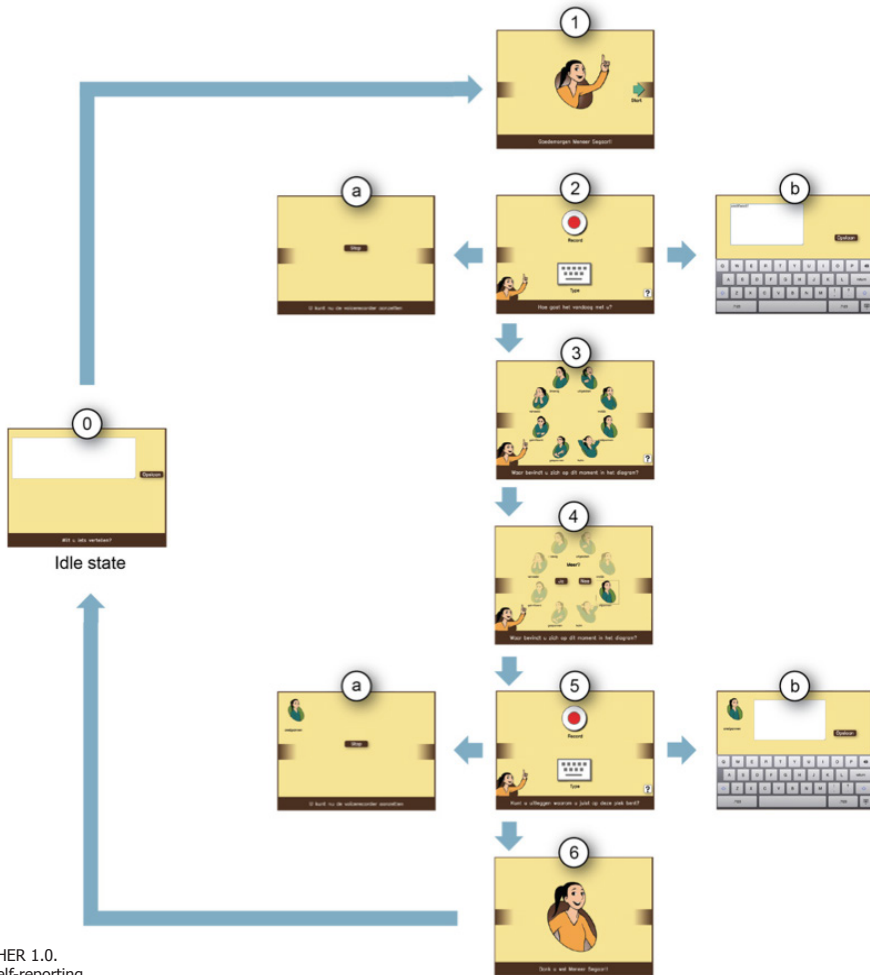


Figure 19. ESTHER 1.0. Screenshots. Self-reporting flow chart.

4.4 Case studies

The aim of the studies was to analyze the sensitivity, longitudinal and granularity features of ESTHER 1.0: is the tool sensitive to capture subjective differences? is the tool able to capture changes over time? and is the granularity of the tool sensible to capture daily based experiences? A coding scheme was developed to describe the data collected by ESTHER 1.0 and provide evidence of its relevance to inform patients and physicians over the recovery process.

Towards the assessment of ESTHER 1.0 as a tool to collect in-situ data from patients' self-reports during the first weeks of recovery, participants' motivation to self-report was assessed. Questions regarding prompting (frequency, timing, relevance and effort), motivation/benefit (sharing, recovery, awareness), and preferences (interaction, visualization and control) were investigated. The resulted data was coded and analyzed.

4.4.1 Data Collection and Methods

Three data collection techniques were used: ESM reports (timing and content of prompts/responses/self-reports), exit interviews, and informal feedback (phone calls, researcher visits, open self-reports). ESM reports were qualitatively analyzed. Qualitatively, a coding scheme was developed (see Table 3) and used to describe the sensitivity, longitudinal and granularity of the self-reported data. In addition to response rate, average lengths of the reports, and time between prompts and responses were quantified.

The unit of coding analysis was each self-report input by participant in response to the prompts sent by ESTHER 1.3, plus the self-reports that participants sent at random times. A unit was composed by a timestamp and two responses: a text response to the first open question and the selection of one or two moods and a text response to the second question. Each unit was analyzed by coding both text responses using the coding scheme. The resulted description was then linked to the reported moods.

4.4.2 Participants and Protocol

In a period of one year, seven THR patients (4 male, 3 female) that were contacted through the Department of Orthopedics, Reinier de Graaf Hospital in Delft, The Netherlands agreed to use the self-report tool during the first two weeks right after discharge. The recruitment procedure started with the last meeting before surgery where the nurse in charge introduced the study and asked the patient if they were willing to participate in the study. If a positive answer was given, an introduction meeting with the researcher was scheduled before the operation at the nurse's practice to introduce the details of the study and its objectives.

During the study two patients stopped their participation in the study since they experienced severe post-surgery complications. A third patient received a surgery cancelation. Therefore the study involved 4 volunteers (1 female) which completed the 2 weeks period: Mr. Smith, 67 years old and without severe medical history, is living with his wife; Mrs. Rose, 68 years old and living with her husband, had a breast cancer surgery two years ago; Mr. Steve, 56 years old without any medical complication and living with his wife; and Mr. Jack, 52 years old also living with his wife in good health. Visits and interviews were conducted with the participant and their partners, to gain insights from the experiences as a patient and as a partner supporting the process. In the first meeting with the researcher a second visit was scheduled on their first or second day back home to introduce the tool and setup the prompting protocol according to the participants' time preferences. An interactive demo is used to train participants how to self-report. Practicalities about the device, such as battery charging and portability were also instructed.

4.5 Results

The total amount of self-reporting days slightly varied between participants. It was expected that all participants would complete 15 days of study (corresponding to the first two weeks of their recovery). Due to technical failures, the connection with the server failed during Mrs. Rose's and Mr. Steve's second week, which resulted in 54 days instead of 60 days of total data logging. Mrs. Rose still used the system during the second week but the data was not stored and sent to the server. Mr. Steve used the system for 21 days to complement missing data collection days. Technical issues also affected a constant number of four prompts/day in Mr. Steve and Mr. Jack cases. The results presented in this section show the full data collected. For the analysis, only the first 8 days of all participants were coded, to perform cross-case analysis.

Mr. Smith received a total of 60 prompts (4 per day, 15 days), with a total re-sponse rate of 95% (100% midday and evening, 93% afternoon, and 87% morning). Mrs. Rose received a total of 36 prompts (4 per day, 9 days), with a total response rate of 78% (89% midday and afternoon, 78% morning, 56% evening). Mr. Steve received a total of 55 prompts (avg. 2.6 per day in 21 days) with a total response rate of 65% (81% in the morning, 76% midday, 48% afternoon and 57% evening). Mr. Jack received a total of 32 prompts (2.1 per day in 15 days), with a total response rate of 53% (47% morning, 47% midday, 67% afternoon and 53% evening).

Participants Mr. Smith and Mrs. Rose did not use the optional self-reporting (without prompting) with the exception of one case when Mrs. Rose knew she had missed a prompt and wanted to provide her response later. On the other hand, Mr. Steve and Mr. Jack used this option more often with 21 and 18 inputs correspondingly. Regarding mood reports, Mr. Smith reported a total of 56 moods in the 15 days of full reports, 5 of them were combination of two moods. The reported moods were 95% positive (34 relaxed, 18 calm, 1 happy). Negative moods were annoyed (2) and bored (1). The 5 composed moods corresponded to positive moods such as relaxed and calm, and happy and relaxed. Mrs. Rose reported 28 moods in the 8 days of full reports, with 1 combination of two moods. From the total responses 82% were positive moods (10 calm, 9 relaxed, 4 happy). Negative moods were stressed (2), annoyed (2) and bored (1). Mr. Steve reported a total of 91 moods in the 21 days of the study, with 38 of them in combination of two moods. Reported moods were 97% positive (46 calm, 39 relax, 5 happy) with tense (1) moods as negative reports. Mr. Jack reported a total of 48 moods during the 15 days of study, with 17 reports with combined moods. The collected moods were 99% positive (19 relax, 15, happy, 9 calm, 4 excited) and only 1 bored mood as a negative report.

Hip Function	Psychological	Social	Context	General Health
[PN] Pain [MO] Mobility [RT] Rest	[WoC] Ways of Coping [RS] Resources [RC] Recovery [DP] Dependence	[SL] Social Life [SR] Social Roles	[AT] Atmosphere	[BD] Body

Table 3. Coding scheme for self-report data.

4.5.1 Coding Scheme validation

The development of the coding scheme consisted of two phases: first two coders iterated together defining the coding scheme; the resulted coding scheme was validated with a third coder where agreements and disagreements were discussed resulting in the final coding scheme (see Table 3). The first three dimensions in the coding scheme represent what have been found in literature about the determinants of THR recovery (Grant et al., 2009, Montin et al., 2002) covering three main areas that are directly related to the recovery: functional, psychological and social aspects. The final scheme added two extra dimensions to the ones identified from literature. They describe external factors that also have an effect during recovery. Context describes the atmosphere at home of the patient commonly triggered by an external event (e.g. a car trip, a sunny day, bad news) which may affect their state of mood for that day. General Health refers to the general physical state of the patient, which is not particularly related to the hip function, but relate to the patient's recovery process (e.g. swallowed legs, bruises, muscle aches).

A unit of analysis could be coded with one or more codes depending on the nuances in one response. Therefore, when necessary a unit was divided in sub units assigning only one code to each. Each code was also signed as positive or negative to identify its effect on the recovery (e.g. a positive pain describes a report that informs less pain).

In total 113 units of analysis were coded, which represented the first 8 days of re-recovery of all four participants (31 reports of Mr. Smith, 27 reports of Mrs. Rose, 29 reports from Mr. Steve and 26 reports from Mr. Jack). Table 4 shows the percentages of the total reports per case where each code was used as a descriptor (positive and negative). The orange cells in the table highlight the differences between codes as descriptors, while the purple cells represent the differences between positive and negative descriptions. A light blue row or cell illustrates the absence of that code as a descriptor.

All five dimensions of hip recovery were represented in the descriptions of the total set of reports: hip function 93%, psychological 83% social 34% context 6% and general health 84% (see Table 4). The sensitivity of the codes was observed in two ways: the representativeness of the codes to describe the different cases, and the variation of valence (positive and negative) between cases.

			Hip Function 93%			Psychological 83%			Social 34%		ContX 6%	Gral H 84%	
			PN	MO	RT	WOC	RS	RC	DP	SL	SR	AT	BD
Mrs. Rose	27 units	Positives	0.0	14.8	11.1	14.8		48.1	14.8	22.2	14.8	0.0	11.1
		Negatives	0.0	0.0	22.2	0.0		18.5	7.4	0.0	3.7	0.0	7.4
		Total	0.0	14.8	33.3	14.8		66.7	22.2	22.2	18.5	0.0	18.5
Mr. Smith	31 units	Positives	9.7	9.7	3.2	6.5		41.9	0.0	6.5	0.0	6.5	25.8
		Negatives	12.9	3.2	22.6	0.0		12.9	0.0	0.0	0.0	0.0	32.3
		Total	22.6	12.9	25.8	6.5		54.8	0.0	6.5	0.0	6.5	58.1
Mr. Steve	29 units	Positives	17.2	13.8	0.0	6.9		82.8	13.8	10.3	6.9	0.0	0.0
		Negatives	0.0	37.9	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0
		Total	17.2	51.7	0.0	6.9		82.8	13.8	10.3	6.9	0.0	0.0
Mr. Jack	26 units	Positives	0.0	53.8	26.9	3.8		61.5	0.0	3.8	0.0	0.0	7.7
		Negatives	11.5	7.7	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0
		Total	11.5	61.5	26.9	3.8		61.5	0.0	3.8	0.0	0.0	7.7

* Note: all percentages shown are not absolute; one unit of analysis can have more than one code. The <purple> boxes represent the difference in valence of the codes between cases; the <orange> boxes represent the difference in total representation of the codes between the cases.

Table 4. Code descriptors per case.

Representativeness

Two codes did not show major differences in representativeness. Resources [RS] was not present in any of the cases while Recovery [RC] showed to be a general descriptor of the recovery process, both factors from the Psychological dimension. Two other codes represent one case remarkably different than the others: Rest [RT] and Atmosphere [AT] describe one participant very different than the others (Mr. Steve and Mr. Smith respectively). The rest of the codes provide a strong descriptive power to differentiate between cases. Mrs. Rose's recovery was uniquely described by Dependency [DP], Social Life [SL], and Social Roles [SR]. Mr. Smith's recovery was uniquely described by Pain [PN], Atmosphere [AT] and Body [CD]. Mr. Steve was uniquely described by Mobility [MO] and Recovery [RC]. Finally, Mr. Jack was primarily described by Mobility [MO]. Comparing between patients, Mobility [MO] was a strong

descriptor of Mr. Steve and Mr. Jack's recovery than Mrs. Rose and Mr. Smith's. Similarly, Dependence [DP] was no descriptor for Mr. Smith and Mr. Jack but somehow important for Mr. Steve and relatively more important for Mrs. Rose. Both Social descriptors (Social Life [SL] and Social Role [SR]) are relatively important descriptors for Mrs. Rose than for the other patients. Body [BD] was relatively a strong descriptor for Mr. Smith's recovery than for the other patients.

Valence

All codes from Hip Function, Recovery and Dependence from Psychological dimension and Body from General Health, presented relevant variance in the code's valence between patients. While Mr. Smith reported relatively equal positive and negative Pain related reports, Mr. Steve only reported positive ones and Mr. Jack only negative ones. Mobility [MO] described primarily positive reports except with Mr. Steve where the majority was negative. Regarding Rest [RT] Mr. Smith and Mr. Jack 's recovery are described quite opposite: with Mr. Smith, Rest's reports been primarily negative while Mr. Jack only positive. Similarly, Recovery [RC] was only positive for Mr. Steve and Mr. Jack, as well as Dependence [DP] been only positive for Mr. Steve. Finally, Body [BD] been majority positive for patients, was the opposite for Mr. Smith.

4.5.2 Self-reports Analysis

The description obtained by the coding analysis addresses the quality and relevance of the self-reports obtained by the ESM tool. They have been categorized in the following qualities.

Strong psychological and hip function representation

The coding shows that participants' reports were strongly focused on psychological and hip function issues. Within the Psychological dimension Recovery (RC) represented most of the reports for all cases (67%, 55%, 82% and 61%). Interestingly, Resources (RS) was not observed in any of the reports during the first eight days of recovery. Although Ways of Coping (WO) was not strong across the participants, it was reported always as a positive factor of recovery. A possible explanation is that participants were able to find solutions to negative issues during the recovery process, e.g.:

- *"Calm, but I am going to return to the hospital again for a check of the wound and leg. Blood pressure is still low 105/79, temperature 37,4" [Mr. Smith]*

The Hip Function dimension also showed to be a strong descriptor during recovery. Not surprisingly, as the surgery directly affects patients' ability to move and rest (mostly sleep). Therefore Mobility (MO) and Rest (RT) were highly presented in all cases. These findings show that patients' general concerns were around these two dimensions. Participants provided information about their attitudes towards their recovery as well as their perception on their recovery progress.

- *"I'm fine", "The feeling is slowly getting better" [Mr. Smith]*
- *"I am still limited in my movement but it's getting better and better" [Mr. Steve]*
- *"Making good progress but taking it slow and getting better with baby steps" [Mr. Jack].*
- *"A bad start, I didn't sleep very well" [Ms. Rose]*

Weak context and social representation

Context was low in all cases. During the first eight days it was observed that few external events were reported as influencing the atmosphere at home in relation to the patient's recovery. Only Mr. Smith reported good experiences related to the context, e.g.

- *"We had to go the hospital several times to check the wound. I felt calm later when I was at home, it was warm"* [Mrs. Smith]

Within the social dimension, social roles also showed a low representation in most cases, which relates to the fact that patients reported a somewhat comfortable relation with their partners, although Mrs. Rose reported relatively more issues concerning social roles, e.g.

- *"Sometimes I'm a bit annoyed because I need a lot of help from my partner and I see he's getting slowly tired"* [Mrs. Rose]

Interesting, a relation is observed between Social roles (SR) and Social life (SL) where external events such as social visits are reported as a positive influence in their recovery:

- *"My daughter doesn't live near and I don't see her often, so it's a party. And of course a little help"* [Mr. Rose].

- *"The pain was bearable. The friends who were visiting really made my day"* [Mr. Steve].

Subjective sensitiveness in all dimensions

Factors in all dimensions were able to differentiate subjective nuances across cases. Been Recovery [RC] the most prominent factor it did not contribute much to describe differences among cases. As described in the validation of the coding scheme (see section 3.4) different factors were predominant to describe the recovery of the different patients involved. For example, Body was primarily observed in Mr. Smith's reports, e.g.:

- *"I was not ok. My leg was thick. We went to the hospital. Internal bleeding"* [Mr. Smith].

While Social Life [Sl] and Social Roles [Sr] were primarily observed in Mrs. Rose's reports:

- *"Good. I can get out of bed on my own. It feels good" "As I said, the attention is not bad, but the feeling of not being able to do my own things is not easy. Not for me"* [Mrs. Rose]

For Mr. Steve, Recovery [RC] was remarkable more observed between the codes, e.g.:

- *"I am getting very happy because of the course of recovery; making good progress but taking it slow and getting better with baby steps"* [Mr. Steve].

In the case of Mr. Jack Mobility [Mo] was the mostly observed, e.g.:

- *"The immobility is less than yesterday. Getting up is difficult but that is not special. Muscle sore is still a lot but bearable. Feel great"* [Mr. Jack].

These descriptions showed that participants focused on different problems depending on what is important for them. Mrs. Rose and Mr. Steve reported generally more experiences related to social aspects (40% and 17% correspondingly) than Mr. Smith and Mr. Jack (6% and

4% correspondingly), which reflected that social roles and the importance of social contacts can affect some people more than others. The medical background of Mrs. Rose (a history of cancer) showed that she was more cautious and able to resist pain as well as more patient and positive towards small improvements. This is reflected in the absence of Pain factor in her reports.

On the contrary, Mr. Smith and Mr. Jack's self-confidence were evident in their reports referring to the frustration towards general health problems or when they felt that the progress was apparently decreasing and the doctor suggested them to slow down the recovery. The excess of self-confidence in Mr. Smith and Mr. Jack was explained by the relatively more negative Pain reports (13% and 11% correspondingly) compared to Mrs. Rose and Mr. Steve (0% and 0% correspondingly). Interviews confirmed as well their attitude (e.g. Mr. Smith's wife reported that nurses had to limit his self-confidence to avoid potential problems of dislocation). Mrs. Rose reported more negative general health issues (7%) than Mr. Jack (0%), she knew better how to proceed with a higher representation of Way of Coping (15% and 4% correspondingly).

Been able to describe (and visualize) these situations on time could be used to "raise a flag" keeping patients from overdoing and maintaining them informed about a good-normal course of recovery.

Relation between moods and text reports

Figure 20 illustrates how the positive-negative valence of the text reports relate to the mood reports over time. In the following four figures, text reports are colour coded as green for positive and red for negative. Moods reports are colour coded as following: light blue=calm, yellow=happy, green=relaxed, grey=bored, light pink=annoyed and dark pink=stressed.

Negative moods were only reported in the first half of the week by Mrs. Rose, Mr. Smith and Mr. Steve, which reflects participants' state of annoyance and stress right after the operation, e.g.:

- *"It's not going very well. Leg is swollen, warm and red. At 11 o'clock we've been to the emergency ward at the hospital and we just came home. Probably an internal bleeding..."* - Annoyed [Mr. Smith]
- *"I sleep rather badly and I'm worried for the night to come"* - Stressed [Mrs. Rose]
- *"Like everyday I am here because I am not able to go anywhere else"* - Bored [Mrs. Steve].

In the case of Mr. Jack his apparent self-confidence at the first half of the recovery made him experience negative recovery situations in the second half, which was also observed by his reported mood:

- *"... Sleeping is difficult. I think because I am less active than before the operation. I have to find something about that. - Annoyed [Mr. Jack]*

Positive moods were predominant in the second half of the week, primarily represented by a relaxed state and first signs of feeling happy, reflecting that the participants became less anxious and that the recovery began to bring them concrete benefits, such as being able to walk. Below quotes of the text reports linked to the first time a happy mood:

- *"It's getting better. Just took a walk outside."* Happy [Mr. Smith]
- *"It's going very well. A fine afternoon."* Happy [Mrs. Rose]
- *"Walking gets better and the pain is also minimal."* Relaxed [Mr. Steve]

- "Great. Slept well and did the exercises..." Relaxed [Mr. Jack]

High arousal of moods was rarely observed, and always related to an out of the ordinary event. For example, the positive exciting moods reported by Mr. Jack early after discharge, was linked to a later report that he had done high physical activity (long distance walking sessions) too early in his recovery process leading to a swollen and leaking wound in day 4.

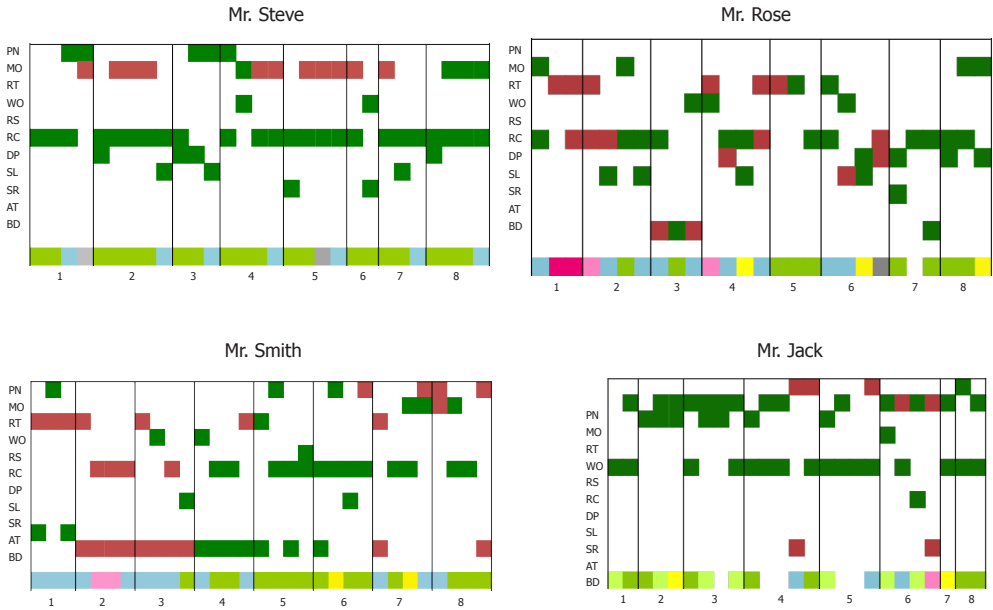


Figure 20. Participants' time line of texts and mood reports.

4.5.3 Interviews Analysis

A semi-structured interview was designed addressing aspects about the overall user experience of the tool, usability issues related to the prompting protocol, motivation and benefits of the tool, as well as its future applications. The interviews were audio recorded with the authorization of the participants. In total 71 minutes of audio were transcribed and translated to English. A coding analysis based on the predefined questions was used.

Easy to use and sympathetic tool

Participants quickly adopted the tool in their daily activities (see Figure 21); hardly missed a notification and the reporting task was perceived as simple and doable. Notifications were perceived as not intrusive. However, after they became more mobile outside their homes they felt the pressure to not miss notifications and respond to all the reminders on time.

- "And I never had a problem that I forgot it. I got used to it. The first week there was always something to tell. So it was enjoyable... The tool's daily scheme is so easy. You know it's coming at certain times.... next [third] week I will be more outgoing, so it will be more difficult... if it is necessary you can take it with you. But then it feels more compulsory" [Mrs. Rose]



Figure 21. Mrs. Rose using ESTHER 1.0 in her rollator.

- *“The first time I wrote you I was wondering how it worked, but after one day, it’s easy. So at the end you know what is coming” [Mr. Smith]*
- *“It was easy to use I think I have reacted to 90% of the questions. The 10% left is because I wasn’t at home, the iPad it is too big you didn’t take it [Mr. Steve]*
- *“Yeah it’s too big to carry. Then a smartphone is much easier [Mr. Jack]*

The interaction with the tool felt comfortable. Mr. Smith, Mrs. Rose and Mr. Jack considered the tool as an entity they share their reports with. None of the participants, however, did use voice recording as an input modality for their reports. They felt awkward to talk to a machine that does not reply them back.

Both Mrs. Rose and Mr. Steve expressed that writing was more valuable than voice recording, as it worked as a practice to reflect on and helped them to later remember about certain situations they wrote about. Mr. Smith preferred that his wife type the answers, as she was faster and more used to technologies.

- *“Sharing with the device was no problem. It is something of today....People are communicating with a lot of machines; youtube, voicemails. It’s something that happens in modern life” [Mrs. Rose].*
- *“I enjoyed typing. I could also delete what I typed. Talking is more direct. You can’t correct it afterwards. If you talk in a machine and there is no response, it’s not so nice. If typing you can reflect on it if you can read it back. You can see what you are doing” [Mrs. Rose]*
- *“I don’t like it [voice recording]. When there is a voicemail on the phone, I don’t like to speak. I like to speak face to face, but not without feedback” [Mr. Smith]*
- *“... with texting you can think what you will do. When you have someone on the phone you can say things that you didn’t want to say (referring about recording voice option)” [Mr. Steve].*

In addition Mr. Smith and Mrs. Rose reported feeling welcome when seeing the female avatar greeting them every time.

- *“I liked the greet from the girl on the iPad” [Mr. Smith]* *“I was in bath and I put the iPad over here and someone was telling me ‘good morning’ and asking how I was doing. That’s fun and nice” [Mrs. Rose]*

Positive user experience: value and effort

Participants reported a general positive experience with ESTHER 1.0. Participant’s first impression of the tool is that it did not have a direct value in helping them improving their physical recovery process. Though unexpected by the researchers, this insight showed the critical importance of patients to get help on this matter. However participants reported the action of self-reporting as a meaningful activity that triggered reflection and helped them in becoming more aware of their progress. Considering self-reporting as the main asset of the tool, participants stated that the tool could be more valuable for patients that live alone as it

would be more difficult to undergo a healing process alone, and they could tell others about their success and concerns on a daily basis.

- *"You always tell what you feel [to the tool] and it was no problem, but I don't think by answering the questions you improve the health" [Mr. Smith]*

"... I have a lot of people around me, so it's not so necessary for me I think. But if you don't have many people around you it [the tool] can be good" [Mrs. Rose]

"I am very positive, maybe too much. So I think it can help those who are not as positive as I am" [Mr. Steve]

Mr. Jack expressed that the value of the tool is more important when people are depended on others or living alone, especially when hospitals quickly discharge patients and focus more on the functional aspects of the recovery. This reflects the aforementioned paradigm shift in shortening care at hospitals:

- *"I think what you see when you are at the hospital they fire you from the operation day minus one. And when you are with somebody it's not a problem but when you are alone and when you are depended ... it can help (the application)... hospitals are only physical and they you open and repair ... get out of here, and mentally you are thrown into the water" [Mr. Jack]*

Regarding the appropriateness of the questions (prompts) participants reported that after one week it became difficult for them to say something relevant or new. The first week can be seen as a roller coaster of mood changes and strong emotions combined with clear signs of their physical recovery. But later, unless a complication arises, their moods become more stable as uncertainty decreases and the recovery progress slows down; they feel they know what to expect:

- *"The first days you are unsure, you feel the pain and you can call the hospital any moment to ask if things are normal" [Mrs. Rose]*

- *"You have always questions in the beginning of recovery... The muscle aches, is that normal? We didn't know". "... when you've got something new to tell, you can tell. But when everything is the same, then you don't know what to say ... I think another [third] week would not have added value, because the situation doesn't change" [Mr. Smith]*

Participants suggested that the tool could ask more personalized and different questions as the recovery progresses to increase its value on the longer term:

- *"Yes, I told my husband sometimes: why don't they ask me why do you feel that?...more direct questions....Are you comfortable with all your pain killers? I hate painkillers... How do you feel like laying in bed like a fish? And don't move around? ... Are there a lot of visitors? are you sleeping well? Something like that. Just one extra question. And they will tell you more I think" [Mrs. Rose]*

- *"... different questions. Then you force people also think more on what they are doing. The questions of the first week can be different from the questions that you ask in the second week because we are in a different phase" [Mr. Jack]*

Awareness, communication and sharing

Participants did not see a direct value of the tool in their recovery process, apart from providing a way to express their moods. Mrs. Rose appreciated the opportunity the tool gave her to express some of her feelings without bothering her husband or other family members, but she

did not relate that to improve her physical recovery. Nevertheless, they could see the value of ESTHER 1.0 to increase their awareness regarding their progress on the first week, as well as the possibility to be able to get some direct feedback if the physiotherapist would read their reports:

- *“If you phone to the hospital, you never get someone you want to speak to you. So, a device that will listen to you will help...even then a call [physiotherapist] can be enough to reassure people that it is alright to be angry, because sometimes that’s alright. Or emotional” [Mrs. Rose]*
- *“How are you today? You could fill in something, I’ve been walking, I’ve been feeling well, I’m a bit tired.... I think that is ok I think that is nice. Also for yourself” [Mr. Jack]*

Regarding sharing their reports with other family members they did not see a clear value; Mrs. Rose indicated that she is always very careful to not bother others with her own problems:

- *“The people surrounding you also have emotions, so if you are a normal person, you won’t bother them too much with you own emotions. You can tell it to a ma-chine, that’s easy. He [husband] wasn’t allowed to read what I typed” [Mrs. Rose]*

The idea to use the tool to share their experiences with other patients was not clear for Mr. Smith. He expressed his concern that different people’s attitudes to the problem, may require different strategies finding difficult to help others:

- *“I’m really positive and I notice that people around me tend to go other way... I think that a lot of people don’t exercise their muscles enough in advance.. they think is convenient ... I try everything until the limit” [Mr. Smith]*

On the other hand, Mr. Jack was more positive about the possibilities of the application to help people to connect and share, especially when they are alone:

- *“I think it can help to connect to experience what have other people thought and thoughts and what have they been doing and why, I think it can help. When you are alone it is not so easy... so certainly the first weeks you need help” [Mr. Jack]*

4.6 Discussion

The design of homecare technologies implies designing for a sensible human condition in the complexity of the daily life practices of an individual. The interest to develop persuasive technologies to improve everyday activities and the possibilities of the wide range of ‘plug and play’ technologies give the opportunity to experiment envisioned interactions in real settings (Rogers, 2011). ESTHER 1.0 is described as a research tool to capture patients’ experiences while at the same time as a prototype to evaluate the acceptance of self-reporting as an interaction element that can be adopted and adapted into existing daily practices in a healthcare situation. As stated by Rogers (2011), the value of prototyping in the wild is associated with revealing insights regarding technology acceptance and adoption different to what can be captured in lab and short term studies. The advantages of these ‘wild studies’ are however challenged by the traditional position in HCI to assess studies on the number of participants, instead of the ecological validity and extend of the studies conducted. Both criteria involve higher cost and tenure that traditional studies: monitoring what people do, what they experience and feel and most important how this changes over time. ESTHER 1.0,

aims to provide knowledge that uncovers interdependences between design, technology and behaviors to explore implementations that support changes rather than looking at cause-effect predictions applied to a specific problem. The presented intervention may be considered as a costly endeavor to address a highly delicate health situation with the care and dedication needed to deep in its subjectivity and complexity. The result: integrated knowledge into how subjective and objective aspects of a health condition are combined and how they relate to technology based design interventions in the complexity of the real context of use.

ESTHER 1.0 has also confirmed the value of self-reporting practices to aid patients' awareness of their recovery. Instead of trying to change peoples' behaviors by influencing directly their actions and thinking process, this intervention focused on how to change the context in which a process of reflection can be supported by an intervention. This opens an opportunity for the design of ESTHER and related supportive systems that aims to empower users to take charge of their care situation. The following discussion addresses the challenges identified in relation to the three main stakeholders of this system: clinicians and researchers, physiotherapists, and patients.

4.6.1 Medical requirement to use experience-based measurements

Despite the value and benefit of including patients' experience insights into the existing measurements of hip recovery, the medical and the research community require validated measurements to incorporate into their protocols. Validating the ESM features of ESTHER 1.0 becomes a challenge since it provides characteristics that are missing in the existing measurements (see Table 1), therefore comparing ESTHER 1.0 against existing measurements will ignore its subjective and long term benefits. Two suggestions are proposed to validate the tool for clinical purposes. First, based on the functional and experiential representation of the five dimensions defined in the coding scheme (see Table 3) the tool could be redesigned by making explicit links between prompts and dimensions, therefore outcomes could be comparable to existing measurements. Second, a validation study covering a larger number of patients would help to analyze the predictive capabilities of a large set of subjective data at the individual but also cross-patients level.

4.6.2 Physiotherapists supportive practices

In designing and deploying a tool to gain understanding of patient's health experiences at home, a self-reporting technique was implemented to capture insights from patients themselves. In addition to the value of the collected data from a research design perspective, the tool also provided valuable insights to patients themselves of their recovery. Patients discussed the opportunity to share their reports with their physiotherapists as the reports could help them recall a more accurate picture of a certain past situation that they would like to talk with the physiotherapist in the next meeting. From physiotherapists, the need to access this information in advance in an efficient way will help them to better prepare to the next meeting. Therefore, the need to automatically process the reported data can provide timing and relevant information to patients and physiotherapists.

Two opportunities are identified. First, it was observed that mood reports could be used to filter the text reports, working as a raising flag mechanism to detect situations of alert. For example, preliminary insights from this study identified that high arousal moods though not commonly used they were always linked to events considered as out of the ordinary, that might need special attention. Therefore, relations between these two input modalities seem worth to further exploit. Second, the benefits of visually displaying the reported data could

help patients to self-reflect on their own process minimizing frustration and empower them to be more in control of their recovery. The moods reports were seen as one way to provide automatic visualizations (as seen in Figures 20) but more nuances could be visualized if relations could be automatically identified with the reported data.

4.6.3. Patients' motivation

One of the biggest challenges of deploying longitudinal studies with ESM tools is to provide appropriate motivational mechanisms to keep participants reporting over time. ESTHER 1.0 has proved to be welcomed by patients in a stressful context where they are confronted with the difficulties of the first weeks after surgery. However after the first critical week, participants perceived the pressure to provide new insights when nothing was happening, and therefore the tool was perceived less useful. In addition, because of the fact that the tool was introduced as for research purposes, patients could not link the tool to their expectations to be helped in their physical recovery process. To keep them motivated, participants suggested to provide personalized questions that adapt to the needs and concerns of patients at the different stages of their recovery. Although this may engage them on the long term, it conflicts with the need for a more structured and systematic tool as described above. One interesting observation is the use of measurement tools like PMRI to filter open text data. More investigation is needed to identify combinations of structured and none structured information.

It is foreseen that by providing clear individual as well as community benefits of the tool it could also increase motivation. ESTHER supportive features aim to empower patients in their process by minimizing anxiety during the first days, as well as frustration later on in the process when things do not go as expected. One could for instance think of a timeline with the typical average recovery process steps so that the patients know that they are on schedule and that everything is fine. In addition, the community of THR patients could also benefit as experiences are shared. Not only could people get insights from previous patients' experiences, but also patients could feel a sense of personal satisfaction, as they will be helping others while coping with their own problems.

4.7 Conclusions and Future Work

THR involves a personal and highly dynamic process where physical and emotional states are affected by unpredicted changes. ESTHER 1.0, Experience Sampling for Total Hip Replacement, is a research tool based on Experience Sampling Method (ESM) (Hektner et al., 2007) developed with the purpose to inform the design of a supportive system for homecare recovery. It goes beyond the architectural components of sensing technologies as such, by aiming to provide an understanding of the situation of the patient, capturing meaningful changes related to determinant factors throughout the recovery period. Special attention is given to understand the influences of experiences related to patients' emotional transition in this process.

The presented study provides evidence of the ability of ESTHER 1.0 to capture data that provides sensitive, longitudinal as well as granular information of the THR recovery process. The descriptive representation of the data collected by the tool shows that psychological and hip functions were dimensions highly represented in the reports from patients. Although a larger number of cases are needed to generalize such description, these first insights indicate that supportive mechanisms should be developed for helping patients to cope with the factors identified in these two dimensions in order to minimize the uncertainty during the first weeks of recovery. For example, situations such as being stressed due to an apparent slow progress can

be better coped by patients if having access to a visual overview of their overall progress and support them to reflect on their positive achievements.

The initial findings can be aligned with the qualitative research of Grant et al. (2009), where Hip Function problems were observed to be more important at the beginning of the recovery (pain and general health), but as the recovery progresses, social aspects become more important for the ease of the recovery. In addition, the first insights provided between the mood reports and the reports over the recovery process, indicate that such mood tool could be used as raising flags to systematically filter the text reports, predict critical moments in the recovery and notify them to the patient and physiotherapist. It was observed that when the trajectory of the recovery was going normal, the arousal of the reported moods remained medium regardless the valence. When a high arousal mood was reported it always relate to an unusual event. For example, in the case of Mr. Jack enthusiastic start and knowing that he was highly confident about his abilities, a flag could have been raised after detecting the high arousal moods, to give feedback to the patient and/or an alert to the physiotherapist to look at the recovery reports and assess whether special assistant is needed

The collected reports represented two types of information: experiences over patients' emotional recovery, based on the moods report, and their experiences over physical recovery, related to the open question 'how are you doing'. The reports indicated that a recovery could be better understood when both physical and emotional dimensions are connected. Making these relations could provide explanations to significant moments, which is considered as a next step in development the presented descriptive model of home recovery.

In summary, the data collection of patients' recovery combining emotional and physical aspects in relation to their daily lives, provided first insights of the potential of ESTHER1.0 as a research tool, capable of collecting information beyond the physiological process of recovery. The future development of ESTHER will address three main findings from this study: 1) the value of the subjective data collected using an in-situ tool that enables timed and situated patients' reports; 2) the potential use of self-reporting as a mean for patients to reflect on their process; and the 3) evident need for patients to understand their physical progress. Therefore, further design research activities will explore the opportunities and challenges to add patients' health sensed data from on-body sensor nodes, and investigate the value of the integration of both subjective and objective sources of data for patients, physiotherapists, medical professionals and researchers.

5 EXPLORING THE CHALLENGES IN INTEGRATING PATIENTS' EXPERIENTIAL AND SENSED DATA



In the previous chapter ESTHER 1.0 showed the value of daily self-reports to capture emotional factors that could not only describe and explain people's behavior but also to support users reflecting on their daily life health experiences. Towards the design of an activity monitoring system for THR, ESTHER 1.2 added to users' psychological reports, physical activity using wireless sensor nodes. This new iteration explored the challenges of deploying a system that aims at integrating self-reports and sensing capabilities to support user-empowerment. While presenting the experiences in conducting situated design research, this chapter also presents the value in understanding the technical as well as the social challenges for the research and design of home health technologies.

The following chapter is based upon the paper:

Jimenez García, J., Romero N.A., Boerema S.T., Keyson D., and Havinga, P. (2013) ESTHER: a portable sensor toolkit to collect and monitor total hip replacement patient data. In Proceedings of the 3rd ACM MobiHoc workshop on Pervasive wireless healthcare (MobileHealth '13). ACM, New York, NY, USA, 7-12.

5.1 Introduction

In the field of healthcare, many approaches with different sensing technologies to collect data and detect physical activity, user state and situation can be divided into four main categories based on the source and type of sensors they use: a) Ambient network sensors, measuring environmental phenomena provide information about the context of a physical activity (i.e. presence, location, humidity, temperature); b) Body Area Sensor Networks (BASNs), are worn sensors that can provide accurate physiological measurements (i.e. heart rate, blood oxygen, respiratory patterns); c) Smartphone sensor capabilities with in-built accelerometers and devices, provide information about physical activity with acceleration measurements derived from human movement (i.e. count of steps, walked stairs); and finally, d) the combination of self-reported data with wearable sensors or smartphones, helping in the recognition of personal information (i.e. behaviors, habits and thoughts) and facilitating self-reflection processes (Li, 2010). This is a relatively recent approach that involves the user in the loop of collecting and delivering information.

Towards the development of a user-centric solution system for THR patients, the new iteration of ESTHER appropriates the last category approach, adding physical activity using wireless sensor nodes to the users' psychological reports. The big potential that this sensing approach offers, is its practical user-adoption should overcome technical, usability, design and social challenges. Technical challenges are related to the accuracy to measure and infer physical activity with the trade-off of energy consumed by processing, storing and delivering the information. Usability challenges are related to the ease of use, wearability, comfort, and intrusiveness. Design challenges refer to the way to interact with the system and the visualization of the information showed to the user once the data has been collected and processed. This also affects the level of usability of the system. Finally, social challenges discuss the user's perceived value on the system its safety and privacy. Striving to increase our understanding in how people self-report and reflect, ESTHER 1.2 explores the challenges of integrating self-reported data with wearable sensors used in real settings. This chapter describes the design and the experiences of implementing ESTHER 1.2 as the first trial to explore and implement the proposed data integration.

5.2 ESTHER 1.2: Goal and scope

ESTHER 1.2 was conceived as an in-situ research tool to sample patients' experiences and context during the surgery recovery; to link physical and emotional aspects of such recovery. Based on previous field trials with ESTHER 1.0, the triangulation of these two sources of data is expected to offer better mechanisms to guide and support the daily life of patients not only from the physiological but also from the emotional aspect. The design and implementation of ESTHER 1.2 resulted in an electronic tool that combines Experience Sampling Method capabilities with physical activity monitoring.

5.3 Description

As conceived with ESTHER 1.0, a female character was used to host the tool, triggering the questions and guiding the patient through the application in a friendlier looking way (Figure 22, left). The insights resulting from previous studies using the Pictorial Mood Reporting Instrument (Section 4.3.1), PMRI showed that four moods were most chosen by patients in describing the THR patients' mood states during recovery: 1) Happy, 2) Irritated, 3) Bored,

4) Relaxed. This insight served to appropriated these four moods and placed them in a single screen to reduce user's burden to self-report (Figure 22, right).

A set of questions was developed as nudges to trigger self-reports (section 4.1.1). First, the level of the patients' physical performance triggered prompts as they request patients' mood reporting when a certain performance threshold was reached. Second, a reminder was triggered when low physical performance was detected.

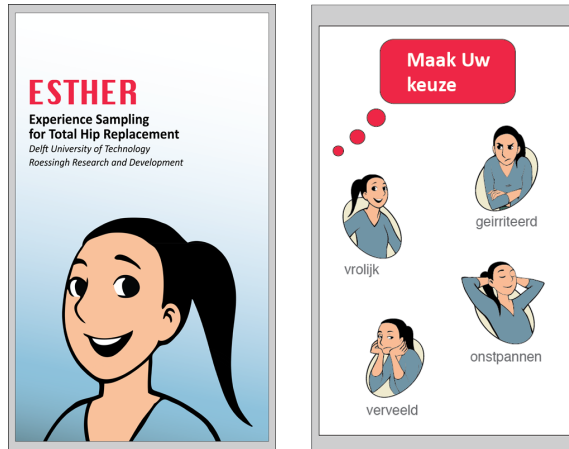


Figure 22: Screenshots. A validated avatar (PMRI) implemented in ESTHER 1.2.

The prompts do not require more than an interaction point to be resolved by the users. They were short, for instance, the four moods options were placed on the same screen to facilitate their selection leading the user to quickly ending with the prompt. When the reminder is triggered (at 40 minutes) the smartphone vibrates and the question “Hello Mr. Rosse. Have you done your exercises?” pops up with two options “Yes” or “No” provided in the same screen. After each block of 60 minutes is finished, the phone vibrates again and it pops up the question screen “How are you feeling”? This screen last for 10 seconds and automatically changes to the screen for “Moods selection”. After the patient selects one mood it automatically changes to the “Thank you” screen.

5.4 Technical elements

The tool was implemented on a mobile phone that was connected to a wearable sensor (Figure 23). The data coming from the sensor was used to identify ‘critical moments’ during THR recovery. Problems such as being too passive or being too physically active corresponded to ‘critical moments’ of a day. An inertial sensor (Figure 23a) placed on the patient’s hip was used to capture IMA values - Integral of the modulus of the accelerometer output algorithm- (Bouten, 1995) to detect these “critical moments”.

The sensor platform consisted of a waist mounted activity sensor connected wirelessly to a smartphone. The activity sensor used was a ProMove-3D sensor node developed by Inertia Technology, which was placed on the patient’s hip to provide an IMA value out of a three-dimensional acceleration data with a frequency of 1Hz. The IMA values were collected and transmitted over Bluetooth to a smartphone (HTC) with ESTHER 1.2 installed. The interface was built using an Android-based application. The software read out the activity data (IMA), stored the values locally and transmitted them hourly to a server that processed the sampling protocol.

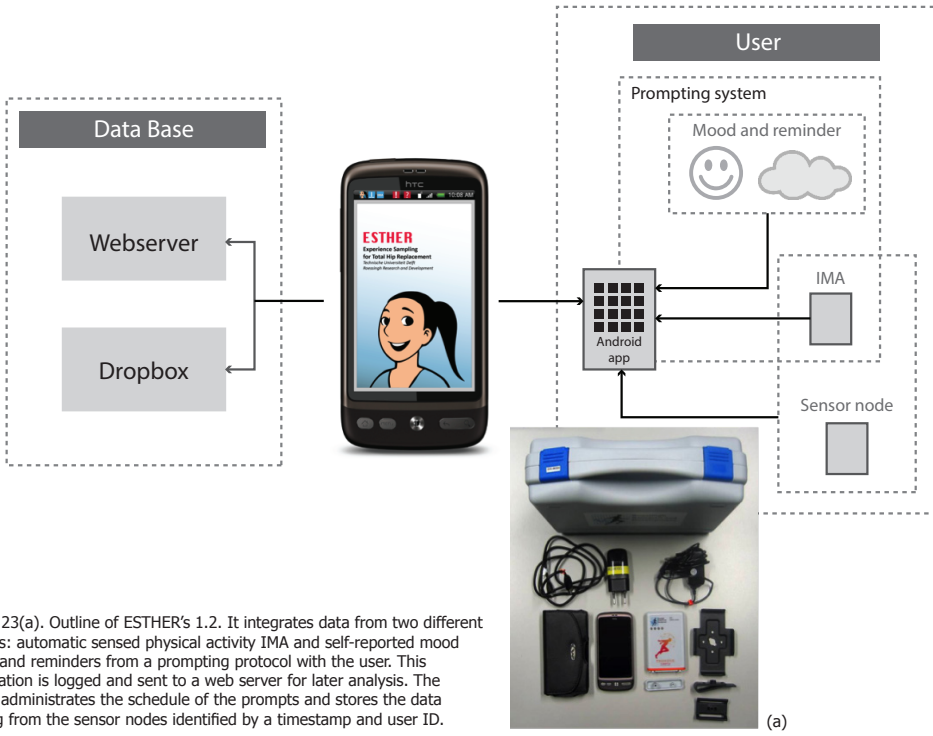


Figure 23(a). Outline of ESTHER's 1.2. It integrates data from two different sources: automatic sensed physical activity IMA and self-reported mood states and reminders from a prompting protocol with the user. This information is logged and sent to a web server for later analysis. The server administrates the schedule of the prompts and stores the data coming from the sensor nodes identified by a timestamp and user ID.

5.4.1 Prompting protocol

A baseline of physical activity was defined according to medical prescription of a THR patient in order to set the threshold that identified 'critical moments'. The prescription, defined in the workshops conducted with physiotherapists, recommends that patients should have at least 10 minutes within an hour of moderated physical activity during the initial two weeks of recovery. Considering that an IMA > 2000 represents moderated physical activity for a normal person, an IMA > 1500 was set for THR patients. In order to provide some flexibility in how the patient reaches the recommended amount of activity, if a patient registered 8 to 15 minutes of IMA > 1500 in an hour it was considered as complying with the level of physical activity. An amount of activity below or above that threshold was considered a 'critical moment'.

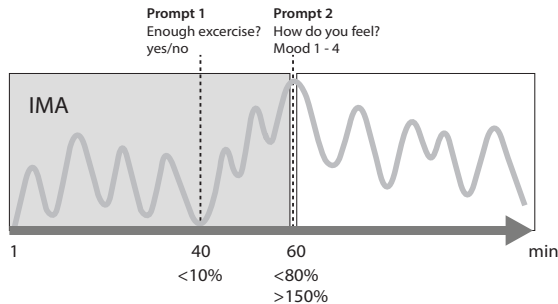
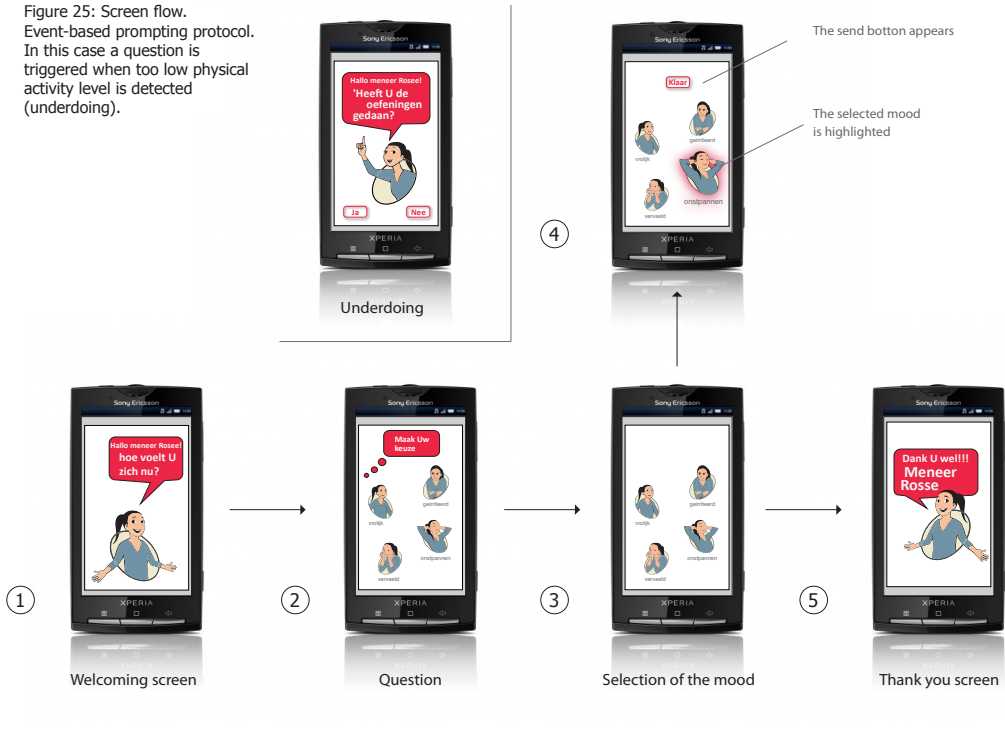


Figure 24: Prompting protocol in ESTHER 1.2.

Figure 25: Screen flow. Event-based prompting protocol. In this case a question is triggered when too low physical activity level is detected (underdoing).



Addressing the issues caused by a fixed-interval prompting protocol in ESTHER 1.0 (section 4.5.3), ESTHER 1.2 worked with a context-dependent prompting protocol. The days were split into twelve blocks of one hour (from 8 am to 8 pm). Within every block an algorithm assessed the physical activity behavior of the patient checking for critical moments as follows: a) when the progress of the patient was <10% at 40min of monitoring time the user was prompted with the question “have you done your exercises lately?” The user could reply to this question by pressing either “yes” or “no”. The goal of this reminder was to help the user to accomplish some physical activity in the last 20 minutes of the monitored block; b) when the physical activity of the patient was <80% or >150% in a hour, the algorithm identified a critical moment and the system will prompt the question “how do you feel?”. The patient could choose from four moods characters: happy, relaxed, bored and angry (based on the Pictorial Mood Reporting Instrument, PMRI). No visualization was given on the current data collection to support the self-report action.

5.5 Evaluation

The goal of the study was to verify the defined thresholds for critical moments and the corresponding sampling protocol in the context of THR patients. In addition, the value of mood states was explored to describe patient’s experience of their recovery in relation to their activity level. The study was conducted with four participants (3 male, 1 female), mean age 60, that were volunteers from the Department of Orthopaedics of the Reinier de Graaf hospital in

Delft, The Netherlands. The study period (Table 5) was set to monitor at least 8 days before surgery and 15 days immediately after discharge. Patients used ESTHER 1.2 during the two weeks after discharge from the hospital. Participants received guidance about the use of the monitoring kit and they were instructed to answer the prompts in relation to their recovery.

The data collected was analyzed by extracting the percentage values per hour of IMA indicating critical moments as described above. Both, IMA percentage and mood reports were plotted according to the prompting schedule (see Figure 24). At the end of the study participants were interviewed to discuss their experience, motivations, benefits and preferences when using the system, as well as future applications of the tool. A survey was used to assess the usability, ease-of-use and usefulness of the system.

#														Hospital	Post-surgery (Home)																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	OK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22			
1	1	2	3	4	5	6	7	8	9	10	11	12	13	OK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22			
2	1	2	3	4	5	6	7	8	9	10	11	12	13	OK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20					
3	1	2	3	4	5	6	7	8	9	10	11	12	13	OK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18							
4	1	2	3	4	5	6	7	8	9	10	11	12	13	OK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18							

Table 5. Monitoring days per patient, relative to their surgery date (=OK). 1-4 are the individual subjects. Light gray = monitoring days. Dark gray = not monitored, due to technical failures or drop-out

5.6 Results

5.6.1 Activity monitoring

The field study resulted in an extensive amount of quantitative and qualitative data regarding physical activity and mood reports. In total 83 out of the 92 expected days of monitoring were collected. However, only 50 days of monitoring were considered as complete and reliable. This low amount of data collection had several reasons and they were mainly related to the technical reliability of the system that consequently affected the normal implementation and use of ESTHER 1.2, as well as personal-health related reasons from the participants to stop using the system.

Regarding reliability of the system the main challenge was the optimization of battery life. Although a functional prototype, the system was not fully optimized for long periods of use. Despite several efforts to lower the battery consumption and improve Bluetooth connectivity, the dataset resulted in more incomplete periods of data collection per day than expected. 603 out of the 1,104 data hours were collected. These challenges not only affected the amount and the reliability of the data but they also created burden to the participants, e.g. after a night of charging the system was possible to be used only during the morning. It was experienced that the smartphone battery was completely exhausted after ~4 hours of use. Then, participants charged the system but they had to stop in using it. Several hours later they wore the system again but the Bluetooth connection was lost. When they found themselves struggling in pairing the system, they simply stopped in using it again until one of the researchers visited their houses. This situation was experienced several times with all the participants.

ESTHER 1.2 used pre-define IMA levels in Bouten, 1995. However, the data showed that patients hardly ever reached the baseline set for normal level of activity, concluding that IMA > 1500 was too high for this target user. This caused a malfunction in the prompting protocol as prompts were triggered almost every hour because of a too low level of activity. Although it is expected that this hourly prompting would be highly disruptive in a longer study, participants accepted and complied with it during the two weeks of study. The preliminary results were analyzed using visualizations that illustrated the intensity of physical activity per hour of a patient linked with mood reports when available.

Figure 26 shows the third day of recovery of each patient. Assuming that the reported moods were related to patients' recovery experiences the analysis presents shows that moods reports enriched the observations gathered by the sensors. A correlation, moods varied widely per patient during the same stage of recovery, even when patterns of physical activity were similar. For example, when comparing patients 1 and 2, physical activity was comparable as both presented two peaks of activity around noon and mid afternoon while in the rest of the day activity was low. However their reported mood was clearly different. Similarly, patients that showed hardly any physical activity, like patients 3 and 4, also varied in their reported mood. The reported moods were also in line with the insights gained from informal discussions and exit interviews, where patients' personalities and individual cases corresponded to their daily mood overview. Patients 1 and 3 were confident and felt easy with their operation and recovery. Patient 2 struggled with a difficult recovery, and patient 4 was the only female who was more expressive than the male participants.

5.6.2 User evaluation

From the interviews it was inferred that participants were positive and open to take part on this study. It was often mentioned that their contribution may improve a system that would eventually help others in their rehabilitation. Later, when the participants were asked for an interview, each patient showed again high interest in providing feedback after the monitoring period. The results of the interviews and the surveys are summarized and categorized as follows:

Usability issues

As seen in Table 6, a provided usability survey consisting of five Likert questions showed favorable scores regarding the use of the ESTHER 1.2 application. However, the usability of the system was negatively affected by constant failures in Bluetooth connectivity and short battery life of all the devices. For instance, some of the participants mentioned how unstable was the application and how difficult was to charge the devices and put them on again.

- *"Yeah, that went alright (the application)... just the charging part every time of course, the entire day, well after 16:00 you had to take it off and plug it, charge it again. And then you had to stay close to it". [Patient 1]*

- *"... but you can't do much about when the battery runs out very fast from the phone but it's on the entire day of course". [Patient 3].*

User experience

With eight questions all participants indicated that they had an overall positive experience with the system. In spite of the reported system failures throughout the monitoring period and some burden in its use, they all recognized the system as a convenient tool during the recovery. Although patients did not see a direct benefit of the system in their physical recovery process, they recognized the role of the tool at increasing their awareness. The most remarkable comment regarding ESTHER 1.2 was how useful it was to keep in mind the prescribed exercises. Although ESTHER 1.2 was not meant to be a feedback system, the short reminder and the mood prompting built in ESTHER 1.2 showed value in their daily life.

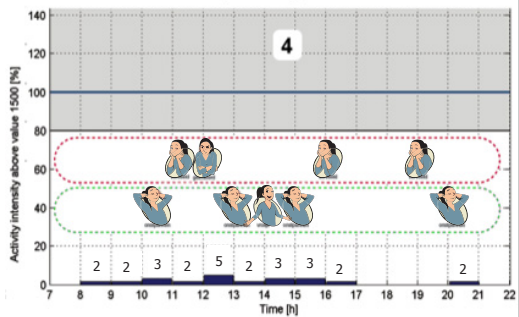
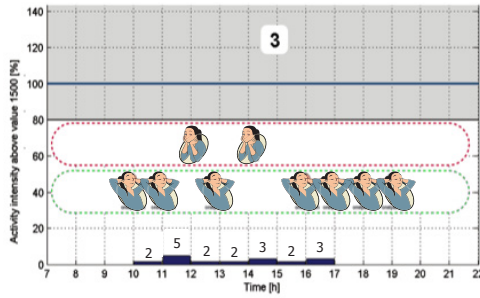
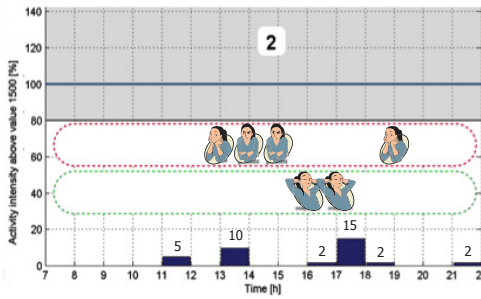
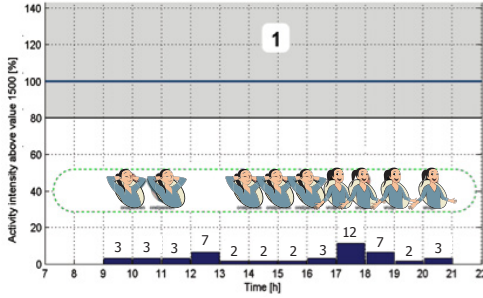


Figure 26. 3rd day of physical and mood reports for each participant. Blue bars represent physical activity per hour; positive mood reports are shown in green (relaxed and happy) and in red the negative moods (bored and angry).

ID	Q1. Wearing sensors	Q2. Use the phone	Q3. Use the app	Q4. App reliability	Q5. User manual
A	4	3	5	5	4
B	5	4	5	3	5
C	4	4	4	3	4
D	3	4	4	3	5
Av	4	3,7	4,5	3,5	4,5

Table 6. Usability of the system.
Answers were given on a 5 point Likert scale from
1 = Very negative to 5 = Very positive. Av = average score.

-*“That it helps you to keep in mind if you did your exercises. It just happens that you’re busy with something like watching a movie or you are with friends and you forget that you need to do the exercises, you know. And then it comes “oh, yes, I’m going to do my exercises” because well. Yeah it comes in hand”. [Patient 2]*

- *“... And it reminds you really do need to do the exercises and that you don’t forget”. [Patient3].*

-*“It was actually the same but the system that came with it “How are you” I think it was a quite a good system and it actually helps you to keep doing the exercises” [Patient 4]*

Moreover, awareness was increased when participants were able to use the mood prompting as a way to reflect on what they were doing at the current moment that could stop them to make the exercises. For instance, they were able to reflect on the amount of physical activity and to take action about it.

- *“... If I did my exercises and it asked me how I felt, well every time I felt good and the exercises well eh... Yes, if it said “did you do your exercises?” then I would answer “yes” while it was actual by “no” and I would think “Well, I’m going to do them now”. [Patient 1]*

-*“ Then I would say “Yes I did them” you know. But if I did. Yes I also answered “no” sometimes, then I think to myself “then I’ll be busy the entire time”. [Patient 3]*

Patient’s recommendations

The participants showed high interest in an application that is capable to collect information about their everyday status that goes beyond the standard information that is collected by the physiotherapist at the practice. For instance, two participants (P.2 and P.4) expressed their wish to not only being prompted with two questions about their mood and a reminder, but also to have the opportunity to share the reasons for certain behaviors. Sometimes patients cannot follow the recommended amount of exercises because, for example, the pain is too strong. The potential benefit of enabling patients to share the reasons for their decisions was already seen in previous studies (ESTHER 1.0).

- *“If you can type something... “Did you do your exercises?”, No? That it will ask “Why not?” I have a lot of pain, I can’t get out of bed, something like that, you know”. [Patient 2].*
- *“... But feelings are sometimes expressed in a very different way. And I did not see that. I would like to answer more to that. Like, I feel like this but right now it’s not going that well. But I think it requires a lot of phone memory”. [Patient 4].*

The participants found interesting to contribute to the system adding personal information instead of only the system working in silence. Because they want to recover as fast as it is possible, they are willing to contribute with more information if this would help to have a faster recovery process.

- *“... (providing data) yes, that you would like to indicate or input other things during the recovery period”. [Patient 3].*

5.7 Discussion

ESTHER 1.2, showed the variations in physical activity behavior and mood reports to profile patients’ behavior and to describe their experiences beyond the functional definition. These results uncover opportunities of ESTHER to be used as a research design tool to capture information and as a design intervention tool to explore the benefits of increasing patients’ self-reflection capabilities by implementing self-reporting mechanisms. Findings from the interviews and surveys provided insights on how participant experience the system as becoming a companion of their process and to what extend technical and design limitations affect the overall experience. Participants found in ESTHER 1.2 a way to communicate their thoughts and feelings during the initial period of recovery. As it was seen with ESTHER 1.0, to be able to report experiences during the recovery makes patients speak knowledgeable about their process describing feeling and events. Participants suggested to add more input mechanisms that consider their personal reasons for certain behaviors or actions. The prompting protocol served as motivational triggers to remind patients to keep physically active and to increase their awareness about daily life activities.

The discussion about ESTHER 1.2 also reflects on how the limitations found with this study provide material to frame the implementation of more dynamic self-reflective applications prompting in following explorations. Working with a vulnerable target group like THR elderly patients was a big challenge. First, the recruitment of participants was very difficult due to the many steps to finally reach the patient. Surgeons, nurses and physiotherapists were part of the recruitment and the communication circle increased the time in which researchers could set the experiment. Second, difficulty is the medical sensitivity to intervene treatment. Not only medical staff but also patients were concerned about how this study could affect their normal recovery process, as their priority is to focus on decreasing pain and avoiding injuries. Several patients declined to participate for these reasons. Therefore, finding participants for ESTHER 1.2 was a long, difficult process.

ESTHER 1.2 also proposed a too ambitious set-up with the included components. On-body sensor nodes were in a too early stage of their technology maturity in the context of healthcare to collect and integrate objective data (on-body sensor) with subjective data (self-reporting). This integration created an unexpected challenge related to technical failures in battery life and Bluetooth connectivity that affected in turn the positive user’s experience of the system. Not only technical failures resulted in a high burden for the patients’ experience with the system but it also affected the amount of collected data to be cross case-analyzed. Both battery life and irregularities in Bluetooth connectivity created gaps of total data logging per hour

and day. During this field trial the researchers had to visit the patients' home several times. Once there, researchers had to check, reset and sometimes collect entirely the system bearing in mind the study was still running. In order to understand the dimensions of these issues a test was performed to identify how much time each device lasted in both alone and wirelessly interconnected modes. We could see that the battery life of the smartphones is reduced (44% in average) when they are coupled via Bluetooth with the sensor nodes; a reduction in battery life was also seen for both IMA sensor nodes (20% in average) and Foot Pressure sensor nodes (9% in average) when they are connected to the smartphone application. Although this test does not contemplate actual user interaction with the application, it already indicates that the system is being affected when running all together. We could see that the system is even more affected on the field when the user is constantly interacting with the application interface.

These lessons learnt led to implement in-situ prompting in a different context with similar objectives. In order to explore further implementations of these promptings it was required to have a more accessible target group. SWELL project (swell-project.net) is related to knowledge workers and their physical activity during working time. Similar from THR patients, physical activity is a concern but not the priority in their daily business as well as knowledge workers also have targets to meet. In this scenario it was decided to use basic technology that is out there ready to use for most people, therefore the smartphone was selected as the only device.

5.8 Conclusions

ESTHER 1.2 opened up an interesting iterative design path to discuss the design of a supportive system that goes beyond the functional/objective aspects of physical activity. The integration of experiential and contextual aspects of users revealed several challenges related to technical aspects of a sensor and self-reporting system, the collection of in-situ data in real context and participation of users in these types of studies.

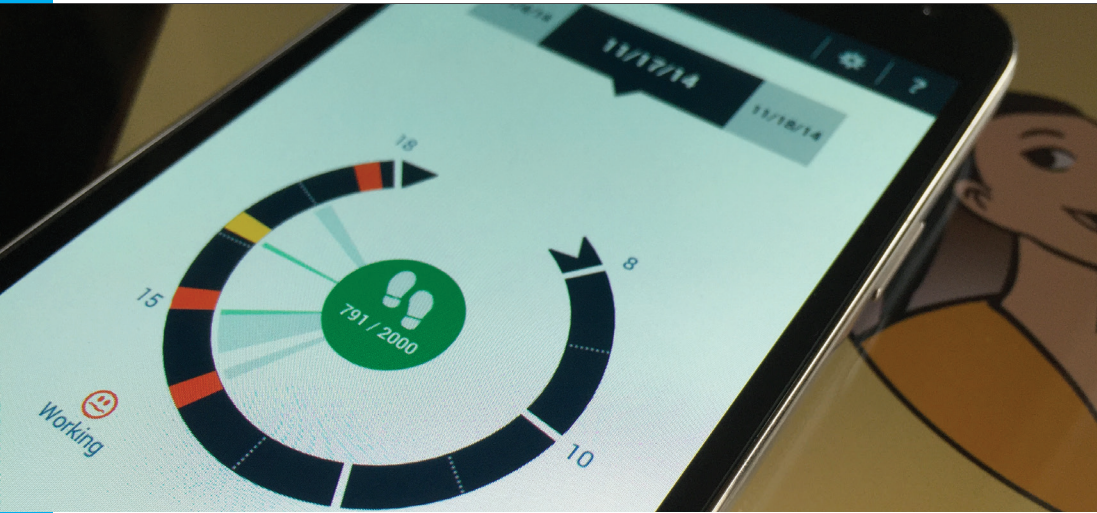
By providing a systematic, coherent and seamless integration between the self-reported and automatically sensed data and its representation, the patient developed ways to evaluate opportunities for improvement. The initial visualizations of plotted data and moods lead to the next iteration that explores real-time feedback to support users' self-awareness and self-reflection. Providing the user with the ability to control and explore these opportunities is the goal for the following iteration when user empowerment becomes the milestone.

As future work it is proposed that additional iterations continue exploring the balance between low effort on participant and richness in their self-reports, which addresses various technical, research and user challenges. Firstly, in-situ reporting tools like PMRI (Vastenburg and Romero, 2010) can be further developed to simplify self-reports without losing richness of information. Secondly, adaptive prompting can be further explored to make prompting more significant to patients and reduce unwanted ones. Thirdly, the ecosystem of the tool can be simplified to reduce patients' burden due to technical failures. Finally, work on analyzing and visualizing both sensing and subjective data sets can be further developed to find interconnections beyond descriptive ones between both data sets.

PART B

DEVELOPMENT OF SELF-EMPOWERMENT MECHANISMS

6 MICRO-CYCLES OF SELF-REFLECTION (mCR)



The findings of the field evaluation of ESTHER 1.2 reflected on the limitations of implementing a wireless sensor network for a vulnerable target user as THR elderly patients. As in the case of ESTHER 1.0, ESTHER 1.3 was found to be a self-reporting tool that can promote self-reflection. ESTHER 1.3 as subsequent design iteration, explores the value of self-reporting prompting as a reflective mechanism in a different scenario. It aims to support knowledge workers in the context of physical activity during working hours through self-reflection.

The following chapter is based upon the papers:

Jimenez Garcia J., Romero N., Keyson D., and Havinga P. (2013) "ESTHER 1.3: integrating in-situ prompts to trigger self-reflection of physical activity in knowledge workers", in: Chilean Conference on Human – Computer Interaction (ChileCHI 2013) conference proceedings.

Jimenez Garcia J., Romero N.A., Keyson D. (submitted, 2014) Reflective healthcare design: micro-cycle of self-reflection, Special Issue on "Designing Self-care for Everyday Life", in Interaction Design and Architecture(s) Journal (IXD&A).

6.1 Introduction

This chapter presents the research and design explorations of implementing self-reporting as a mechanism to support reflection. ESTHER 1.3, aims to implement micro-Cycles of Reflection (mCR) to activate patients in the phases of integration and reflection when applying the staged-model of Personal Informatics (PI) (Li, 2010) in the design of personal healthcare systems. The stage-model of personal informatics (section 3.6) considers how an assistive or supportive a system should be designed and to facilitate the user in processing large set of data.

To consider a more supportive approach, we discuss that when the integration stage of PI is a more assistive/system-driven process the results are visualizations that are far from personal, leading to a passive role of users with the data, which limits an effective reflection on it. As stated in (Pirzadeh et al., 2013; Koldijk et al., 2012) a key challenge in the design of a Personal Informatics (PI) system is to provide people with meaningful information from the data collected. Based on the theory of Reflective practices (Schön, 1983) short but active involvement of the user in the integration stage may result in more personalized visualizations; such design could then actively support the user in their reflection process.

Acknowledging the advantage of technical computation to minimize user effort in the process of collection and integration, a challenge for designers is to identify the value and meaning of the resulted integration of data. When integration stage involves several sources and large data sets, providing relevant and easy to digest information for individuals to reflect upon is a major challenge. Integration involves selecting and highlighting what is relevant to show, providing meaningful links between the data. Individuals' interests, cognitive capabilities and emotional states, will influence the way they will benefit from a certain integration strategy. Based on the experience-tag concept envisioned by Vastenburg and Romero (Vastenburg and Romero, 2011) and considering the challenge to capture both objective and subjective data from people's practices and experiences, a proposition to use self-report techniques to actively involve users in the integration phase is explored in this chapter. Light and short instances of self-reports could be used as experience-based tags to label a certain piece of objective data captured by sensors, which are then timely visualized. Therefore, self-report techniques could extend the implementation of the collection stage with Integration, which may increase people's ability to reflect. In turn, more reflection will provide individuals with valuable personal insights that may increase the motivation to self-report on a frequent basis.

6.2 The concept of micro-cycles of self-reflection (mCR): how framing reflective practices in PI systems may empower users

As mentioned by Pirzadeh et al. (2013), reflection is a process in which one thinks and explores an issue of concern to make it meaningful for oneself, leading to the development of a new conceptual perspective. Reflection mechanism increases awareness (Van Hoyer et al., 2012) and it becomes a motivation for users of Personal Informatics systems that seek to understand relationships between different sources of data (MacLeod et al., 2013). The staged-model (Li, 2010) captures five phases to describe the use of Personal Informatics: preparation (what data will be collected), collection (how data will be collected), integration (how data will be processed and presented), reflection (what strategies to develop) and action (implementation of strategy). Where technology can fully cover the first three phases, users are supposed to be the primary actor in the last two. This logic division of using technology to minimize human effort in managing data, becomes also a barrier for users to make sense and use of the information presented. Therefore it is proposed to investigate a way to bring users more actively involved in the integration phase to support reflection. Therefore a proposal to

extend the integration stage by combining self-reported data with automatic collected data is enclosed by the concept of “micro-cycles of self-reflection - mCR”. mCR based on self-reporting techniques which defined properties to ensure active participation with minimal effort. The properties of mCR are:

PROPERTIES	CHARACTERISTICS
ENERGETIC	Opens a moment of reaction; provokes reaction
LIGHT	Minimal cognitive effort to report
SHORT	Minimal time effort to report
HIGH FREQUENT	Able to capture nuances and fluctuations
LINKED	Prompts are triggered and linked to relevant situations, context, etc

Table 7. Properties of micro-cycles of self-reflection (mCR).

The concept micro-cycle of self-reflection can be compared with the term microsuation quoted by Fogg (2002) when discussing the design of persuasive systems. This is an element in computing systems that incorporates smaller elements of influence to achieve other sub-goals. Examples of microsuation elements are reminders, pokes, notifications or nudging pop-ups windows. In the case of micro-cycles of self-reflection, self-reporting works as an embedded element in supportive systems. Examples of mCR are self-reporting techniques. The challenge to implement micro-cycles is that while microsuation elements are triggered by the system, micro-cycle is a user’s responsibility.

6.2.1 Components of micro-cycles of self-reflection

At the root of the concept of mCR is the work done by Donald Schön (1987) who introduces Reflective Practice, as the way people analyze experiences in order to learn from them. As the author defines, Reflective Practice is a process between reflection-in-action and reflection-on-action and happens when thinking and acting are combined. Reflection-in-action helps people in the activities of completing a task. It is a process that allows to reshape what people is working on, while they are working on it. Reflection-on-action is a final reflection, thinking back on what has been done in order to understand why things did not work out as expected (Schön, 1983, p. 26). Schön goes further describing this process by involving linking elements:

- Knowing-in-action:* tacit knowledge that is implicit in one’s patterns of action and the feelings towards a situation that someone is dealing with.
- Surprise result:* an unexpected result to be made sense of, and an opportunity to be exploited.
- Knowledge-in-action:* when the surprising information triggers reflection.
- Reflection-in-action:* thinking what is happening without stopping the action.
- Reflection-on-action:* framing the problem to reshape the strategy for further action.

These linking elements constitute a mental process and they have been brought and integrated into the mCR to support reflection-in-action. The properties of a micro-cycle may support the creation of knowledge-in-action when the system prompts the user to self-report. The action of self-reporting could bring new thinking upon surprising data that leads to reflection-in-action, making the integration a more active stage. The implementation of a Reflective Practice process within the Personal Informatics staged-model is described in Figure 27.

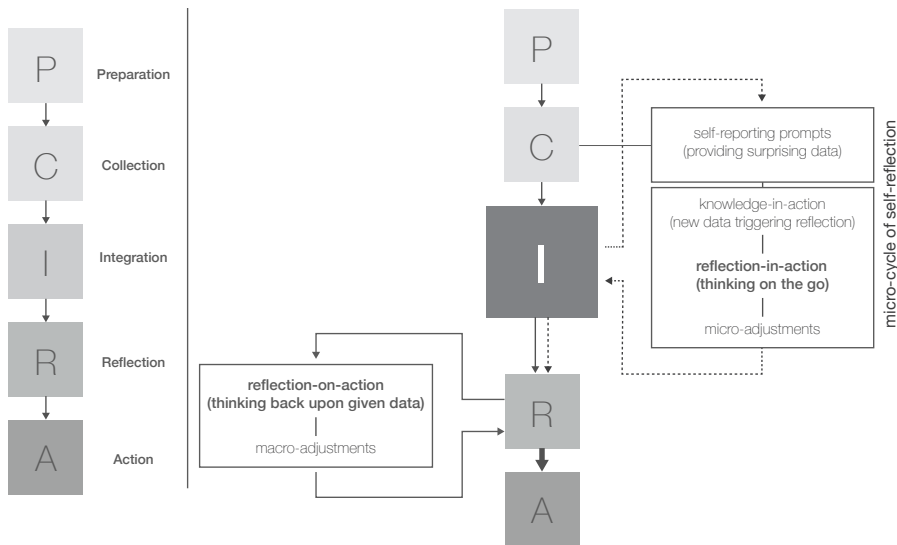


Figure 27. Traditional “staged-model” (left) and “active integration stage model” (right) of personal informatics.

In the following sections, ESTHER 1.3 is presented as a situated design intervention implementing micro-cycles of self-reflection in the context of knowledge workers and physical activity during working hours.

6.3 ESTHER 1.3: Goal and scope

ESTHER 1.3 illustrates one implementation of mCR in the context of physical activity monitoring and feedback by means of in-situ self-reporting mechanisms. A functional prototype is developed to test this implementation in the field and to obtain insights of the value of mCR. In the development of the prototype previous knowledge and experience regarding the design of personal informatics systems were also considered.

The context of knowledge workers and physical activity in working hours is chosen as an interesting scenario, where a health related issue is at stake, physical activity, but it does not fit in the busy minds and schedule of knowledge workers.

6.4 Physical activity in knowledge workers

Due to the sedentary nature of their work, knowledge workers have little opportunities to engage in physical activities during the working hours. In addition, physical activity is not a priority in their busy agendas, which results in knowledge workers being unaware of their physical behavior at work. In an effort to promote physical activity at work, most initiatives refer to company policies and campaigns to reduce sedentary behavior by promoting regular work breaks as opportunities to perform some physical activity (Dodson et al., 2008; World Health Organization, 2006). However, these initiatives do not directly support the worker to implement and accomplish the minimal required in physical activity at work. On average a worker should accumulate at least 30 min of moderate-intensity physical activity, either during work, during the lunch break, or on the way to or from home (Li, 2009).

In practice, knowledge workers require supportive tools beyond policies and infrastructures to help them to self-reflect and become aware of their physical activity levels to be able to integrate more physical activities in their schedules without affecting their work routines. However, there are little initiatives in supporting knowledge workers in implementing physical activity as part of their work routines. In the context of knowledge workers, Office Exercise and Exercise Booster (<https://play.google.com>) are two Android applications available for people with sedentary jobs. The first one prompts users to perform certain exercises so as to change posture after a prolonged period, for example an exercise is to hold the phone above the face and keep it there for a while. The latter is an application that helps keeping a record of exercise sessions based on manual entry. This application allows planning and scheduling and it displays weekly activity in a progress bar. WalkMinder (Hirano et al., 2013) encourage physical activity and self-awareness by a glanceable display and mobile phone vibrations are used to interrupt extended periods of inactivity. MoveLamp (Fortmann et al., 2013) is an ambient light display that serves as reminder to move, as a feedback on recent activity during work occupation.

Most of these systems fall in the category of assisting people, by keeping users in a passive role, rather than providing them with information to support their awareness and understanding (Hirano et al., 2013). These systems mostly focus in implementing collection and visualization of objective data. As mentioned by (Moore et al., 2010) current personal information technology is being designed to optimize productivity rather than self-understanding. Physical activity behavioral change is also related to identify opportunities thus focusing only at the level of physical activity may not be sufficient (Li, 2009). The assistive approach of these systems focuses their benefit on providing engaging instructions rather than increasing reflection. As pointed by (Pirzadeh, 2013) there are a limited number of studies that focus on the process of reflection in designing personal informatics systems.

6.5 Design elements

ESTHER 1.3 features two types of interaction elements: active elements that require explicit user actions and assistive elements that provides relevant and timing information to user. Active elements are implemented by means of in-situ prompting mechanisms of self-reporting (mCR) and goal setting. While assistive elements provide physical activity monitoring and visualizations, and notifications.

6.5.1 Physical activity monitoring

Based on a minimal recommendation of 2000 steps during working time (Fortmann et al., 2013), ESTHER 1.3 advises the knowledge worker to perform at least one activity, consisting of 5 minutes walking every three hours, with a total of at least four such activities per day. This represents in total 20 minutes of physical activity as researchers have determined that a rate of at least 100 steps per minute achieves moderate intensity activity (in: <http://www.sciencedaily.com>). In order to provide detailed representation of physical activity over the day, a ring circle is broke down into small segments to 5 minutes to show in real-time the physical performance (Figure 28, group 3). Four different performances are represented by 4 different shades of green: white=non-existing activity/0 steps/0 min.; light=low/100 steps/1 min.; mid-green=medium/300 steps/3 min.; and saturated green=high/500 steps/5 min. This data is collected by an in-built accelerometer and assessed by using an algorithm that processes movements into number of steps.



Figure 28. Design elements of ESTHER 1.3: In-situ self-report prompting, daily activity planning and physical monitoring.

6.5.2 Scheduling targets of physical activity

In order to accomplish the minimum of 2000 steps as a daily physical activity goal, ESTHER 1.3 asks the user to schedule at least 4 targets of 5 minutes walking throughout the day, which is displayed in the outer (blue) ring of the interface (Figure 28, group 2). Each target of 5 minutes represents 500 steps as the minimum threshold. The ring circle is divided in 4 segments of 2 and 3 hours to help users distribute their goals accordingly to specified health standards. It also aims to help users map their own personal work routines such as coffee breaks, lunch or meetings in such division. In this implementation of ESTHER 1.3, targets cannot be changed once they have been set. This has the purpose of encouraging reflection upon the planning of new targets.

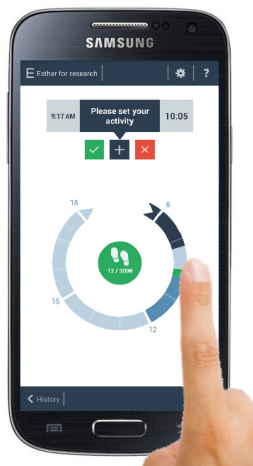


Figure 29. Planning of targets.



Figure 30. ESTHER 1.3 screenshots. On top the prompting according to three status of physical performance (WOW, OK and OOPS). Left down comment note pad; centre down emotions and activities selections; right down notification of an approaching target.

Activities are displayed by default in a green color; they may change to yellow or red depending whether the minimum threshold of 500 steps was not achieved (red), just achieved (yellow) or far achieved (green). This enables easy comparison between the planned activity in the outer ring and the real activity performance displayed in the inner space (white area) at any particular time. The activity performance uses three tones of green to reflect the number of steps registered every 5 minutes. This, will help the user to spot, for instance if the activity at lunchtime was achieved or not. In addition, a reminder in the form of a notification with vibration and sound is provided 5 minutes before a set target is approaching.

6.5.3 Implementing micro cycles of self-reflection, (mCR)

ESTHER 1.3 implements mCR by developing two mechanisms: in-situ prompts and self-reports. In-situ prompts use an algorithm that triggers a prompt every quarter when met and not met targets occur. Prompts are notified by an on-screen visualization and optionally vibration and sound. The visual notifications use exclamations (WOW!, OK!, OOPS!, for green, yellow, red targets respectively) with the aim to provoke the user to self-report. The self-report offers two options: report the current emotional state in reactin to the prompt and report the activity performed when the target was prompted. Users can select one emotion from a list of five: happy, confused, annoyed, great and sad and a maximum of two activities from a list of six: meeting, working, eating, phone, chatting, and other activities. The self-reports are visualized next to the prompted target. Additionally, users can add an extra emotion and activity at any time as well as comments, without the need of a prompt. These extra self-reports are also displayed on the outer ring positioned at the time when the user input the self-report,

whereas the comments can be accessed on an in-built notepad. Finally, a history of previous days is accessible by navigating through the history option. Additionally, the user can add an extra emotion and activity at any time, without the need of a prompt. These extra self-reports are also displayed on the outer ring positioned at the time when the user input the self-report. Besides, the user can add open comments. This information will be accessed on an in-built notepad. A history of previous days is accessible by navigating through the history option.

Technically, ESTHER 1.3 is developed for Android platform. The application is a stand-alone system and does not need Internet to function. To implement the counting step, it uses the accelerometer integrated in most smartphones and an adjusted open source Android pedometer algorithm. The use of pedometer is an unobtrusive and effective way to measure activity (Van Hove et al., 2012) and it is suitable to assess the level of physical activity in knowledge workers, as walking is considered a moderate activity if done frequently (Fortmann et al., 2013). The application counts steps while the worker is carrying the phone in the pocket aiming to sense small but significant steps.

6.6 Study goal

The goal is two-folded: first to test how the implementation of mCR assists the reflection for planning targets; second to assess the effectiveness of targets reached when mCR is present. The study setup involves knowledge workers and two test conditions of two week (plus baseline of three days) performed in two different working environments. In the baseline condition steps are monitored, without providing an interface to the user; the control condition allows setting targets and provides real time visualization of physical activity; the experimental condition includes mCR by offering the previously described self-reporting mechanisms in the user interface. The setup is within-subjects, where the baseline is scheduled for 3 days, and the other two conditions take 10 working days each.

6.6.1 Data collection

Both quantitative and qualitative data linked with a time stamp are collected for analysis: a) system generated data of physical activity data in form of number of steps every 5 minutes and prompts and notifications; and b) users' inputs from setting targets, emotion reports, reported activities, and text comments. Additionally, the system stores a screenshot of the main display at the end of the day. General demographics of the participant are asked and capture once after the first time of use. All this data is stored locally in a text file.

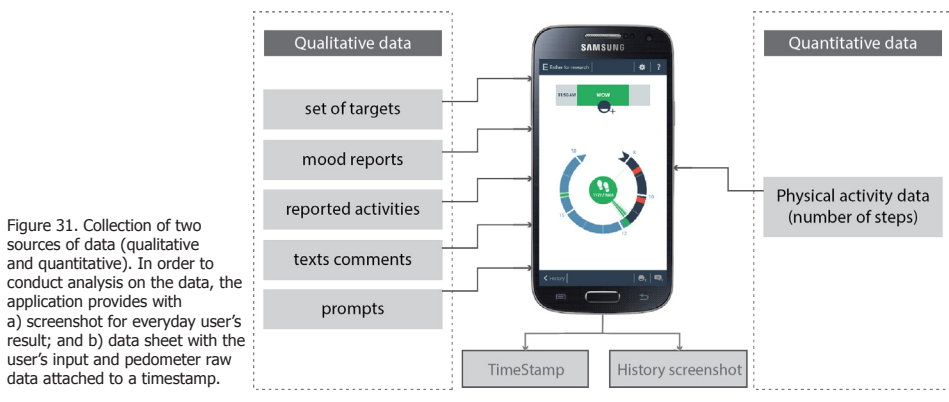


Figure 31. Collection of two sources of data (qualitative and quantitative). In order to conduct analysis on the data, the application provides with a) screenshot for everyday user's result; and b) data sheet with the user's input and pedometer raw data attached to a timestamp.

As part of the experimental procedure, the Flemish Physical Activity Computerized Questionnaire (FPACQ) was conducted at the beginning of the study and after each condition as a reference of the level of physical activity of each participant and to identify possible changes in the self-perceived physical activity level performed between conditions. This questionnaire determines the physical activity and the sedentary behavior of a usual week in employed/unemployed adults by determining the type of work (sedentary, sitting, manual or heavy manual work); the sedentary behavior (time spent in sitting, light/moderated intensity activities or hard intensity activities); amount of physical activity at work (vigorous, moderate or light activities); walking behavior (slow, average, brisk or fast pace); amount of steps; and performance (scale between 1 to 5) (Van Hoye et al., 2012). The study ends with a semi-structured interview to discuss participants' experiences and the given value to the design and functional elements of the application. In order to guide these discussions, the history of days were printed out and the results of the FPACQ questionnaire were presented to each participant. The final interviews were transcribed and translated from Dutch to English.

6.6.2 Participants and Protocol

Six knowledge workers (3 female and 3 male) were invited to participate, two of them volunteers from an ICT company and four from a university in The Netherlands. All participants contributed to the baseline (no-GUI) as initial activity; afterwards three of them (B, D, and F) were assigned to start with control condition (without mCR) and three (A, C, E) with experimental condition (with mCR) for the first 10 days and then alternate to cancel out order effects. During the study, participant F was unable to be actively involved with the study, therefore the analysis of the data was based on a total of five subjects. Their average age was 34.6 (SD=11.7). The three stages of the study were spread over four weeks, with 4-5 days available to conduct the interviews and questionnaires. The study protocol was conducted by an assistant researcher who was first trained to do so.

During the introductory interview, ESTHER 1.3 was downloaded to participants' smartphones from Play Store. The application was first ran by the assistant researcher to enter demographic information and to setup the condition. In all conditions, participants were asked to carry their phones in their pocket following their normal daily office routines. For the control and experimental conditions participants were also asked to interact with the app (previous demonstration and short training on how to use it). After each condition the assistant researcher visited each participant to download the locally stored data and to change the application setting to activate the new condition.

6.7 Results

Excluding the days affected by technical failures with the application, Christmas holidays, absent days and participants forgetting to bring the phone, in total 99 days of data out of 136 days from the initial plan are included in the results and analysis. Per day 10 hours of data plus one screenshot were collected from each participant. Due to the prolonged absence of two participants during the study period their participation was extended under their own will. Table 3 provides an overview of the data captured. Out of a total of 392 users' inputs, 46.4% corresponded to setting targets and 53.6% correspond to self-reports. From the 210 self-reports 47% were emotion (75% related to a target), 45% activities (56% related to a target). Three out of the five Participants (P) were the most active during the experimental condition with PA=112, PB=103 and PE=104 compared to PC=31 and PD=42.

PARTICIPANTS	I	II	III
A	Baseline	Experimental	Control
B	Baseline	Control	Experimenta
C	Baseline	Experimental	Control
D	Baseline	Control	Experimenta
E	Baseline	Experimental	Control

Table 8. Order of condition per participant.

		Number of entries					avg.
		A	B	C	D	E	
Targets	TOTAL	40	42	29	31	40	36.4
Self-reporting	Happy	5	2	0	3	4	2.8
	Stress	0	1	1	4	4	2.0
	Proud	1	3	0	0	2	1.2
	Excited	5	0	0	0	3	1.6
	relax	11	13	0	1	3	5.6
	Tired	6	4	0	0	14	4.8
	Bored	0	2	0	0	2	0.8
	Angry	0	3	0	1	0	0.8
		28	28	1	9	32	19.6
	Activities	28	31	1	2	32	18.8
Comments	16	2	0	0	0	3.6	
	44	33	1	2	32	22.4	
	TOTAL	72	61	2	11	64	42.0
Prompts	Responded	17	18	1	7	20	12.6
	No-response	23	24	28	24	20	23.8
	TOTAL	112	103	31	42	104	78.4

Table 9. Data flow.

This table shows the total number of inputs per participant. Sub-total number of goals set, self-reporting (moods, activities, comments) and the number of responded and no-responded prompts are also presented.

6.8 Analysis and findings

The presented analysis focuses on the data collected during the mCR condition. The data collected during the baseline and control is used as reference. The analysis includes the data collected from the results above presented, interviews, the self-perceived questionnaire (FPACQ) and the history of screenshots of each participant.

All participants used ESTHER 1.3 to set daily targets during the 10 days of without and with mCR. The amount of targets per day was, on average 3.82 ($SD=0.52$) in the without mCR condition: PA=4, PB=4.2, PC=2.9, PD=4, and PE=4; and 3.64 ($SD=0.59$) in the with mCR condition: PA=4, PB=4.2, PC=2.9, PD=3.1, and PE=4. With a recommended amount of four targets per day, this result represents an active involvement of users in setting goals. However, when looking at the number of reports (emotions, activities and comments) two sub-groups of participants can be identified: a) the active-involved including PA=72, PB=61 and PE=64, and b) the passive-involved including PC=2 and PD=11. Beyond the high involvement of all participants in the setting up of targets, the analysis of these two sub-groups becomes interesting when the individual's level of physical activity collected by the application (steps) is compared with the users' self-perceived physical performance and how they varied through the conditions. Additionally, how targets (achieved and failed) varied between the conditions and overtime also deserved special analysis. To further investigate these two sub-groups the analysis per participant was divided in two phases:

a) Effects in physical activity awareness: understand how awareness on own physical activity changes between the conditions and what elements support the possible changes by analyzing the differences between participant’s physical activity (sensed data) and the self-perceived assessment (FPACQ)

b) Performance in achieving physical activity targets: understand the changes of setting targets between conditions and overtime, and what elements of the application supported these changes by plotting the changes overtime of planned targets are plotted and complementing the results with interviews’ insights on participants’ experiences with the application and the value given to different interaction elements.

6.8.1 Participant A

Participant A was the most active using ESTHER 1.3 with a total of 112 entries (see Table 3). All emotions reported were related to set targets and half of the activities and comments reported were also related to set targets. With more than 3 hours of moderated and light physical activities off work and a brisk pace walking behavior recorded from the initial FPACQ, Participant A is considered as physically active.

DAY	NUMBER OF INPUTS				
	A	B	C	D	E
1	18	11	2	4	10
2	13	14	4	0	12
3	6	12	5	0	10
4	12	11	4	8	8
5	11	6	4	5	8
6	10	11	2	6	12
7	12	11	4	6	12
8	11	9	3	5	12
9	9	8	3	4	12
10	10	10		4	8
S.D	3.08	2.21	1.01	2.53	1.84
Mean	11.2	10.3	3.4	4.2	10.4

Table 10. Daily use of the application per participant during the experimental period (10 days).

a) Effects in physical activity awareness

In the baseline condition Participant A estimated that 1000 was the amount of steps he performed in a typical working day with a level of performance of 3 (from 1-5 scale). Later, in the control condition (without mCR) the participant estimated the average of steps with 40000 steps per day during working time but a reduction in performance to 2. At the end of the experimental condition (with mCR), 7000 steps per day was the estimation with an incremental performance of 3. The participant reported 40000 steps because that was what the application displayed, but he scored himself lower. The application at that condition was set too sensitive providing wrong information of more than 70000 steps everyday. Interestingly, the participant estimated a lower performance in this period compared to the baseline. This high level of self-awareness is revealed when comparing the self-perceived physical activity with the collected data from the pedometer:

“... I mentally walked to the secretary and back and roughly thinking of how many steps it would be and walking to the station and things like that; But I can imagine that is very inaccurate”.

“this period [control condition] was around the holidays, and I worked at home a few days, so that could be why I walked a bit less then; ... I think I mainly came by car”

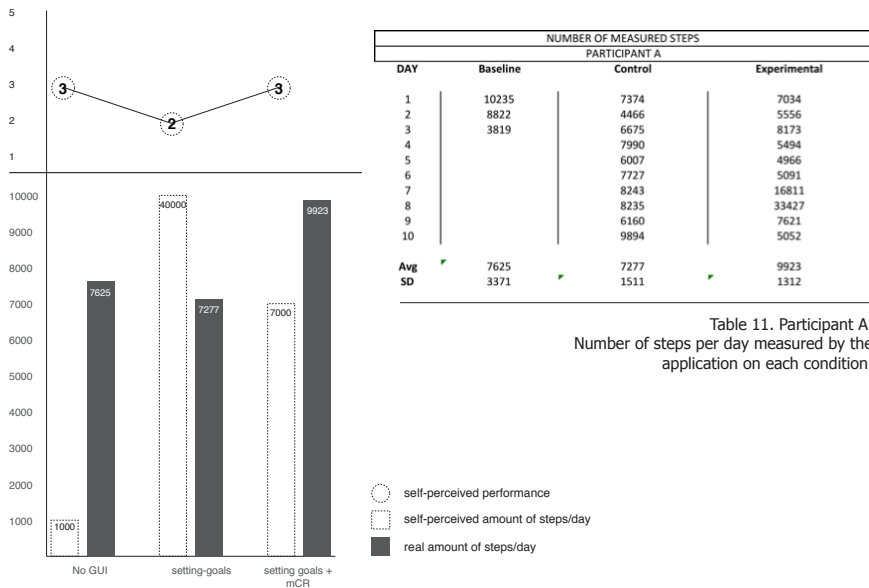


Figure 32. Participant A. Correlation between conditions: the self-perceived performance (top), the self-perceived amount of steps/day (dashed line columns) and the sensed amount of steps/day (orange column).

The participant reported that the **inner space** (with visualizations of actual physical activity) was the most helpful function to gain awareness:

“I became more aware of what were the moments that I was active, and their relative intensity or their length or so. For example at a certain point I knew what to expect when I walk from the railway station to here and when I walk through the whole building I saw only a tiny line that would still be very insufficient”.

The participant exhibited a high degree of physical activity behavior on all conditions, exceeding the recommended amount of daily steps. With an average of 7625 steps in the baseline, that decreased to 7277 steps in the control condition and then increased to 9923 steps in the experimental condition (Table 11), the physical activity was comparable to the self-perceived level of physical activity through all the conditions (Figure 32). It is important to note that the average of the baseline condition shows a high variability in the data. The reasons of this may be due to the not stable daily work routines for personal reasons presented during the baseline conditions that were shared by the participant during the interview.

b) Performance in achieving physical activity targets

Out of the 40 targets set during the control condition 13 were not achieved (red), 12 were close to target and 15 achieved. In the experimental condition also 40 targets were set, with 11 not achieved (red) 6 close to target (yellow) and 23 achieved (green). Considering yellow and green as “achieved targets” of physical activity in a time frame of 5 minutes, the experimental condition improved the number of achieved targets in only 5%. Showing the history of screenshots to the participant during the interview, he confirmed this little change:

“So from here [condition 1 to 2], there might be some effect from the app, from here [condition 2 to 3] I don't think so”

The participant perceived **notifications** as bringing little value to achieve targets:

“In a number of cases these moments [notifications] where scheduled because they were in between meetings. So in that case I would become active because I would walk from a different room to my own room. So the walk would be there anyway, so then the notification doesn't help, because if there is a notification or not, the walk would be there anyway”

“But I think in many cases the targets where scheduled in a time that I would walk anyway so then the notification is of no help”

The **notifications** were more valuable as a reminder to set new targets everyday in the morning:

“So what did help here [experimental condition], was that in the morning it gave me a reminder to set the targets. Otherwise I would have totally forgotten about the app. That was important”

The participant considered that adding **comments** attached to the targets was useful to remember later what happened.

“Yeah, I looked back one or two days to see how I did. And how the day was compared to the day before or the day before that”.

However, the emotions provided by the application were considered as not suitable for the work environment:

“The smileys I think the categories didn't fit, I can't remember what the categories were exactly, but some didn't seem very much related to office work”

As the participant reported, the most helpful function of the application to think about setting new targets was looking at the **inner space** and the **step counter**:

“why is that pattern so strange at that day? So during the day I looked at these rays, the inner space ... so the most valuable things to me were those rays and the step count”.

During the experimental condition the participant returned from holidays and time at work was more stable. This in turn increased the number of steps due to the walking between the train station and the office in several occasions. Some of these activities were self-reported as comments attached to a goal. When mapping the targets overtime (Figure 33) it is possible to see how gradually the performance of targets improved.

Although the participant was highly involved with the application and reported as valuable to understand personal daily habits in physical activity, his general perception towards the app was that it did not provide new information to find new ways to improve his physical activity at work:

“I realized (sometimes) it would help me to move more, but it didn't help me in finding new ways to do that”

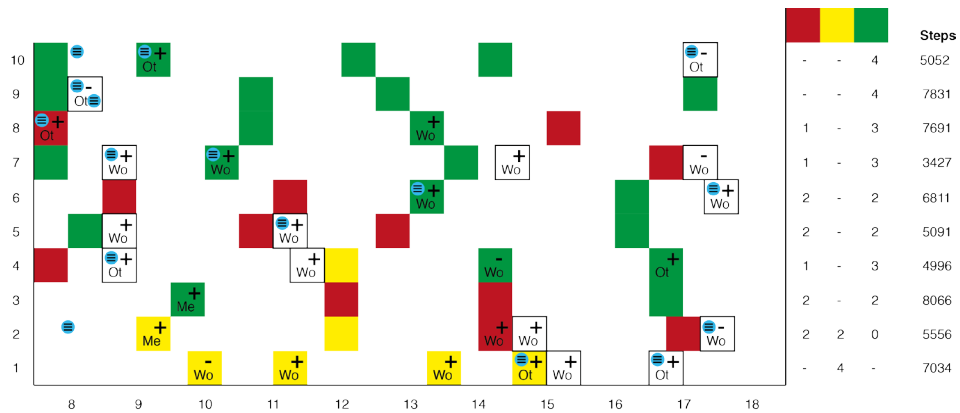


Figure 33. Participant A time line of setting targets and self-reports. X-axis shows the work time between 8am and 6pm. Y-axis shows the number of days. Green and yellow boxes represent achieved targets and red as not achieved. Participant's self-reports activity (Wo=work; Ot=other; Me=meeting) and mood (positive or negative) are displayed as white boxes when representing extra reports (not related to a prompt). Columns at the right represent the total number of targets achieved and the number of steps performed in a day.

6.8.2 Participant B

This participant was the second most active-involved users with the application with a total of 103 entries (see Table 3). More than half of the emotions (17) and activities (19) were related to set targets. Based on the FPACQ questionnaire, this participant is considered as non-active with 1-3 hours a week of light activities off work and a steady average pace walking behavior.

a) Effects in physical activity awareness

Participant B first self-assessment reported that 100 steps was her estimation in a typical working day with a level of performance to 2. For the control condition the participant reported an estimated amount of 3000 steps with an increment in performance to 5. At the end of the experimental condition, 1800 steps per day was estimated with a little reduction in performance to 4. These estimations matched how the actual physical activity performance steadily decreased with an average of 4674 steps in the baseline, 3471 steps in the control condition and 2611 in the experimental condition (Figure 34). The participant also confirmed these changes:

“So the 3000 was fitting in that time that I was walking a lot around, the 1800 is actually a number.. the goal was 2000, in this last week or two weeks I had troubles to reach my goals. But the 1800 was a relevant number”

As in the previous case, the control condition provided the user with visual information facilitating a better self-awareness, similar to the experimental condition. The difference between them in this case is, however, that the performance in achieving set targets was improved in and during the experimental condition.

A

	control condition			experimental condition		
	R	Y	G	R	Y	G
1	2	1	1	-	4	-
2	3	-	1	2	2	0
3	1	2	1	2	-	2
4	-	2	2	1	-	3
5	1	2	1	2	-	2
6	1	1	2	2	-	2
7	2	-	2	1	-	3
8	1	1	2	1	-	3
9	1	2	1	-	-	4
10	1	1	2	-	-	4
	13	12	15	11	6	23
				27		29
avg	1.4	1.5	1.5	1.6	3.0	2.6
SD	0.73	0.53	0.53	0.53	1.41	1.24

B

	control condition			experimental condition		
	R	Y	G	R	Y	G
1	3	1	-	3	1	-
2	3	1	-	2	2	-
3	5	1	-	4	-	1
4	3	-	1	2	1	1
5	-	-	3	2	-	2
6				3	1	-
7				3	2	-
8				2	1	1
9				2	-	2
10				1	-	3
	14	3	4	24	8	10
				7		18
avg	3.5	1.0	2.0	2.4	1.3	1.7
SD	1.00	0.00	1.41	0.84	0.52	0.82

C

	control condition			experimental condition		
	R	Y	G	R	Y	G
1	3	0	0	0	1	1
2	2	1	0	3	0	1
3	3	0	0	0	2	1
4	3	0	0	3	0	1
5	0	0	3	3	0	1
6	2	0	1	0	0	2
7	2	1	0	2	0	2
8	0	1	1	1	0	2
9	0	2	1	0	1	2
10	1	1	1	0	0	0
	16	6	7	12	4	13
				13		17
avg	1.6	0.6	0.7	1.2	0.4	1.3
SD	1.26	0.70	0.95	1.40	0.70	0.67

D

	control condition			experimental condition		
	R	Y	G	R	Y	G
1	3	1	0	4	0	0
2	4	0	0	0	0	0
3	3	0	0	0	0	0
4	3	1	0	0	0	0
5	4	0	0	2	2	0
6	4	0	0	3	0	1
7	4	0	0	2	0	1
8	4	0	0	0	2	2
9	4	0	0	2	1	1
10	3	1	0	4	0	0
	37	3	0	21	5	5
				3		10
avg	3.7	0.3	0	2.1	0.5	0.5
SD	0.48	0.48	0	1.66	0.85	0.71

E

	control condition			experimental condition		
	R	Y	G	R	Y	G
1	4	0	0	2	1	1
2	1	2	1	1	3	0
3	0	3	1	1	3	0
4	1	3	0	2	1	1
5	2	2	0	2	1	1
6	1	2	1	1	2	1
7	3	1	0	1	2	1
8	3	1	0	2	0	2
9	2	1	1	1	2	1
10	1	2	1	1	1	2
	18	17	5	14	16	10
				22		26
avg	1.8	1.7	0.5	1.4	1.6	1.0
SD	1.23	0.95	0.53	0.52	0.97	0.67

Table 12. Participants' performance in achieving targets. Amount of achieved targets (R), just achieved (Y) and far achieved (G) per day between control and experimental condition.

b) Performance in achieving physical activity targets

Participant B forgot to use the application during the control condition, thus targets were set in six out of the ten days. This resulted in a total of 25 targets, with 18 not achieved (red), 4 close to target (yellow) and 3 achieved (green). In the experimental condition, 42 targets were planned during the 10 days, 24 not achieved, 8 close to target and 10 achieved (Table 12). By taking into account the first six days of these two conditions, it can be seen an improvement in 11% of targets achieved. This improvement is further seen when looking at the overview of targets during the control condition (Figure 35), where more green targets were gradually incremented overtime.

During the interview the participant reported how the self-report prompting helped in reflecting how to achieve a target:

“How the prompting helped me reflect? Well it helped me prepare mentally to find how to do some activity. In terms of the prompts help me think of the overall, I realized ‘Oh I didn’t walk that much, so maybe I will take a quick walk’. So to change that I would go to the bathroom in the other department or something like that”

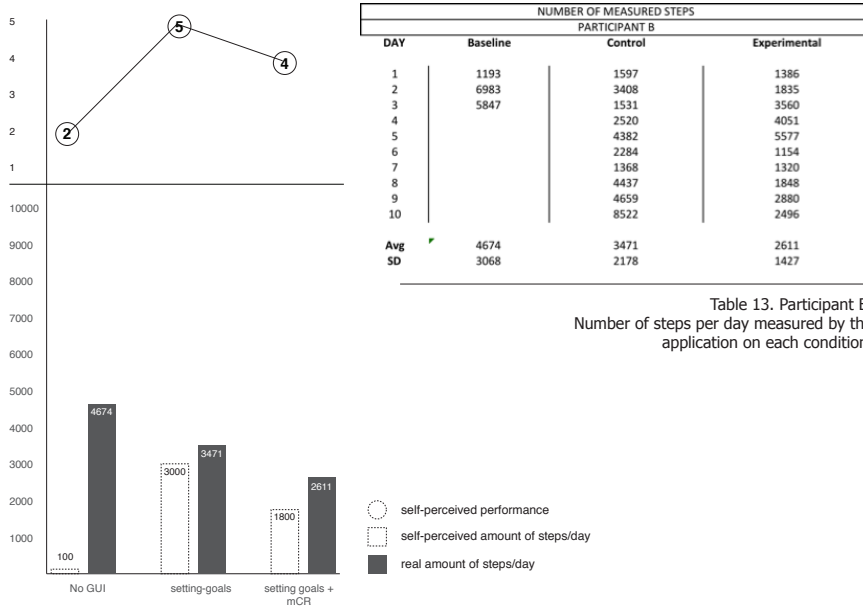


Figure 34. Participant B. Correlation between conditions: the self-perceived performance (top), the self-perceived amount of steps/day (dashed line columns) and the sensed amount of steps/day (orange column).

The emoticons were used to either express feelings concerning personal emotions or the state of mind at that particular moment in time instead of reactions against the promptings. This made difficult for the participant to apply them in a useful way.

The history was perceived as valuable as a source of information to remind her what happened days before:

“I like to look at the history, because I can see if I in that week didn’t walk at all or if I should walk more”;... well, you should look back at the history, it can help you remember what were you doing at the time”.

On the other hand, the notifications were perceived as valuable to help take action towards a coming target:

“It did remind that I have to remind myself to go. It was more a mental preparation than anything else. “cos I had to make the decision to stop my work and go. Otherwise I would not go”

The outer ring was perceived as a source of motivation:

“But in the moment when I walked and I made it yellow, I was kind of happy. But I really changed my behaviour in order to meet these targets”.

In general this participant found the application valuable to gain awareness and reflect about her physical activity behaviour:

“It made me think [the application] that I do very little activity during the day and it left me curious to track my physical activity myself. I did change my behavior”

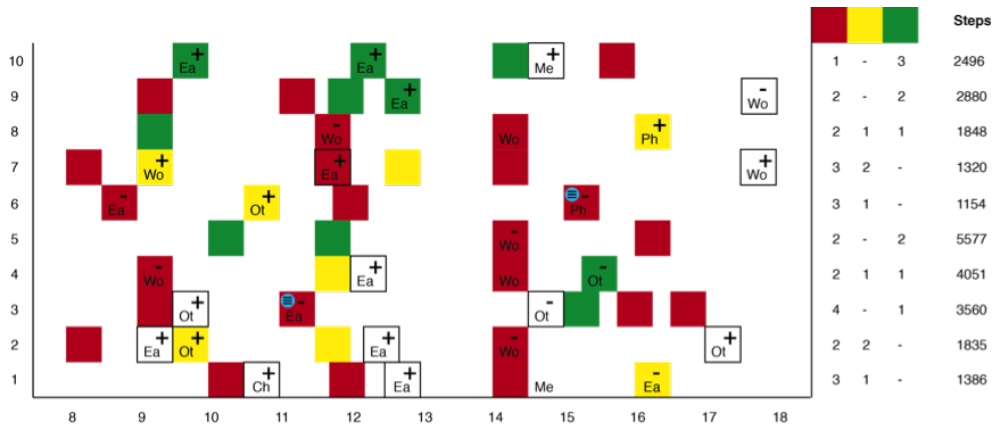


Figure 35. Participant B time line of setting targets and self-reports. X-axis shows the work time between 8am and 6pm. Y-axis shows the number of days. Green and yellow boxes represent achieved targets and red as not achieved. Participant's self-reports activity (Wo=work; Ot=other; Me=meeting) and mood (positive or negative) are displayed as white boxes when representing extra reports (not related to a prompt). Columns at the right represent the total number of targets achieved and the number of steps performed in a day.

6.8.3 Participant C

With a low involvement with the application, Participant C provided a total of 31 inputs, which 29 corresponded to targets, 1 activity and 1 emotion. One possible reason for the low involvement relates, as the participant reported during the interview, to the technical problems experienced with the smartphone:

"Sometimes I had to get used to recharging it often, I was walking around with no battery".

The initial reference of physical activity level correspond to an active person with more than 3 hours of moderated and light physical activity off work every week and brisk pace walking behavior.

a) Effects in physical activity awareness

Participant C finished the baseline condition estimating that 5000 steps was his personal average everyday during working time with a performance of 2. In the control condition his assessment was 3000 steps with a performance of 2. In the experimental condition his estimation stayed the same with 3000 steps and an improvement in performance to 3. Participant's actual physical activity was in average 3137, 2669 and 3261 steps in baseline, control and experimental condition correspondingly. When compared, it can be seen that the level of awareness was stable through out the conditions.

b) Performance in achieving physical activity targets

A total of 29 targets were planned during the control condition, 16 were not achieved (red), 6 close to target (yellow) and 7 achieved (green). In the experimental condition the same number of targets were set, 12 corresponded as not achieved (red), 4 close to target (yellow) and 13 achieved targets (green). Only 1 emotion and 1 activity were reported. There was an improvement of 14% in achieving targets between the conditions.

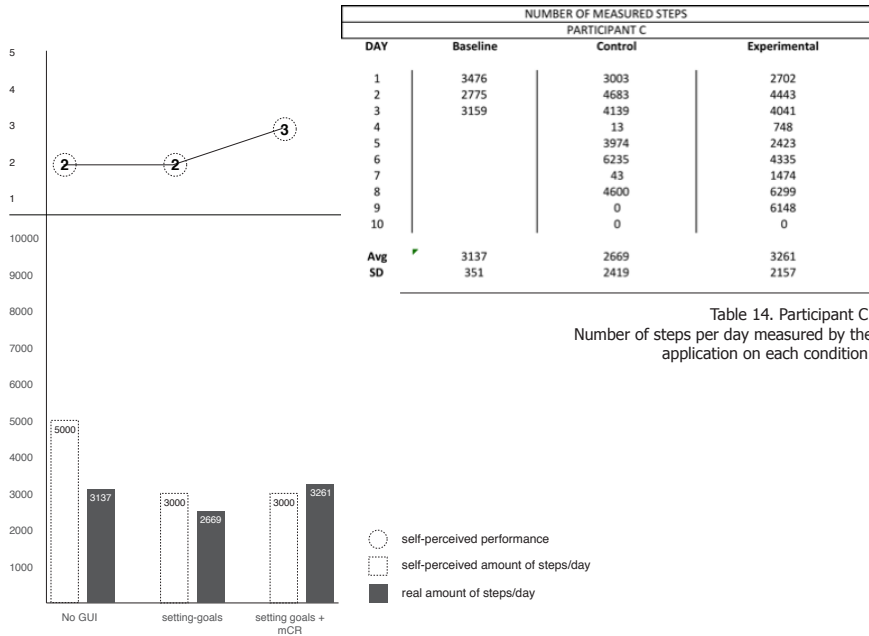


Figure 36. Participant C. Correlation between conditions: the self-perceived performance (top), the self-perceived amount of steps/day (dashed line columns) and the sensed amount of steps/day (orange column).

As stated by the participant, his working day was very diverse making it hard to plan enough targets ahead. Although struggling in setting targets in the outer ring, this task was seen as highly valuable to reflect about the day that is coming, and as a motivator to be active during the day:

“My days are so different, and I have very different kind of activities. And I tried to fill it in accordingly to appointments, so if I have a meeting or something, then I place it before or after”.

“But to have this moment of planning in the morning where you think about it is really nice I think, it motivates me”

“Well its nice that you plan it for the day, it gives some motivation in the morning, like Im going to do this 3 times and that you can plan it”.

With the step counter, realizing that the daily steps quota was reached was a strong motivator for this participant. He did not pay much attention to the self-report prompting. However, the performance overview displayed in the inner space was perceived as more functional:

“I think the green stripes, and how big they are in a day had more that function for me, so I could see how it differs. And setting the targets maybe was more valuable than the prompting for me”.

In general Participant C did not find the application as useful to improve his current physical activity. But the application was seen as a good instrument to identify daily habits in physical activity.

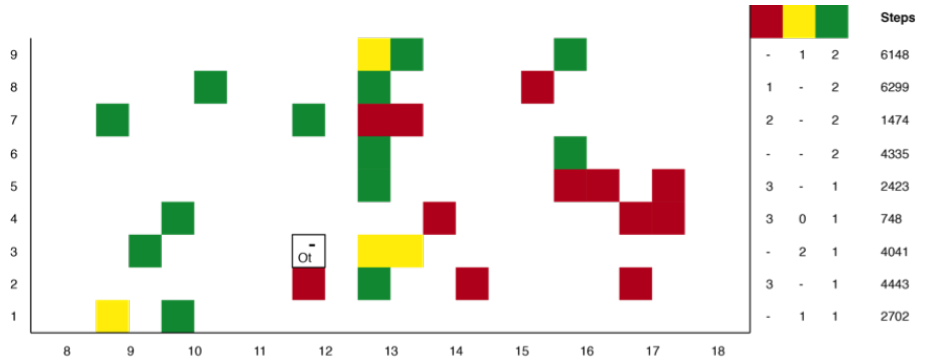


Figure 37. Participant C time line of setting targets and self-reports. X-axis shows the work time between 8am and 6pm. Y-axis shows the number of days. Green and yellow boxes represent achieved targets and red as not achieved. Participant's self-reports activity (Wo=work; Ot=other; Me=meeting) and mood (positive or negative) are displayed as white boxes when representing extra reports (not related to a prompt). Columns at the right represent the total number of targets achieved and the number of steps performed in a day.

6.8.4 Participant D

Participant D provided a total 42 inputs, with 31 targets, 9 emotions and 2 activities reported. The reference physical activity level of this fourth participant is established as active with 3 or more hours of moderated and light off-work activities and a brisk pace walking behavior.

a) Effects in physical activity awareness

The baseline condition assessment resulted in 30-60 steps during working time with a performance of 1. The control condition resulted in an increased self-perceived amount of 150 steps and performance of 4. The questionnaire for the experimental condition reported an amount of 500 steps with a stable performance of 4.

Participant's actual physical performance was in average 482 and 1987 steps in control and experimental condition correspondingly. There is no record of sensed data during the baseline condition due to an incompatibility of the application with the participant's Android smartphone operative system (Gingerbread, 2.3). The application had to be re-coded to broad its compatibility with old OS android versions.

b) Performance in achieving physical activity targets

The performance during the control condition was considerably low with 40 targets, 37 not achieved, 3 close to target and none achieved. In contrast, more involvement with the application was seen in the experimental condition with a total of 31 targets, 21 not achieved (red), 5 close to target (yellow) and 5 achieved (green). The participant reported 9 emotions, 6 related to targets, and no added comments.

Although the participant did set targets during the control condition, it was perceived as no high value in meeting those targets. The participant stated:

"I know that I missed several targets every day, but that doesn't really matter for me"; "...I want to walk. And I don't really care about the targets"
"... there was no real intention of the time. I know somebody would probably check their schedules to check when they could have a walk or whatever. But I don't"

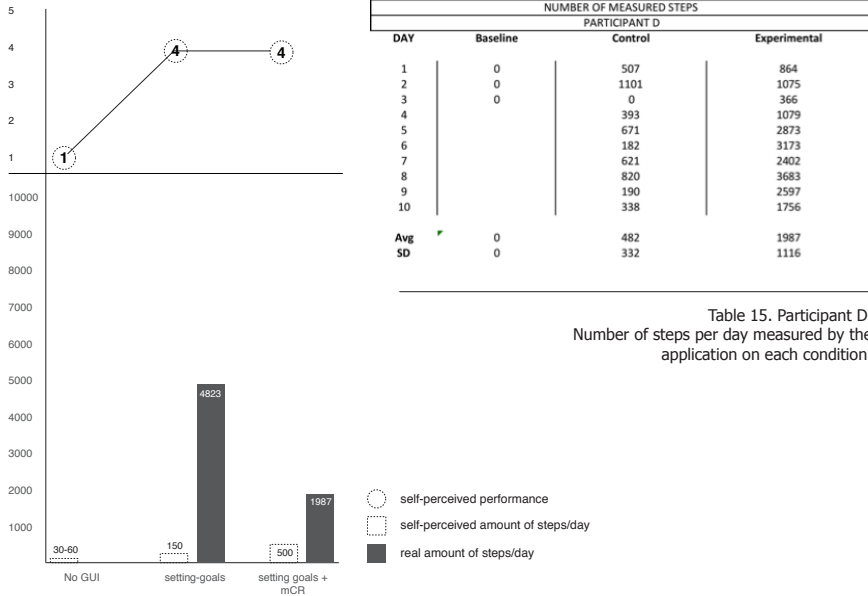


Table 15. Participant D. Number of steps per day measured by the application on each condition.

Figure 38. Participant D. Correlation between conditions: the self-perceived performance (top), the self-perceived amount of steps/day (dashed line columns) and the sensed amount of steps/day (orange column).

The notifications could be the reason for the slightly improvement performance in achieving the targets in the experimental condition:

"I noticed the notifications, because that would vibrate... I would be reminded... it sort of influenced me"
"there are some situations that prompt you to walk more. And I like to collect the points of steps, I like to see the steps growing!; ... I think those numbers really matter"

The possibility to share information with friends was seen as a motivation mechanism to reach a target:

"I then go for a walk... I would probably use it as a topic to have a conversation with my friends 'Look at my records, today I have achieved one thousand something steps!'"

Having access to the history was the element in the application that helped the participant to reflect about the performance of a particular day:

"When I arrive home, when I charge my phone, I would check it and see how many steps I actually walked during the day. So it is possible I would see the orange, but I would take it as 'Wow that is a coincidence, so I actually stayed on my schedule!'"

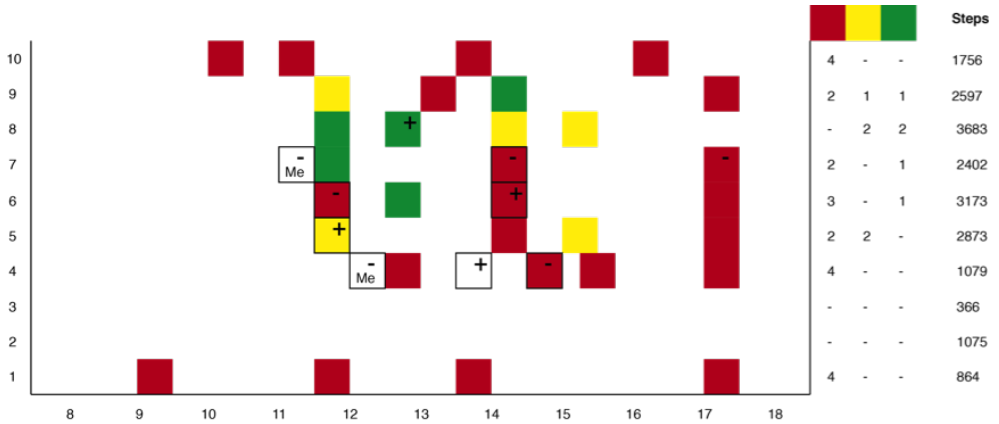


Figure 39. Participant D time line of setting targets and self-reports. X-axis shows the work time between 8am and 6pm. Y-axis shows the number of days. Green and yellow boxes represent achieved targets and red as not achieved. Participant's self-reports activity (Wo=work; Ot=other; Me=meeting) and mood (positive or negative) are displayed as white boxes when representing extra reports (not related to a prompt). Columns at the right represent the total number of targets achieved and the number of steps performed in a day.

The self-report prompting was perceived as a not valuable function in the application. When the participant self-reported, it was used as a way to tell the application that it was not the best moment to be physically active:

“Telling the phone that ‘Meh I’m not in the mood, I’m super stressed, do not bother me!’ So that was like the reason”

In terms of how valuable was the application for the participant, it was reported that it was found useful to see personal progress, more than to change or modify physical activity habits.

6.8.5 Participant E

Similar to participants A and B, participant E was actively involved with the application with a total of 104 inputs, were 40 corresponded to targets, 32 emotions and 32 reported activities. The participant is classified as no active with less than 1-3 hours a week of light activities and less than 1 hour of moderated activities off-work, with an averaged pace of walking behavior.

a) Effects in physical activity awareness

The participant finished the baseline condition estimating 500 steps during working time and a performance of 2. At the end of the control condition his assessment in number of steps increased to 1800 and a stable performance of 2. The experimental condition ended with a higher assessment of 2000 steps and a performance of 3. As for the actual number of steps, the results were an average of 5100 in the baseline, that decreased in the control condition to an average of 2786 steps and incremented to 4055 in the experimental condition. There is a better match in participant's accuracy of his awareness between the average steps and the increased self-perceived average steps and its performance level at the control and at the experimental condition (Figure 40).

b) Performance in achieving physical activity targets

During the experimental condition, out of 40 targets 14 were not achieved (red), 16 were close to target (yellow) and 10 were accomplished (green). With a total of 32 emotions reported, 20 emotions were reported to the targets; and 32 reported activities. In the control condition 40 targets were set, where 18 were not achieved, 17 were close to target and 5 achieved. Similar to Participant B, there was a performance improvement of 10% in meeting targets between the control and the experimental condition.

The participant reported that the notifications promoted to be more active:

“Oh most of the time I ignored it [notifications].. Then I saw, oh yes its almost time again. Yes, then I was deep in programming code and then I thought: ‘Hello.. eh.. I am not getting up”

“You have to do those things [targets]. ‘Oh yes I have to go up using the stairs because I have the telephone in my pocket, so.. Yes well and it’s pretty intensive..”

“most of the time in the morning when I got a notification I would say okey lets go for a little walk”.

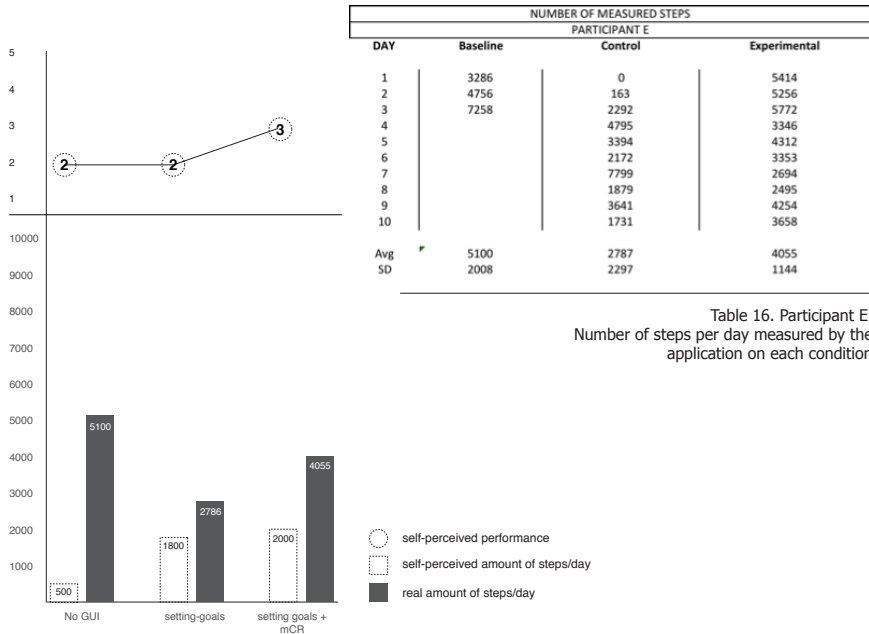


Table 16. Participant E. Number of steps per day measured by the application on each condition

Figure 40. Participant E. Correlation between conditions: the self-perceived performance (top), the self-perceived amount of steps/day (dashed line columns) and the sensed amount of steps/day (orange column).

The impact given to those notifications can be seen in the Figure 41, with the major number of achieved targets in the morning. The self-report prompting was perceived as a valuable element to achieve a target since it asks to look at the application and then think about ones progress:

“Here I didn’t feel very well probably, it could be that I was a little sick... Then lunch, and I thought I do two targets after it. But well then I often missed those, so I thought well then I do two around lunch, then I may only miss that one in the afternoon”

As an integral overview, the history helped to reflect upon the previous day towards planning new targets. This helped participant E to map the day and plan targets ahead:

“I can see how much I moved and at which moments. And here I walked to my car and here I took the stairs.. and here I walked around..”

“.. I think that I, yes, I had to have four moments of course where I had to walk, so I think I go more often with the stairs. After lunch I would take the stairs when I went up..”

Participant E showed high involvement with the application and it was perceived as both a valuable tool to understand daily habits in physical activity and to find new ways to improve.

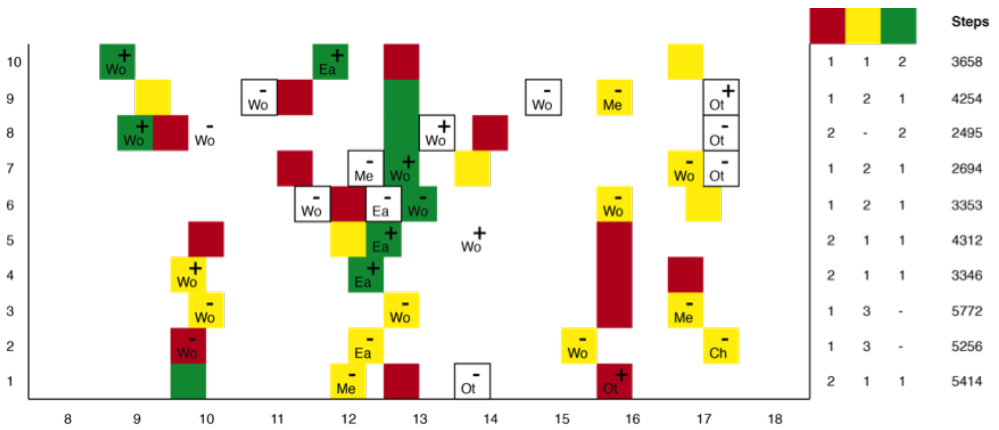


Figure 41. Participant E time line of setting targets and self-reports. X-axis shows the work time between 8am and 6pm. Y-axis shows the number of days. Green and yellow boxes represent achieved targets and red as not achieved. Participant’s self-reports activity (Wo=work; Ot=other; Me=meeting) and mood (positive or negative) are displayed as white boxes when representing extra reports (not related to a prompt). Columns at the right represent the total number of targets achieved and the number of steps performed in a day.

6.9 Discussion

The goal of this study was to explore the implementation of self-report prompting as a mCR mechanism applied in context. The discussion presented below reflects on this implementation and the value of mCR as empowering through reflection. The discussion is then structured based on the empowerment process addressing awareness, reflection and action (section 1.2) through ESTHER 1.3 design elements.

Despite the small sample size in terms of number of participants, possible trends were observed across the qualitative and quantitative data collected. The most salient result showed that ESTHER 1.3 affected participants’ physical activity in three different aspects. First, it influenced the level of awareness when compared between conditions. Second, an improvement in achieving targets was observed across the participants between control and experimental conditions and within conditions. Third, the application provided an explicit

means for reflection. However, the way these aspects were supported and what elements of the application were perceived as valuable for awareness, reflection and action seem to differ between the active participants (A, C, D) and not active participants (B, E).

6.9.1 Empowerment by awareness

Based on the quantitative and qualitative data collected, a general improvement of the accuracy of their physical awareness was observed in all participants. The level of actual physical activity (steps), regardless it increased or reduced through the conditions, matched with the level of physical activity estimated by participants in both active and not active groups. However, while the individuals of the active group may have a positive correlation between the levels of awareness with the actual activity, their level of involvement with the application was rather low (with exception of participant A). In contrast, non active participants, who also presented a positive correlation, showed higher involvement with the application. This may suggest that active individuals do not require much effort to maintain a positive level of self-awareness, or that the implementation of mCR tested in ESTHER 1.3 was too limited for them to benefit from. For example, the design rationale of the emoticons was to provide a way to report the feelings towards whether they meet or not the prompted target, however participants expected to be able to report their overall emotion of that moment (regardless the target status). When the app prompted and asked: “what is your emotion?” may have caused the participants to react against a general feeling rather the target as the study intended.

Active participants already have the knowledge and the habits, making their needs different from the non-active participants. People with strong habits tend to favor or seek out information that confirms their views, beliefs and behaviors (Maréchal, 2010). Active participants found valuable the notifications and the inner space because these are more descriptive and informative in nature. They are interested in following progress and maintain or improve. On the other hand, none active individuals lack of self-knowledge and need to build it in order to be more self-aware, and thus take action to change behavior.

6.9.2 Empowerment by Action

The application may also have an influence in the performance (achieving set targets). All participants improved the average performance between control and experimental condition, as well as within the experimental condition. Both active and not active participants considered valuable the prescriptive functions such as the notifications and the outer ring. They described these elements as assistive and reflective to take action towards achieving the next target. The activity to set targets in the morning is perceived as combining all three empowering elements from awareness to reflection, by looking at history and reflecting on how to project past experiences in the future (of that day) and action by reflecting on the performed targets.

6.9.3 Empowerment by Reflection

As seen in Chapter 1, the bridge between awareness and action is related to the process of reflection. In ESTHER 1.3 this process is represented on how mCR may have influenced participants in planning and achieving targets. In contrast to awareness and action, where the same elements of the application were considered valuable, the elements perceived valuable to the process of reflection differ between active and not active participants. It was found that the value given to different elements of the application as reflective means related to how active or not active was the participant on a daily basis.

The active participants defined the self-report prompting (emotions, activities and comments), as a high demanding task. Its value was secondary and useful as long as it complements and integrates the history of previous days, so that they can reflect on them later. Instead, they reported as more valuable elements that are mostly numerical and informative such as step counter and the inner space visualizing real physical activity. Those elements were seen as contributing both awareness and reflection to track progress or plan a new target. For instance, Participant A reported that the inner space is a “good source for good insights”, or Participant C “a way to think how far you are” and Participant D “a good visualization to see progress”. Self-reporting was perceived as most valuable to the not active participants. The lack of previous habits regarding physical activity, they benefit from both the reflective elements of ESTHER in order to create self-knowledge and awareness, and the persuasive elements to facilitate taking action upon planned goals.

Based on the staged model of Personal Informatics, micro-cycles of self-reflection (mCR) is introduced to empower users by enabling their active role in the integration of data. The results showed preliminary insights that for those no physically active, their level of involvement with the app was more dynamic, managing a higher number of inputs with the system and improving the performance of targets over time within the experimental condition. ESTHER 1.3 features the first implementation of mCR and its properties:

Energetic

The application used exclamation words (WOW!, OK, OOPS!) attached to specific colors (green, yellow and red) as provocative prompts.

Light

The self-reporting protocol involved simple questions that were easy to understand. However, participants misinterpreted the question reporting general moods instead of emotions related to the failure or achievement of a target. Future implementations should investigate the value on reflection by reporting on specific emotions related to provocative prompts, as it is expected that it could nurture a longer term engagement.

Short

The prompting protocol aimed for quick reactions. Participants did not reported burden in replying the self-report prompting.

High Frequency

The application was conceived to support participants in achieving at least 20 minutes of physical activity during working time. Moreover, the application aimed that those minutes were equally distributed along the day. The frequency of the prompts was based on those requirements. In future implementations the frequency of the prompting protocol could be more dynamic, for instance, by decreasing the amount of prompts when the user’s performance of achieving targets increases.

Linked

the self-report prompting was related to the user’s physical performance. Future implementations could involve other sources of data such as agenda, indoor climate, day of the week, etc. to open the prompting protocol to related factors that can directly/indirectly influence physical performance.

One of the most interesting suggestions for improving the design of ESTHER 1.3 came from the participants. They wanted to shift in minutes or hours the targets that have been previously scheduled. Although this was not allowed in this study, further research should be performed to investigate how much users delay or avoid a following a target just like we do with the snooze of an alarm clock. This can make the application more flexible for the unpredictable work environment.

6.10 Conclusions

ESTHER 1.3 implements mCR by using self-reporting as a reflective mechanism to facilitate critical thinking in knowledge workers and support awareness and reflection during working hours. The implementation provides knowledge workers means through several interaction elements to reflect on their own physical behavior during working hours. The interaction elements allow them to set targets of physical activity over the day, monitor their progress and report on their current activities and emotional states in relation to their targets.

A field study evaluation, performed among five participants for a period of 23 days in their working environments, indicated that ESTHER 1.3 had an overall positive effect on the physical awareness and performance of achieving targets. All participants were initially highly involved in setting targets but further analysis showed changes in involvement which could relate to differences in how physically active and not active individuals valued the interaction elements of the application as a means to support awareness, reflection and taking action. Physically active participants valued more the interaction elements that assist (notifications and physical activity visualizations in the inner space) to get confirm what they know about their physical behavior. In contrast, physically non active participants considered valuable a wider spectrum of interaction elements in which both assistive and supportive elements play a role for them. With the aim to have a better understanding of the implementation of mCR in context, the study provided with interesting insights to further improve self-reporting as a mCR mechanism and propose extended developments to support reflection.

In summary, this chapter presents ESTHER 1.3 as the first design implementation to validate self-reflective mechanisms, that explores five interaction design properties to enable self-reporting as a energetic, light, short, high frequent and linked interaction. The properties offer ways to maximize the benefits of been actively involved in the integration of data by 'tagging' personal and subjective insights into the more objective and automatic data collected. This active involvement is seen as a first step to support empowerment by addressing the design challenge to balance user effort and engagement in the complexity of daily life practices. Following, Chapter 7 will briefly present two master graduation projects that explored the implementation of different mCR mechanisms in personal informatics systems.

7 EXTENDING THE IMPLEMENTATION OF MICRO CYCLES OF SELF-REFLECTION (mCR) IN PERSONAL INFORMATICS SYSTEMS



This chapter outlines two design research studies that were conducted to consider different micro-Cycles of self-reflection (mCR) mechanisms in the stage-model of Personal Informatics Systems: a) A smartphone application for THR elderly patients for sending and receiving tips from peers based on their home recovery experience. Physical activity behavior during their recovery period was also monitored by the system; and b) WRISTWIT, a wearable device presenting information on attention and time for ADHD children to increase on-task behavior.

The following chapter is based upon the paper:

Jimenez Garcia J., de Bruyckere H., Keyson D., and Romero N. (2013) "Designing Personal Informatics for Self-Reflection and Self-Awareness: The Case of Children with Attention Deficit Hyperactivity Disorder", publication on progress for Ambient Intelligence Conference – AmI, 2013, Dublin, Ireland.

And the work done by: Dirkje Johanna Kroon, as part of her MSc. Graduation project.

This chapter presents an overview of two master graduation projects exploring different micro-cycles of self-reflection (mCR) mechanisms: a) sharing, b) friendship and c) timing. The design and test of the different prototypes were conducted by means of the Empirical Research Through Design (ERTD) process (Keyson and Bruns, 2009) in which design concepts were evaluated with teachers, parents, medical staff and target users to define the functional characteristics and the scope of the solutions through iterative design prototypes, which were tested with specific research variables embedded in the designs. The design experiences gained with these cases aimed to provide insights in two aspects: 1) inform the potential of designing and implementing mCR as supportive/reflective mechanism for THR and ADHD, and 2) explore the development of devices that focus on the reflection stage as a core source for users empowerment.

7.1 Exploring sharing as a mechanism for self-reflection and self-awareness in THR patients: TiPi

by Dirkje Johanna Kroon
Supervisor: ir. Msc. Juan Jimenez Garcia
Chair: Prof. dr. David Keyson

A personal mobile application to support THR patients by creating a network of peers to share “tips and tricks” about their experiences during recovery as developed called TiPi. The main goal of the application was to: 1) focuses on increasing self-reflection and self-awareness by sharing “tips” to a social network, and 2) monitor physical activity and provide personal feedback via on-body sensors.

7.1.1 Background

The design of TiPi involved several explorative phases to get acquainted with the process of THR recovery at home. In the first phase of research the focus was on the hospitalization, recovery and rehabilitation of THR patients. This study consisted of a one-on-one qualitative interview with a hospital-based physiotherapist from Reinier de Graaf Hospital in Delft, The Netherlands. The interview of 60 minutes aimed to gain knowledge about the THR surgery procedure, aspects of recovery process and the motivation of the target group to follow the rehabilitation.

The second phase, encompassed two user studies; the first study focused on how physiotherapists guide patients during their rehabilitation at home and their influence on patients’ motivation during the whole process. It consisted of one-on-one qualitative interviews with two physiotherapists from the Harry van Vliet physiotherapy practice in Pijnacker. The second study focused on the Activities of Daily Living (ADL) of THR elderly patients and the rehabilitation from the patients’ point of view. The study involved the distribution of individual sensitizing sets among a group of six elderly patients (3 men and 3 women; age average 71) who received a hip prosthetic in the last 12 months. The sensitizing set comprised four exercises focused on a) who I am, b) my daily activities after surgery, c) my social contacts after surgery, and d) the biggest differences before and after surgery. Each assignment could be completed in about 10 minutes. These assignments were followed by one-on-one qualitative interview with each of the participants. The interviews were held at home and audio recorded for later reference. The goal of these interviews was to explore deeper into the subjects of the sensitizing materials and inquire after the self-awareness and motivation of the user.

The results of these explorative phases led to representation of THR recovery as a process, divided into two phases. The first is a short period of only a few weeks. During this time patients receive intensive physiotherapy and make significant progress in a short amount of time. The second phase is long-term, involving several months without the regular assistance of a physiotherapist. The rehabilitation in this phase is primarily dependent upon the motivation and commitment of the patient to continue with their exercises. Based on the interviews with patients and physiotherapists, it was evident that it is during the second, long-term phase that elderly patients experience the most difficulties in their rehabilitation process.

Motivation fades away

Based on the insights gathered with interviews with physiotherapists, one of the first encountered difficulties in the recovery process is to keep a constant physical activity level over time. When a patient shifts from the short to the long-term rehabilitation, they are already physically much more fit but they are not aware about this improvement. At the same time the feeling of urgency caused by the surgery decreases and patients start to lose their interest in the completion of the recovery process. This, combined with the loss of an external motivation source (in this case the physiotherapist), causes many patients to decide that their current condition is acceptable and to forget further rehabilitation. This can be countered by introducing a product that compensates for the loss of the physiotherapist. These factors helped to envision a system that can connect users with a supportive group, for example a group of peers, and became a new source of external motivation. By sharing their information they become both receivers and providers of support.

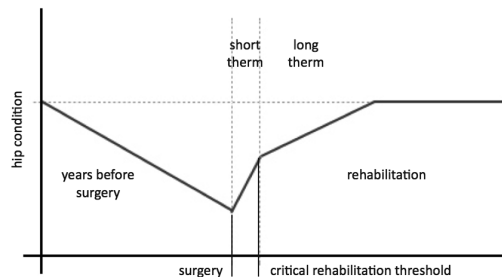


Figure 42. Overview of the recovery process before and after surgery.

Lack of self-awareness

The second difficulty reported by users during the recovery process is related to the perception of the rehabilitation progress. The results and improvements may not be as noticeable as in the first phase, because they are subtler and occur over a longer period of time. Combined with the loss of their physiotherapist as an external source that confirms their progress, patients no longer 'see' their own progress. This lowers their self-awareness and causes them to doubt the efforts they are putting into their rehabilitation. Through the use of a Personal Informatics system elderly patients may improve their self-awareness with regards to both the progress and knowledge about their rehabilitation and physical activity level.

7.1.2 Final Concept and Prototype

Traditionally within the stage-model of PI described by Li (2010), self-awareness is seen as the reaction of the user to the integration stage and the basis for the reflection stage. Their reflection then motivates the user to take action. However, this is a very one-dimensional

way of viewing these important characteristics within PI. It is important to understand that motivation and self-awareness are not just two separate aspects that are woven into PI. They are linked with each other as well. To reach this type of link between self-awareness and motivation the standard stage-model of PI needs to be enhanced. Even though this model does utilize both aspects, the focus is more on the means of creating awareness and does not allow many options for motivational aspects. To create the desired balance, the focus of TiPi therefore strengthens the integration and the reflection stages of PI by implementing a micro cycle of self-reflection (mCR) in the form of sharing experiences with a peer group as a source of motivation (Figure 43).

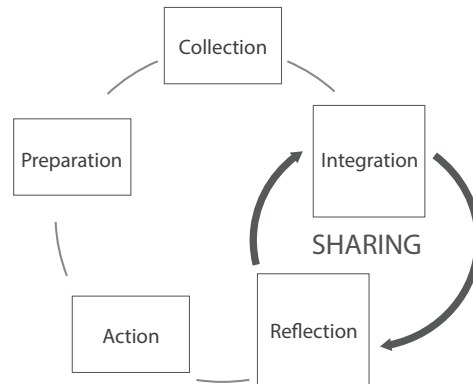


Figure 43. Integration and Reflection stages revolve around the social aspect of 'sharing' with a peer group.

TiPi prototype was implemented as an Android smartphone application (Figure 44a). It aims to facilitate sending and receiving tips between THR patients based on their home recovery experiences. Everyday users receive a 'tip of the day' that is written by fellow users. This tip provides not only practical advice, but also reminds the users that others are rehabilitating just like they are and that can relate to them. This creates a relationship that may help patients to be motivated as well as promote awareness about their situation. The application will also ask the user to send a tip once a day. This makes users reflect about their day and their rehabilitation and increases their self-awareness. An added bonus of this type of interaction is that users are not only receiving support, but also actively supporting others that make them feel good about themselves (insight identified during the qualitative interviews). To further increase self-awareness and motivation the application also supports physical activity monitoring. This information is private and cannot be shared through the application with other users.

The TiPi prototype features eight functions in total, three main and five supporting ones. The main functions are physical activity overview (Figure 44b) and receiving/sending a daily tip (Figure 44c and 44d). The supporting functions are the mood indication, sensor alert, personalized messenger bird, rating of received tips and received 'likes' for tips sent.

TiPi consists of two physical components. The first is the same node sensor used in ESTHER 1.2 worn on the hip (Chapter 5). This sensor collects physical activity data, which is sent to a smartphone. The second component is an Android mobile application. This application displays the physical activity data and it serves as the link to the peer network. The architecture of the system network for this link is displayed in Figure 45. This shows how all the users are connected to a group that corresponds to their progress phase of rehabilitation (e.g. all the users in their third week of rehabilitation). Sharing 'tips and tricks' has three components: the application that triggers the request for a tip (1), sending the given tips from the users to the corresponding groups in the cloud (2) and sending tips from the cloud to the correct users (3).



Figure 44. TIPI. Top left a) Android application in use; top right b) personal physical activity overview; below left c) tip sending; and below right d) tip receiving.

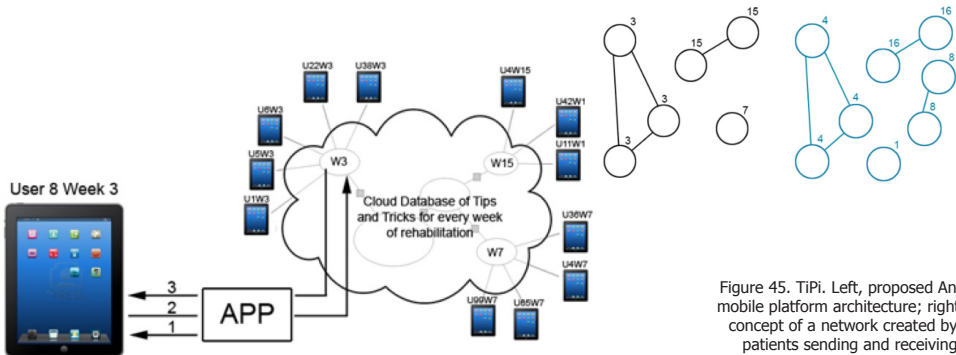


Figure 45. TIPI. Left, proposed Android mobile platform architecture; right, the concept of a network created by THR patients sending and receiving tips.

This leads to a social network where all users are connected (through the tips) with peers who are in the same stage of rehabilitation. These groups are anonymous and dynamic, changing whenever a new user appears or shifts from one phase group to the next. This is shown in Figure 45, where the black circles represents the network in a random week with users in week 3, 15 and 7. One week after, in blue circles, the groups change. Some groups shift together, from week 3 to 4 and 15 to 16, while user group 7 gets a new member and a whole new group for week 1 has started.

7.2 Exploring timing as a mechanism for self-reflection and self-awareness in ADHD children: WRISTWIT

by Hester de Bruyckere
Supervisor: ir. MSc, Juan Jimenez Garcia
Chair: Prof. dr. David Keyson

WRISTWIT focuses on the perception of time where a faulty sense of time awareness and management is seen as one of the underlying symptoms in ADHD (Hallahan et al., 2005). As Barkley states, self-awareness across time is the ultimate yet nearly invisible disability afflicting ADHD individuals (Hallanhan, 2005). A deficit in time perception is also mentioned by Yang et al. (2007), suggesting that children with ADHD have a faster sense of time internally. Therefore, future goals do not guide their present behavior, leaving them easily distracted by more immediate satisfaction in the here and now when a situation does not provide the immediate consequences or rewards. ADHD children are unable to estimate time spans and seem to feel no clear difference between small and large amounts of time. During classes where the child has to work independently this behavior is more evident. Their uncertainty about time, makes it difficult for them to independently adjust their behavior (Yang et al., 2007) ADHD children need support on-task behavior as well as support to get their attention back to class when being distracted. Motivation needs to be provided to increase their attention during the complete class section.

WRISTWIT is a wearable device targeted at ADHD children between 8-12 years old to improve their ability to work independently by supporting sense of time and attention in classes, where the environment cannot provide this much needed support. Described in following sections, context mapping techniques (Visser et al., 2005) observations and a focus group with children provided insights to frame the design concept into a personal bracelet that provides information to the child. WRISTWIT is designed to increase on-task behavior by: (1) increasing the sense of time, the bracelet displays time progress in a low-complex visual representation of 60 minutes by using 12 LED lights, each LED representing 5 minutes; and (2) increasing the level of attention, the device monitors body movement by means of an accelerometer alerting the child when he or she is inattentive.



Figure 46. WRISTWIT. This bracelet aims to support ADHD children to increase on-task behavior by increasing the sense of time and attention.

7.2.1 Background

The final concept of WRISTWIT was preceded by two explorative phases to understand time perception in ADHD children. The first phase consisted of observations and interviews that took place at two schools in The Netherlands to understand how ADHD behavior is specific to time in the school context. In total seven observation sessions of one to three hours took place and 17 qualitative interviews were conducted with eight teachers, four experts and five parents, giving the possibility to pose questions that arose during observations. Observations started at a regular elementary school in Delft, at the De Oostpoort. Two groups of 25 children

(age 8-10) and two groups (age 10-12) were observed during times in which at least one hour of independent study was required. Next, observations took place at a special elementary school, De Elsenburgschool, in Rijswijk for children with learning disabilities where 10-20% of children are diagnosed with ADHD. The researchers attended a regular class day with three groups of 20 students with ages ranging from 8-9, 9-11 and 10-12. Later, in order to receive more in-depth information regarding time, attention and motivation, a focus group was conducted with five children. The qualitative information provided by sensitizing booklets used during the session was analyzed and categorized in quotes and themes with concluding statements that helped to define the requirements for WRISTWIT. When looking over the resulted insights, the need to help student's behavior by providing a sense of time and help focus attention was evident here. It was also found that children with ADHD work best with a qualitative over quantitative way of representing time.

In the second phase insights were gained on body movement as a mean to predict child's attention. Three children participated in a test using the 3-axis accelerometer of an iPhone with the application Accelerometer Data Pro (Wavefrontlabs, 2012). A consent form was provided before the session allowing the researchers to observe and videotape the tests. Before the test children wore the iPhone on their wrist for an hour and a half without measuring in order to get used to it. Next, each child worked independently for 20 minutes while wearing the smartphone measuring movement of the non-dominant hand. The data of all axes provided by the accelerometer is combined to come to one value of movement, allowing the plotted graph to be compared with the observations made by the researcher.

The comparison of the observations and the measured activity lead to a classification of three types of behavior: 1) On-task behavior (e.g. working as required by the teacher), is measurable by little movement, whereas 2) clear off-task behavior (e.g. when the child throws up his arms or acts goofy) is seen with larger amounts of movement above a threshold and 3) intermediate behavior involves an amount of movement larger than on-task but smaller than off-task behavior (Figure 47). ADHD children often do tasks that seem useful at first, for instance, getting up to get a book, as a result of inattention and looking for stimuli. Such activities can be distinguished by longer performance of movement and a more frequent occurrence within a certain timespan. Two children showed on-task behavior the first 8 minutes and performed more intermediate and off-task behavior later, whereas the third participant displayed regular intermediate and off-task behavior from the beginning. The results showed that an off-task behavior or larger amounts of intermediate behaviors are often the start of more and consecutive off-task behaviors, confirming literature (Fowler, 2010) and demonstrating that returning to on-task activities by themselves is difficult to do. The types of behavior classified matched the amount of movement in 25 instances, and only in four instances it did not.

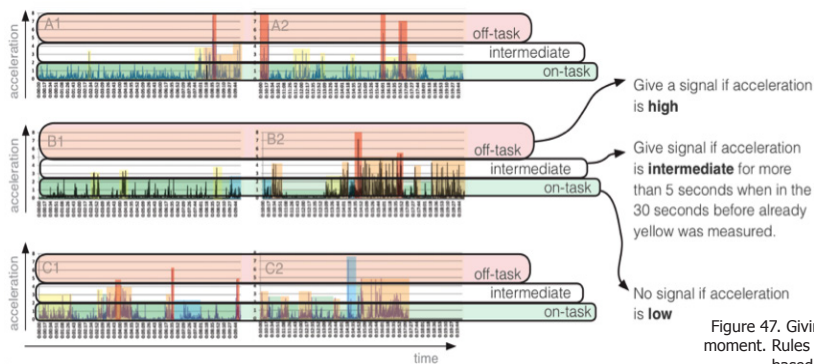


Figure 47. Giving the signal at the right moment. Rules on when to give a signal based on movement and time.

7.2.2 Final Concept and Prototype

WRISTWIT appropriates “timing” as a mCR mechanism to trigger quick self-reflection and self-awareness moments by means of four visual feedback forms to support on-task behavior: a timer, a work signal, performance during class and score (Figure 49). When inattentive behavior is visible in an increased amount of restless body movements, the device provides feedback in the form of a work signal to get their attention back to work. The visual feedback is combined with vibration stimuli to make the child aware of their inattention.

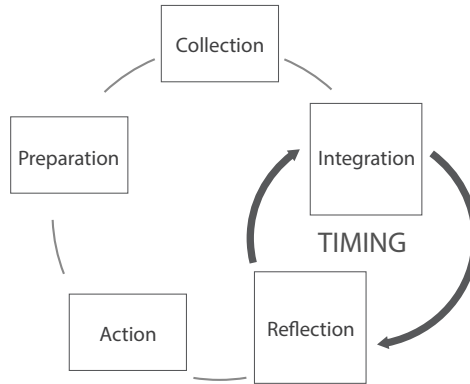


Figure 48. Integration and Reflection stages revolve around “counting” which provides to ADHD children a way to self-monitor and self-reflect about their own performance during class assignments.

To build up self-reflection moments and give children with ADHD the ability to link behavior to consequences, two additional forms of feedback are provided. Both are shown at the end of the class to ensure their attention to be on-task during class and create a motivating form of engagement. The performance of the class is shown on the prototype at the end of each class by LEDs in the timer presenting a green, yellow and orange color-coding. It displays how the child behaved at which point in time: green for little movement and therefore attentive, yellow for less attentive and orange for even less. To keep the system positive red is not used (see Figure 49c). The amount of drop-shaped LEDs increase as the behavior is better. The drops, made up with 12 LEDs next to the LEDs from the timer, motivate the child to do better as it is something they desire to have: collect more of and share with others the results if wanted. The bracelet has a simple design that blends in with other bracelets children wear.

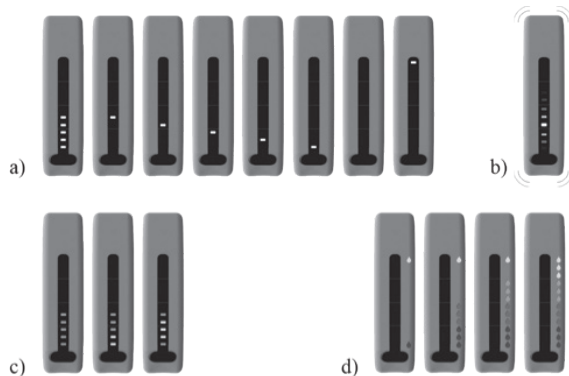


Figure 49. WRISTWIT. feedback visualizations: a) timer b) worksignal c) performance d) score.

Later at home, the child connects the bracelet to the computer and the drops collected on the bracelet are translated to an amount of water to nurture a plant (Figure 50a). The amount of water represents the score of that day, more water means better behavior; the child can compare today's performance to other day of the week (Figure 50b).

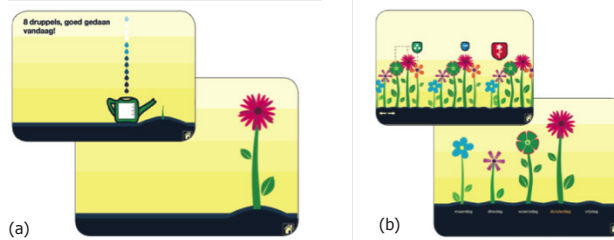


Figure 50. WRISTWIT. Complementary software.
a) Left, today, drops grow a flower;
b) right, comparison between days.

7.3 Discussion

One of the biggest challenges in the design of Personal Informatics systems is to provide meaningful information in which users can reflect upon in order to support self-awareness and self-reflection, such that behaviors can be changed. The TiPi and WRISTWIT prototypes share a common aspect, namely, they support awareness and reflection strengthening the Integration stage in PI systems with the implementation of different mCR mechanisms (sharing, time counting). In order to facilitate an active role of the targets users in the use the PI systems, TiPi and WRISTWIT prototypes were based on the mCR properties (as outlined in section 5.2), similar to the case of ESTHER 1.3 with knowledge workers at the target group.

7.3.1 TiPi

Light and short

Sending and receiving tips trigger easy and quick moments of reflection and awareness. When a tip is requested and then created, its content as a short text is the result of a brief moment of recalling recent memories and reflect upon personal experiences. Beyond how useful a tip is when it is received, this tip facilitates awareness when the user has to think if that tip in particular is already experienced, done or performed. This enhances awareness when the user has to think when and how he/she is along the recovery process.

High frequency

TiPi could be programmed to request and receive tips based on how much the user needs help or is willing to help. The motivation of sharing experiences and creating a network of peers could increase the frequency of the tips.

Linked

Requesting and receiving tips are related to the physical activity of the user. When TiPi detects too low physical activity over a period of time, the prompting protocol is modified motivating the user to be more active and/or receive tips from peers related to physical activity.

7.3.2 WRISTWIT

Light and short

It provides data abstraction and visualizations facilitating the aspect of self-monitoring during on-tasks behaviors at school. Not only by measuring child's inattention by assessing excess of body movement, but even more important to visualize time progression in a simple way, WRISTWIT gives the opportunity for children to self-monitor time on the go and sustained interest over time.

Linked

This quick feedback is associated to the time students have to spend in their assignments during class time. Including this contextual information not only supports tailored feedback but also enables children to reflect upon recent events, which is the feedback that caregivers cannot provide most of the time. Moreover, the characteristic of WRISTWIT as a bracelet offered opportunities to initiate an immediate engagement with children, inviting them to explore. A sensing-based interaction with meaningful information can engage children in a new way of thinking and it can fit their natural way of learning by exploring and playing with the material world.

7.4 Conclusions and Future Work

The design process of the TiPi and WRISTWIT prototypes were based on Empirical Research through Design process (Keyson and Bruns, 2009), User Centered Design methods and in-situ evaluations. Two mock-ups were built, one designed for TiPi using a sensor-node and an Android application and one more built specifically for WRISTWIT using an Arduino micro-controller. The experimental prototypes focused on extending the implementation of mCR in supportive systems for THR and ADHD. TiPi takes THR daily life experiences translated into meaningful information (tips) with a prompting protocol (requesting tips) based on physical activity behavior; WRISTWIT measures physical activity data to detect on/off-task behavior or when time-based concentration is at risk.

The insights gained through these prototypes in the field showed a potential for supportive/reflective sensing technology in healthcare scenarios that require a higher level of self-awareness and self-reflection. In the case of TiPi, initial results showed that the mCR mechanism was a rewarding experience to both motivation and self-awareness (Kroon, 2013). On the other hand, with WRISTWIT, initial results with mCR mechanism showed that the provided feedback elicited the intended reaction and children were able to evaluate their performance (de Bruyckere, 2013). These research explorations provided initial data that is possible to detect most of the physical behaviors to provide feedback when the feedback signal can be given. Further research could be conducted to explore the impact of these mCR mechanisms in self-reflection and how this may support users' actions for a longer period of time.

8 GENERAL FINDINGS AND DISCUSSION



Based on several design driven research studies in the field, the work described in this thesis explored the integration of experiential and sensed data to develop user-centered supportive health systems in the context of daily life practices. This final chapter provides a summary of the general findings of these studies, followed by the discussion of research limitations and contributions of real life experience based research tools and implications in the design of supportive/reflective/empowering health systems. Furthermore, considerations for future research work are presented.

8.1 Summary of the findings

This thesis addresses the design of supportive home health system technologies that are integrated into people's daily life, empowering users to play an active role by contributing and deciding what is important to take from the large amount of data that such systems can potentially collect.

Understanding-user and user-empowerment are fundamental aspects in the design of home healthcare systems that aim to embrace an active role of people in their health related practices. An integrated patient-centric approach was defined that considers users' health experiences and daily life context to bring together the complexity of health activities in the design of supportive systems.

Chapter 1 provided an overview of this thesis. The problem definition, the cornerstones and the research approach undertaken in this thesis were introduced.

Chapter 2 the two cornerstones of this research work are discussed, namely, understanding and empowerment as fundamental aspects in the design and implementation of personal healthcare solutions to support users' reflection over their own data. Special attention was placed to expose the existing gaps and limitations to implement and synchronize these elements in Human Computer Interaction practices, which in turn, became the research drivers of this thesis.

Chapter 3 provided a reflection on the state of the art of clinical efforts to reach patients at home, technological solutions to monitor and assist physical activity and methods that consider a user-centric approach. This chapter concluded with design directions towards reflective technologies as a next step in pervasive healthcare systems.

The research studies were organized in two main sections as they tackled the cornerstones of this thesis, namely: A/ understanding the user in context and B/ empowering the user in personal healthcare systems.

Part A:

Chapter 4 introduced the Total Hip Replacement as a test bed scenario for the first step towards the definition of a supportive system for THR. Physical recovery in THR, as in other medical related conditions, changes overtime and involves several dimensions that are close to patients' daily life experiences and beyond the functional recovery. Different User-Centered Design techniques were applied with THR's stakeholders resulted in gaining knowledge that a more holistic approach was needed, an approach that considers users' health experiences overtime and in relation to their daily practices. A description of the experiences developing and implementing a research tool (ESTHER 1.0) that aims to capture the recovery process of Total Hip Replacement (THR) was provided.

The experience of designing a tool that can be adopted into the daily practices of THR patients, to maintain a valuable experience, unveiled the potential of self-reflection as a mechanism for user empowerment.

In Chapter 5 research work based on ESTHER 1.2, a research tool that added to users' health experience reports functional data using wireless sensor nodes, was described. Using certain thresholds of physical activity, this iteration implemented an event-based protocol

based on in-situ prompting mechanisms. The chapter dealt with how participants experienced the system as becoming a companion of their process and to what extent technical and design limitations affected the overall experience. The study reinforced previous findings suggesting that reporting experiences make users speak with more knowledge and being aware about their health recovery process describing feelings and events.

Part B:

In Chapter 6 ESTHER 1.3 was presented, being an Android application applied to the context of daily office work routines and the observable physical activity of knowledge workers. The ESTHER 1.3 research prototype featured the micro cycles of self-reflection mCR, a self-report prompting mechanism to trigger the user to reflect upon his physical activity during working time. The mC was integrated with assistive mechanisms such as notifications and informative visualizations. The study presented in this chapter aimed to implement and evaluate how mCR is valued as a mean to facilitate the identification of opportunities to perform physical activity during working time. Based on the preliminary results of this study, it was found that mCR as a supportive element is valuable for non-active participants. mCR supported them in having a better performance at achieving physical activity targets overtime. Although active participants also showed an improvement in achieving targets, they assigned more value to the assistive elements of the application.

In Chapter 7 an overview of two design studies that explored different mCR implementations as supportive mechanisms for self-reflection in context was presented. A prototype interactive mobile application for THR elderly patients called TiPi, explored the value of sharing tips and advice between THR peers; a personal device for ADHD children called WRISTWIT, explored how to support on-task behavior during school time by making them aware about the sense of time. These master projects extended the work done on ESTHER 1.3 to explore other mechanisms than self-reporting to implement mCR.

8.2 Challenges and limitations in design research in the field

Several authors point to the importance of having a deeper user-centered research approach in the product development. Tidball et al. (2010) describes how design research on Human Computer Interaction (HCI) uses methods and tools that enable: 1) incorporating users' information (needs and desires) into the design process, 2) incorporating users into the design process, and 3) unlocking the information they hold. The field of User Experience considers the relevance of people's feelings in relation to their daily practices as an important focus for the design of technologies that aim to have a positive impact on people's life (Hassenzahl and Tractinsky, 2006). This thesis goes further by not only highlighting the importance of understanding the user, but also by proposing and testing research tools in context to facilitate a holistic understanding of the variable users' needs and desires overtime.

This approach is particularly relevant in healthcare scenarios where functional aspects of health are linked with emotional and experiential ones. As pointed out by Rogers (2010), new pervasive technologies should address a wider understanding on how people experience daily life, moving from the laboratory to more realistic design and testing settings. Intille (2003) also states that developing meaningful ubiquitous computing applications that involve health informatics requires first a global understanding of how people behave in context. However, when the goal is to investigate patients' experiences in the field, which are related to individuals' moment-to-moment changes of feelings regarding a specific situation and context (Roto

et al. 2010), limitations coexist. The first encountered limitation in this thesis reflects on the use of traditional methods like interviews and questionnaires that were considered insufficient to capture the rich and lively aspects of daily experiences. The shortcomings of these methods, that is, relying primarily on the participants' ability to recall past memories, result in obtaining an inaccurate view of past experiences based on guesses and estimations.

As described in Chapter 3, the exploration of several User-Centered Design methods resulted in initial requirements for the design of a technology supportive system for Total Hip Replacement (THR). As emphasized in the conclusion of the chapter, the design of technology systems for healthcare demands an alternative approach that provides the designer with holistic elements to understand the user's momentary experiences, their context and daily life practices. This conclusion opened the research challenges of capturing overtime changes of users' health status, at home and in a context that relates to vulnerable health conditions.

While traditional practices and tools mainly take place in laboratory set-ups, this thesis takes a step forward by bringing these practices in to the users' home addressing challenging circumstances such as THR elderly patients recovery after surgery. When the goal is to develop technological research tools with the purpose of capturing user experiences in-situ (i.e. timed and situated in the users' home context), and for extended period of times (i.e. through the recovery process), in relation to care critical conditions and in the context of home, the challenges of this type of field studies are related to:

1) *Engaging patients in field studies*: in contrast to laboratory studies in which specific appointments are defined and independent variables are in control, when design research goes "in the wild", as quoted by Rogers (2010), there is a risk of a long process of recruitment and participation of study subjects that can disturb the progress of planned studies, making scattered collection of data.

2) *The sensitivity of intervene health conditions*: when the scope of the research and the implementation of design tools are related to healthcare situations, both patients and medical staff may be sensitive to participate since, for instance, THR in elderly patients may involve parallel health related conditions, such as cancer, COPD or pain.

3) *The vulnerability of the target user*: nine potential participants quit the study of ESTHER 1.0 because of health complications, changes in the surgery planning or became too concerned about their recovery process. Subject dropout also occurred with ESTHER 1.3, which involved knowledge workers. As noted by Lui (2014), office workers may not continue to participate in studies because an experience sampling tool may distract them from work, or participants may simply forget to use the tool.

4) *The technological robustness and readiness of these tools*: the technical maturity of the sensor technology was a limitation in these studies. Examples here included, low battery efficiency, weak Bluetooth connectivity within sensor nodes and smartphones, and sensitivity calibration among different Android versions dealing with this while in the field and with users can lead to an extended, and sometimes undesirable, study period, significant data loss, or participants dropping out of the study.

5) *Capturing users' experiences may fall into a burden*: the way to implement self-report prompting protocols may interfere with the daily life priorities of users such as THR undertaking a recovery process, or the busy schedule of a knowledge worker. Consequently, burden may affect negatively the user's perceived value of the personal system.

8.3 Design contributions

In the context of Personal Informatics and healthcare systems, user and contextual data plays a central role in developing informative and persuasive strategies to support professionals and patients in their health related activities. This thesis develops a methodological approach to move from data-centric to user-centric design to enhance the inclusion of empowerment-user in HCI practices. It has been reported that only providing data that assesses physical performance limits the impact this information could have on patients and medical staff (Wong et al., 1999). An holistic approach where physical and emotional aspects are considered, brings experiences of patients as an important ingredient to include in the design of healthcare systems. This would on the one hand provide a more comprehensive view of a patient's needs and preferences regarding his health condition but more important it will facilitate the creation of personal knowledge to empower the patient to make more independent and better-informed decisions. This thesis discusses that the digitalization of medical data provides substantial information, but only exposing patients to data is far from providing insightful information to the patient for two main reasons: 1) the data remains static and 2) patients are playing a passive role with their own information.

From the aforementioned reflection and by the experience gained from designing a research tool for THR (ESTHER 1.0 and 1.2) and a supportive tool for knowledge workers (ESTHER 1.3), this research provides insights in three aspects: 1) an understanding of the evolving needs of patients along the recovery process may support a system that triggers "raising flags" to optimize the patient's progress updates medical staff would receive from such systems; 2) the integration of experiential and physical data may support a system that is able to profile patients along the recovery process. These two aspects contribute to the design of supportive healthcare systems that aim to improve patient's experience and wellbeing regarding their health recovery process by informing both the user and the medical staff about patterns or anomalies; and 3) the micro cycles of self-reflection, an extension of the stage model of Personal Informatics to empower patients by supporting self-awareness and self-reflection processes.

8.3.1 Rising flags

As described in Chapter 3, the intervention of ESTHER 1.0 provides knowledge on the evolving needs of patients along the recovery process. For instance, participants experience their health recovery progress was different between the first week and the second week of recovery. The first week, described by participants as a physical and emotional rollercoaster, was characterized by continuous ups and downs that related to a health condition that was new to the patient. When this understanding was captured by the system, relations between the mood reports (short and light) and the reports over the recovery process (extensive and richer) were identified as possible filters to optimize the communication of the data to physiotherapists and patients. The mood reports could be used as raised flags to systematically filter the text reports, and predict critical moments in the recovery at a glance.

8.3.2 Profiling users

The following iteration, the introduction of ESTHER 1.2 in Chapter 4, explored the challenges of integrating self-reported data with wearable sensors by users in the field. The tool developed was designed to: a) work in the context as an in-situ tool, b) be expressive when combining both sensed data and subjective data, c) capture individual's experiences using prompting mechanisms that are context-dependent to the individual's physical activity, and

d) provide both quantifiable (moods) and qualitative (text) from patient's reports by offering different input mechanisms. These characteristics of ESTHER 1.2 explored explicit links between sensing and subjective data by triggering questions only when special events were detected. The implementation of this tool in the field provided data that when integrated gave an overview of momentary reports linked with physical performance. From a research perspective, these overviews could optimize the understanding of the patient's profile, as the integration connected patient's attitudes (captured from demographic data) to specific cases during recovery. These results led to reflect about how these overviews can be designed and implemented to support users.

8.3.3 Micro cycles of self-reflection, mCR

Personal Informatics systems involve reflection as part of the process to support behavioral change. However, the PI approach is typically data-centric with the goal to optimize patients' involvement in their health improvement by offering assistive mechanisms that based on computational means (e.g. pokes, reminders, notifications, nudges). These mechanisms enforce a passive role of patients thus limiting the opportunity to empower them to become more involved in the decisions taken regarding their recovery or health status. Muller et al, 2012 states that one common strategy used by these systems is to enforce desired behavior by pinpointing possible flaws.

The data-centric approach focuses on assisting performance and assessment rather than on supporting learning and awareness. Inducing a change in behavior by nudging elements does not support users to explore, change perspectives, and learn about the reasons of certain outcomes. Self-learning is key in reflection processes, therefore, this technology should support the return to user experiences and provide the user with mechanisms to create personal changes that ultimately may facilitate a change in behavior (Muller et al, 2012).

8.4 Reflections about the research approach

One of the first conclusions of this thesis states that a shift in design research is needed to respond to the current healthcare shift from hospital to homecare support. While traditional approaches pinpoint functional requirements and users' needs and desires in a medical environment, the new homecare scenarios required design research to focus in a holistic understanding of patients' progress and experiences in context and over time. This shift involved two research steps 1) moving from laboratory to design and testing in situ, and 2) integrating functional and experiential aspects of health related practices. These two steps led to a transformative research approach where the initial goal was to investigate the value of an in-situ research tool to capture momentary experiences, and moved to gradually and iteratively explore and implement the effects of the in-situ characteristic into the design of a supportive healthcare system, along several design interventions (Figure 51).

The transformative research approach describes a research process that focuses on the patient and iterates from explorative to supportive research and from research tool to application. By extending self-reporting techniques with self-reflection the transformation of an initially exploratory research to an applied research opened the opportunity to support more complex participation. The research tool came as an exploratory tool that offered open and technologically simple mechanisms, to an applied tool that provided more specific and technological complex mechanisms.

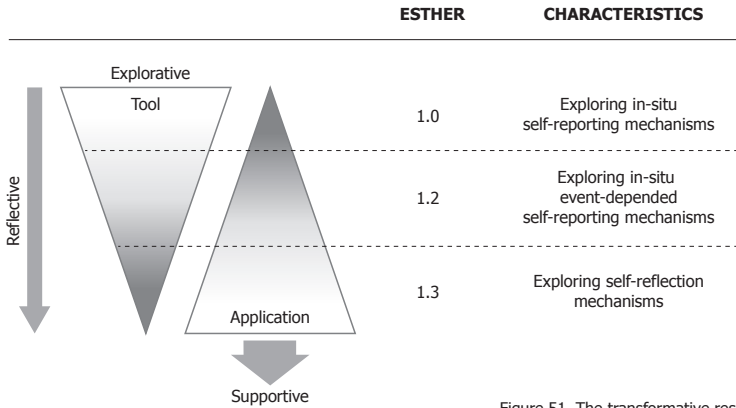


Figure 51. The transformative research approach.

8.4.1 Towards a more complex intervention: from exploratory to supportive

The prompting mechanisms in the different iterations of ESTHER, ranging from a simple fixed protocol to a context-dependent sampling protocol with mCR mechanisms that combined sensing and subjective data illustrates this transformative process. The analysis of the three iterations of ESTHER explored, identified, and applied significant events and actions that describe the recovery process of a THR patient. For instance, patients’ emotional and social aspects vary along the day affecting their progress. The visit of a patient’s granddaughter in the morning, or a phone call informing that friends will visit are context-related aspects that are able to slow down or increment physical performance during the day, and it replicates to the emotional state of the patient.

One consequence of this possible new generation of “research to application” tools is to get research and design of healthcare systems closer to design solutions that in addition to guaranteeing a healthcare impact will empirically address the acceptance of innovative technologies in daily care practices.

8.4.2 Towards a supportive intervention: from reporting to reflecting

Exploring different strategies of self-reporting to capture data for research purposes as well as a design mechanism opened the possibility to implement self-reports as personal tags for users to stamp relevant moments during the day. These self-reports were presented as a first implementation of mCR to support users’ reflection of momentary and episodic experiences.

This is the result of a research design process of implementing ESTHER in the field, and revealing the reflective effects of reporting mechanisms in patients. This transition is explained by the insights gained during the field studies conducted in this thesis. ESTHER 1.0 and 1.2 elicited in participants an important experience of the tool as a mean to be more knowledgeable about their health status. During the interviews users provided insights about how they used self-reporting to know more about their recovery process, recalling and reflecting over stand out situations. The complexity of the prompting mechanisms in ESTHER is the result of a gradual transformation of the research goal from exploratory to explain the effect of different reporting mechanisms on the participants’ experience.

8.5 Implications

8.5.1 Applied research: implications in research in the wild and HCI

Acceptance of technology is a major threat in the design of innovations for daily use. Vastenburg (2007) showed that users in controlled labs studies behave and experience innovative solutions differently than if placed in real context. Designing innovative technologies that aim to positively influence people and their lifestyles, require a holistic and realistic understanding of people's experience in relation to their everyday lives (Rogers, 2011). This thesis focused on including field studies in the explorative and applied phases of a research through the design process to develop insights on the experiential daily life aspects of health. In line with Visser (2012), the evaluation of prototypes in the field is essential to capture the real-life experiences of users towards a better understanding of how to design technology systems, it helps to counter the novelty effect and provide insights into user-adoption over time. The features of ESTHER offered a way to implement tools that integrate real-life context situations and emotions as relevant aspects to understand users' needs and preferences related to health.

Sengers et al., (2005) draw the attention to Human Computer Interaction designers to build a technology that considers reflection itself as the core design outcome for HCI. The authors define reflection as a fundamental activity that allows people to bring aspects of real-life experience into self-conscious information allowing them to make free choices related to their practices. This thesis conducted a study that brought this concept of reflection to support user empowerment by activating users in the transition from knowing to action. The approach discussed in this thesis proposes new research practices to address people's experiences using interventions that capture experiential data and to validate the acceptance of ESTHER's role as part of the daily life practice of users in their own environment.

The staged-model of personal informatics (Li, 2010) describes five stages the system needs to support. Reflection is one of them and it is presented as a straightforward step, a clear cut between collecting data and user action. Instead, this thesis subscribes to a view of reflection as a more engaged interaction, an active process in itself that goes from knowing to action and not a detached, isolated assessment. This thesis explores this concept of reflection by means of mCR mechanisms, small elements in personal informatics that rather than assistive aim to be supportive allowing users to make conscious value choices in their attitudes and practices. With this, mCR are user-driven elements supporting user empowerment. The research presented in Chapter 5 showed an implementation of mCR in the field. Four properties guided the design of mCR for knowledge workers: energetic, light, short, high frequency and linked.

8.5.2 Reflective mechanisms: an implication for related research

Persuasive technology

A review of the last decade research developments in supportive technologies for physical activity shows the interest in the design of glanceable (non-literal) displays that provide feedback using abstract representations of physical activity. Fish'n'Steps (Linn et al. 2006) provides real-time information with glanceable visualizations about levels of physical activity with the purpose to serve as external motivation and provide awareness. Houston (Consolvo et al. 2009) is a mobile application that tracks step counts allowing users to set weekly goals and promote physical activity awareness, sharing their goals and meet targets within a group. Of particular relevance to this research, is the work of Consolvo et al. (2008) UbiFit Garden, where the idea of manual journaling was explored by inviting users to tag the activities inferred by the system with corrections or personal comments. Although the mechanisms for journaling were

perceived as light and simple, participants reported that the value of the journaling could be improved if better integrated with sensor data. Other commercial devices for fitness and sports such as Nike+ or Adidas miCoach automatically collect physical activity data and display it in the form of graphs and statistics. While they also support some kind of journaling this is done in a form of reconstruction of the activity after it was finished, therefore the focus is more on assessing the experience rather than collecting aspects of the experience itself.

As argued in this thesis, episodic experiences are hard to assess if no view on the momentary experiences is presented. The provision of overviews and statistics of physical performance may not be enough to help individuals become self-managers of their own goals and actions. As mentioned by Moore et al. (2010), current personal information technology is being designed to optimize productivity rather than self-understanding. When personal systems focus only on the amount of physical activity it is insufficient to help users in finding new ways to improve and change. This argument is followed by Li (2009b), who states that physical activity behavioral change is also related to identify opportunities for change. Optimizing performance relates to systems that have a stronger assistive approach where the user gets little opportunities to learn, but just receive instructions. The value of reflection has been critically examined as a positive influence in providing empowerment to change behaviors (Pirzadeh et al. 2013).

Personal Informatics

As claimed by Detweiler et al. (2013) when personal informatics systems take an assistive approach they restrict the user to make choices. These systems act in a paternalistic fashion protecting users from possible harm. This may reduce not only users' autonomy, as the authors describe, but it will also affect the extension in which design practices can develop systems to support user-empowerment with the system. In this thesis the focus was on the need to explore to what extent a personal healthcare system is assistive or supportive by balancing user's effort and involvement to go through different states of reflection when using personal informatics systems. In order to address the lack of mechanisms to implement user-empowerment in pervasive technology, it is introduced in Chapter 5 the implementation of the concept of micro-cycles of self-reflection (mCR) that contributes to 1) integrate physical/functional with emotional/experiential data, 2) trigger experiential reports by using visualizations, and 3) combine physical and experiential visualizations to support reflection. The mCR extends the staged-model of personal informatics (Li, 2010) with Reflective Practice theory (Schon, 1983) to promote the design of reflective systems that involve a more active role of users with the computational features of pervasive systems.

In-situ data collection

The research work in this thesis also reflects on the challenges of ESM and self-reporting in daily basis and over a long period. The initial experiences with ESTHER 1.0 exposed the effort from users to self-report with a fixed prompting protocol over an extended period when the recovery process reached a stable phase. Consequently, users may decrease their motivation to self-report as they perceive this as a tedious task in the long run. The research work developed in this thesis explored parallel solutions to address some of these challenges of ESM. One example is ESTHER 1.1. Although this iteration was not presented in this dissertation - due to a short pilot study and different technical difficulties -, an initial exploration provided insights into how different mechanisms can be implemented to minimize the load of moment-to-moment reports. This iteration used shorter and quicker input mechanisms in a smart watch and open questions were limited to one time at the end of the day using an iPad (see Jimenez Garcia, et al. 2013).

There are other related techniques that aim to overcome with the shortcomings of ESM. For instance, the Day Reconstruction Method (DRM) (Kahneman et al., 2004). The authors consider this method of experience capture as less intrusive and requires minimal resource compared to ESM. In contrast to ESM, this method collects data of a person has on a given day. Later, users systematically reconstruct and reflect on their activities and experiences of the preceding day. One more approach that deals with the challenges of ESM, has been explored by Gouveia and Karapanos (2013) with the Lifelogging mechanism. Its goal is to impose no burden to the participants while maximizing the amount of collected data.

Other approaches have explored how to increase compliance in ESM by using feedback and visualizations. Ian Li (2010) states that providing feedback increases the motivation to respond to the sampling request. In this thesis, this approach was explored with different master graduation projects. For instance, Kruijssen (2013) developed “Blue Book”, a tool to support prostate cancer patients deal with the daily life difficulties during the cancer treatment. This tool explored anonymous and abstract visualizations of self-reported data in a time-line journal and then compared them with the experiences of other patients. It was observed the potential of this feedback as it kept patients motivated to learn from the experiences of others and to contribute to the time-line structure.

While related in-situ methods, such as DRM or Lifelogging aim to reduce user’s burden and user’s responsibility to collect data, the scope of this thesis considers the active role of the patient in capturing health experiences as a central aspect to be explored. As explained in Section 2.4, patients are the experts in their daily life experiences and how they make them feel. In-situ self-reporting is an area of research that has not been widely explored in home recovery systems. ESM was, therefore, considered with the proper mechanisms to capture these experiences. The initial goal with ESM was to investigate the value of an in-situ self-reporting technique to capture patients’ momentary health experiences. Further, the use of ESM in this thesis focused on exploring how the property of ESM to actively report could support the process of reflection.

8.6 Future directions

Across the design iterations of ESTHER the primary focus was the patient. However, opportunities to extend recovery support to involve other stakeholders are considered relevant for further investigation. As concluded in Jimenez Garcia et al. 2011, the self-report data gathered in ESTHER 1.0 could help physiotherapists to build an efficient and personalized judgment of the progress of patients’ recovery. The patient’s in-situ reports represented the patients’ background and attitudes, which eventually could help the physiotherapist formulate a sensitive judgment in addition to only looking at the objective information of a patient. As presented earlier, self-reports were a less dense data collection in terms of data points when compared to sensor data. This gave the perception that they may serve as potential filters of the sensor data to be able to raise flags when attention is needed. If this is developed further, it could address one of the important trade offs between the physiotherapist’s workload and their need for more personalized support to patients. Future work may look at existing measurements and investigate the value of deploying them as part of the in-situ self-reports to personalize the objective data gathered.

The characteristics of ESTHER 1.2 as a supportive tool for THR patients, illustrate the potential of guiding patients in their recovery process by minimizing anxiety during the first days, as well as frustration later on in the process when things do not go as expected. One could for instance think of a timeline with the average recovery process steps so that the patients know that they are on schedule and that everything is fine. This potential was explored

by van Kruijssen (2013), a master graduation project developed under this thesis, presenting information to the user about the status of other prostate cancer patients. This master thesis considered ethical issues, such as privacy, making this information anonymous and abstract in the way to visualize it. In addition, the community of THR patients could also benefit as experiences are shared, so new patients could get insights from previous patients, but maybe even more important, patients could feel more valuable as they will be helping others while coping with their own problems. This idea was further developed in the master thesis of Kroon (2013), creating a network of shared tips between THR peers. The transition of ESTHER 1.0 and 1.2 from a research tool to ESTHER 1.3 as an application can be seen as part of a process to inform the design of supportive technologies while uncovering challenges in relation to technological aspects such as stability, complexity and acceptance; research in terms of validity and resources; users regarding their needs, values, and engagement; and design with reflection mechanisms and feedback characteristics.

With the user as a main focus, the work developed and presented in this thesis always kept in mind Bob, the senior user introduced in the opening scenario of this dissertation. Bob represents all the participants of this research work and the iterative process of developing prototypes aiming to integrate their daily life experiences to design for user empowerment. To achieve this, first an understanding beyond the functional aspects of a system was required, and the presented work assumed the challenge to conduct field studies with real settings to understand more about what users need to use technology which main objective is to support their physical status.

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Summary

The current healthcare paradigm shifts towards considering the patients' home as the primary self-care environment. Health care is changing from being solely delivered by professionals in hospitals, to considering daily-life experiences and patients' personal contexts. The increasing accessibility to health related data has created an opportunity for the healthcare community to address care outside of the hospital context. Personal systems with built-in sensor technology such as smartphones and wrist devices aim to facilitate the monitoring of people's health condition. These systems blur the line separating lifestyle and healthcare by addressing the continuum of health and care. A rather subtle consequence of this increasing amount of personal data is that patients are becoming more proactive in managing their health. Increasing access to personal health care data implies that people also are considered to be more responsible to monitor and reflect on their health condition.

Homecare technologies can focus on supporting a reflective approach by providing users with relevant information that they can reflect upon, making them self-managers who are in control of their own care. In contrast, technologies that are only assisting the patient, commonly assume a more data-centric approach, in which the system takes a prominent role by nudging people towards a goal.

This dissertation explores and validates the design of supportive technologies, which aim to comply with the upcoming paradigm by helping the user in having control over his own data. The digitalization of medical data provides substantial clinical information, but just exposing patients to data not yet providing insightful information to the patient for two reasons: 1) the data remains static, i.e. the data stays as data points or trends and 2) patients have a passive role in terms of expressing their experience and context. Enabling the user to understand, explore, reflect and act upon personal data could empower him to play this active role, letting him to contribute and highlight the important parts of content from the complete data set. This is a novel design research challenge that requires more than an understanding of the functional characteristics of a system. In order to develop technology supporting the patients' physical condition, a holistic understanding of their needs is required, involving both the subjective, self-reported data, as well as automatically collected and clinical data.

The Human Computer Interaction (HCI) community has also identified this need. Technologies to support patients become important when the user experience is considered of prime focus for research exploration. However, there is a lack of tools to facilitate this exploration from a holistic perspective. In addition, there seems to be a lack of mechanisms to implement empowerment in personal healthcare systems. This thesis exposes and explores that understanding and empowering the user are fundamental aspects in the design of supportive pervasive healthcare systems. However, they have until now not been deeply synchronized and applied in real life situations.

The research work presented in this dissertation assumes the challenges described above by exploring in-situ mechanisms in the design of personal reflective health care systems. An integrated patient-centric approach was defined by zooming in from the general user context to a centralized focus on user experience. The approach was supported by methods that bring together the complexity and diversity of different health activities.

The first field study introduced Total Hip Replacement (THR) as context for defining a supportive system for THR. Physical recovery in THR, as other medical related conditions, changes in the course of the recovery process and involves several dimensions that are close to patients' daily life experiences and beyond the functional recovery, such as social roles, mobility and independency. For this study ESTHER 1.0 was developed. This is an in-situ research tool using Experience Sampling Method (ESM) techniques implemented on an iPad. It aimed to provide an understanding about users' health conditions in their living context and during their daily activities. Four case studies were conducted during the two initial weeks after surgery. These revealed the value of the ESM platform in serving as a reflective mechanism to support patients. The facilitation of self-reporting techniques was found as a means to achieve a sense of self-reflection and empowerment among users.

In the second study, the in-situ self-reporting principle was extended with contingent experience sampling by means of on-body sensor nodes. Based on physiotherapists' information, these sensors assessed a recommended threshold of physical activity by measuring body acceleration. ESTHER 1.2, an Android phone application, addressed the technical challenges of integrating self-reporting and automatically collected sensor data. The results obtained in the study with ESTHER 1.2 underline the potential of self-reporting as a mechanism to increase awareness about users' health process through describing feelings and events. Interestingly, participants experienced the system as becoming a companion in their process, identifying a clear user experience benefit, beyond clinical outcome. This study also unveiled to what extent technical and design limitations affected the overall user experience.

The third field study explored the potential of Personal Informatics (PI) to support the well-being of knowledge workers in the office place. ESTHER 1.3, an Android phone application featured physical activity monitoring and self-report prompting. It aimed to trigger users to reflect on their physical activity during work time. While building on the previous studies in terms of design and context, ESTHER 1.3 also served as a research platform to expand upon a design model for developing future reflective interfaces. The study conducted with ESTHER 1.3 led to the notion of micro-cycles of self-reflection (mCR). mCR is a self-report mechanism based on reflective practice, which integrates "energetic, light, short, high frequent and linked" in-situ self-reporting actions. The mCRs were integrated with widely used assistive mechanisms such as notifications, goal setting, self-monitoring and informative visualizations. Preliminary results of the ESTHER 1.3 study show that mCRs can serve as a supportive and valuable element for motivating non-physically active participants. mCRs supported them in having a better performance in achieving physical activity targets overtime. While the more physically active participants also showed an improvement in achieving targets, they assigned more value to the assistive elements of the application.

Based on the experiences obtained from the field studies, this dissertation reflects on the following challenges for real-life experience based research: (a) the challenges in engaging participants in a field study, (b) issues relating to sensitivity and privacy in intervening with personal health, (c) the vulnerability of the target user, (d) the technological robustness and readiness of current tools; and (e) the potential burdens in capturing users' experience.

The results from the first field studies provided insights into how the integration of mood reports and the reports over the recovery process may enable the identification of key-incidents for healthcare professionals. Flagging these incidents could help to optimize the communication between the physiotherapist and the patient during the recovery process. Following studies provided further insights into how the integration of momentary reports linked with physical performance data might have the potential to optimize patients profiling.

In summarizing, the core contribution of this thesis is in its thorough empirical exploration and discussion of the contrast between assistive and supportive homecare technologies. Supportive home healthcare technologies may be better integrated into people's daily life as they empower users to play an active role in contributing, reflecting and learning from the data collected by such systems. The potential of persuasive technology could be increased by using the notion of self-reflection and empowerment to change user behavior. In addition, this dissertation developed an approach to move from data-centric to user-centric design to enhance the inclusion of user empowerment in HCI practices. This approach is novel in that it engages the user by considering users' personal experiences, social context and personal physical level collected in real life, in real contexts. These are crucial aspects when providing care support, making the research process more representative for real users' daily life needs and desires.

Samenvatting

Het huidige paradigma in de gezondheidszorg is aan het verschuiven naar een situatie waarin het huis van de patiënt als eerste zelfzorg omgeving geldt. Gezondheidszorg verandert van louter verzorgd te worden door ziekenhuis professionals, naar het in acht nemen van de ervaringen van patiënten in hun dagelijks leven. De steeds eenvoudiger wordende toegang tot gezondheid gerelateerde data creëert mogelijkheden om zorg aan te pakken buiten de ziekenhuis context. Technologieën zoals smartphones en smartwatches met ingebouwde sensoren, kunnen de gezondheid van hun gebruiker monitoren. Dit soort systemen vervaagt de scheidingslijn tussen lifestyle en gezondheidszorg en beschouwt het des te meer als een continuüm. Een subtiel gevolg hiervan is dat door de beschikbaarheid van deze hoeveelheid data, patiënten proactiever kunnen worden in het managen van hun gezondheid. Omgekeerd betekent het ook dat gezien de eenvoudige toegang tot de persoonlijke gezondheidsdata, van patiënten verwacht wordt dat ze hun verantwoordelijkheden nemen in het bijhouden en actie ondernemen voor wat betreft hun gezondheid.

Thuiszorg technologieën kunnen zich richten op het ondersteunen van een aanpak van reflectie, door gebruikers te voorzien van relevante informatie. Dit maakt ze zelf-managers die de controle hebben over hun eigen zorg. In tegenstelling tot dit type technologie, zijn er ook assisterende technologieën, die de context over het algemeen meer vanuit de data zelf beschouwen, en waarbij het systeem een prominente rol heeft in het sturen van de gebruiker richting een doel.

Dit proefschrift verkent en valideert het design van ondersteunende technologieën, die meer gericht zijn op de eerder genoemde paradigma verschuiving. De digitalisering van medische data voorziet in substantiële klinische informatie. Echter, het enkel confronteren van de patiënt met deze data is niet voldoende, om twee redenen: 1) de data is statisch en bevat geen interpretatie, en 2) patiënten hebben dan een passieve rol voor wat betreft het communiceren van hun ervaringen. Door de patiënt in staat te stellen zijn data te begrijpen, verkennen en er op te reflecteren, kan het hem helpen een actieve rol te spelen in zijn gezondheid management. Hij zou zo inzicht kunnen geven over welke data het meest relevant zijn. Dit is een nieuwe ontwerp onderzoek uitdaging, die meer vereist dan een enkel begrip van de functionele eigenschappen van een systeem. Om een technologie te ontwikkelen die de patiënt op een dergelijke manier ondersteund is het noodzaak om een holistisch beeld van de behoeften te krijgen.

Hieronder vallen zowel de subjectieve self-report data, alsmede de automatisch verzamelde en klinische data.

Het Human Computer Interaction (HCI) vakgebied heeft deze behoefte ook geïdentificeerd. Technologie die patiënten ondersteund wordt belangrijk zodra de gebruikerservaring als de belangrijkste focus gezien wordt. Echter, er zijn weinig hulpmiddelen om een dergelijke verkenning te ondersteunen vanuit een holistisch perspectief, en er zijn ook weinig methodes voor de implementatie van deze visie in het gezondheidszorg systeem. Tot nu toe zijn de meeste bekende systemen niet voldoende in lijn met en toegepast op de context van het echte dagelijks leven. Dit proefschrift legt bloot dat het begrijpen van en de controle geven aan de gebruiker fundamentele zaken zijn in het ontwerpen van ondersteunende gezondheid systemen.

De studies in dit proefschrift gaan de hierboven beschreven uitdagingen aan. Dit wordt gedaan door het in-situ verkennen van het dagelijks leven. Het uitgangspunt is het ontwerp van persoonlijke zorgsystemen, die zich richten op het ondersteunen van reflectie door de patiënt. Er is een geïntegreerde aanpak gedefinieerd, waarin de patiënt centraal staat, door in te zoomen van een algemene gebruiker context, naar een focus op de gebruikers ervaring. De aanpak wordt ondersteunt door methoden die de complexiteit en diversiteit van de verschillende gezondheidsactiviteiten samen voegen.

De eerste veldstudie richtte zich op de gebruiker na een heupvervangende door middel van een heupimplantaat (THR). Zoals bij veel gerelateerde medische situaties, verandert het fysiek herstel na THR gedurende de tijd in het herstelproces. Er zijn meerdere factoren in het dagelijks leven van de patiënt die hier invloed op hebben. Veel van deze factoren staan los van het fysiek herstel, zoals ervaringen in het dagelijks leven, sociale factoren, mobiliteit en afhankelijkheid. Voor deze studie werd ESTHER 1.0 ontwikkeld: een onderzoekstoel die Experience Sampling (ESM) implementeert op een iPad. Het doel van ESTHER is om inzicht te geven in de gezondheid van de patiënt in hun dagelijkse omgeving, gedurende hun dagelijkse bezigheden. Er zijn vier case studies uitgevoerd die zich richtten op de eerste twee weken na de operatie. Deze studies toonden de waarde van het ESM platform voor het ondersteunen van reflectie bij de patiënten. Het ondersteunen van self-report technieken bleek een goed middel om bij de gebruikers een gevoel van zelf reflectie en controle op te wekken.

In de tweede studie werd het in-situ self-report principe uitgebreid met sensoren die op het lichaam van de patiënt geplaatst waren. De sensoren meten lichaamsversnelling en gebaseerd op de door de fysiotherapeut vastgestelde aanbevolen grenswaarden worden deze metingen beoordeeld voor fysieke activiteit. ESTHER 1.2, een applicatie voor Android telefoons, nam de uitdaging aan van het integreren van self-report data met de verzamelde sensor data. De resultaten van deze studie benadrukken het belang van het door de patiënt laten beschrijven van gevoelens en gebeurtenissen in het verhogen van het zelfbewustzijn van de gezondheid. Verrassend was dat deelnemers aan deze studie ESTHER begonnen te zien als een vriend in hun herstelproces, wat duidelijk de positieve gebruikerservaring benadrukt, los van klinische resultaten. De studie liet ook zien hoe technische en ontwerp beperkingen invloed hebben op de gebruikerservaring.

De derde veldstudie verkent de potentie van Persoonlijke Informatica (PI) in het ondersteunen van het welzijn van kenniswerkers in een kantooromgeving. ESTHER 1.3 is ontwikkeld voor zowel het meten van fysieke activiteit, als het mogelijk maken van self-reporting aan de hand van notificaties. Het doel was om gebruikers te triggeren om te reflecteren op hun fysieke activiteit gedurende kantoor tijden. Bouwend op de vorige versies van ESTHER, diende deze versie ook als een platform om toekomstige reflectieve onderzoeksinterfaces op te laten draaien. De studie leidde tot het begrip van Micro-Cycles of self-Reflection (mCRs). Het principe van mCRs is dat self-report momenten snel, licht en met hoge frequentie in-situ aan

de gebruiker worden gepresenteerd,. De mCRs werden geïntegreerd met alom gebruikte assisterende principes, zoals notificaties, doel bepalen, zelf-monitoring en informatie visualisatie. De voorlopige resultaten van de studie laten zien hoe mCRs een waardevol ondersteunend element kunnen zijn voor het motiveren van mensen die normaal gesproken niet erg actief zijn. De mensen die normaal gesproken redelijk actief zijn lieten ook verbetering zien in het bereiken van doelen, maar ze zagen vooral waarde in het assisterende element van de applicatie.

Op basis van de inzichten uit de veldstudies geeft het proefschrift een reflectie op de volgende uitdagingen van onderzoek in het dagelijks leven: (a) de uitdagingen van het betrekken van patiënten bij een studie, (b) zaken gerelateerd aan de gevoeligheid en privacy omtrent personal health, (c) de kwetsbaarheid van de eindgebruiker, (d) de robuustheid van de technologie in beschikbare tools, en (e) de belasting van gebruiker bij het verzamelen van gebruikerservaringen.

De eerste veldstudies gaven inzicht in hoe de self-report ervaringen over emoties en over het herstelproces het mogelijk zouden kunnen maken voor zorg professionals om kern-incidenten te identificeren. Het expliciet maken van deze incidenten zou kunnen helpen bij het optimaliseren van de communicatie tussen de professional en de patiënt. Daarop volgende studies gaven verder inzicht in hoe de patiënten optimaal geprofileerd kunnen worden door in-situ self-reports te combineren met sensor data over fysieke activiteit.

Samenvattend, de kernbijdrage van dit proefschrift is de empirische studie naar het verschil tussen assistieve en ondersteunende thuiszorg technologie. Ondersteunende technologie is wellicht beter geïntegreerd in het dagelijks leven van mensen. Gebruikers kunnen daarmee een actieve rol te spelen in het bijdragen aan, reflecteren op en leren van de data die automatisch verzameld wordt. De potentie van persuasive technologie kan vergroot worden door het gebruik van zelfreflectie en empowerment in gedragsveranderingsprocessen. Daarnaast beschrijft dit proefschrift de manier om van data-centraal naar gebruiker-centraal design te bewegen, door het meenemen van gebruiker empowerment in HCI praktijken. Dit is een vernieuwende aanpak, waarbij gebruikers betrokken worden in het gezondheidsproces en hun persoonlijke ervaringen, sociale context en fysieke niveau gemeten en in acht genomen worden. Dit zijn cruciale zaken bij het geven van zorg ondersteuning, omdat ze het onderzoek representatiever maken voor de behoeften en wensen van gebruikers in het dagelijks leven.

Acknowledgements

This thesis represents not only my work; it is a milestone in my life. It contains the results of many experiences during this journey that has been nothing short but amazing. And those experiences are closely related to the remarkable individuals who contributed and helped to make this thesis possible. Without them, this journey would never have started and ended.

David, I am heartily thankful to you for introducing me to the world of research. You have given me the opportunity to expand my academic career to a level I never imagined. You were there at the beginning of this journey in 2008 and you are still here with your support and guidance. That is very precious for me. *Paul*, thank you for embracing me in your research team. Your point of view was always inspiring, and your critical observations always helped me to stay focused during my research. *Natalia*, you are a terrific supervisor. Your efforts as supervisor went beyond all my expectations. Thank you for the inspiring discussions, research lessons, teamwork and heart-warming support. I learned from you a lot about scientific thinking and research. Your positivism and passion into all aspects of life made this experience insightful and enjoyable.

This research would have been impossible without the help of my study participants in Delft and Enschede. I am very grateful for your willingness to collaborate in this research. Thank you for opening your home, give me your time to try the prototypes and share your experiences with me. I would also like to thank the Department of Orthopedics in both Reinier de Graaf hospital in Delft and University of Groningen. *Dr. Pilot* and *Dr. Stevens*, thank you for your trust in my research. You contributed to keeping a health-oriented perspective in my work. All students that have contributed to this research: *Joris, Hilde, Dicky, Nur, Johan*, and *Robbin*, thank you for your hard work! *Lisanne, Kah, Dennis* and *Ankit*, thank you for your help as student assistants. Thanks to the current and former members of the Pervasive Systems group in UTwente: *Nirvana, Hans, Siavash, Mitra, Alireza, Muhammad, Zahra, Okan, Kyle, Supriyo, Majid, Ramon* and *Marlies*. I have very good memories with all of you. Special thanks to *Nicole, Thelma* and *Marlous* for you support and always warm welcoming.

StudioLabbers!!! *Rob*, thank you for a coffee break at 10:00h, the music, your sense of humor and positive spirit. I will never forget our fitness sessions. I have to say that you are the responsible of my healthy physical activity habits; you are one of a kind. *Nazli, Katinka, Mafalda, Deger, Fenne, Olivia*, and *Lavender*, it is always good to run into a friendly smile every day. Thank you for the nice chatting, the good vibes and energy every day :) *Reinier*; it was interesting to discuss and share experiences about photography. At this point, you can be a

professional photographer! *Marc*, thank you for your expertise in programming. Your help was very valuable. *Aadjan, Pieter Jan, Paul, Pieter, Jie Li, Nynke, Steven, Tomasz, Abhigyan, Anna, Ricardo, Marco, Boudewijn, Holly, Stella, Jasper, Gert, Lyè, Froukje*, and *Hester* thank you for the positive and comfortable environment. *Maarten*, it was enjoyable to have a shared enthusiasm for photography. Thank you for your kindness.

Odette, I appreciated when we had the time to catch up and talk about life beyond the faculty. Thank you for all the sweets: Chocolate muffins, chocolate bars, Venezuelan delights, I could not be happier to get energetic and fat! All this made my days happier. *Jay*, thank you for your friendship, tips, advices and all the interruptions while I was working (you know what I am talking about). You helped me when I needed the most. You both made my daily life in the faculty much more enjoyable. It is an honor for me to have you both as my Paranympths.

Thomas, thank you for your critical comments on my work and the spiritual support during the last bits of this dissertation, and most importantly, for being such an amazing person you are. Life always rewards good people like you. *Maria*, I am grateful to have met you. You played a vital role in this journey. Thank you for taking care of me, for your company and kindness. I will never forget the karaoke, the dinners, the lunches, the brunch, the movies, the trips, and the tequila combined with aguardiente. I miss all the enjoyable moments I shared with you. *Simone*, I started this journey working next to you. I am very lucky. I liked the synergy when we had the chance team up. *Lian*, thank you for your care and everything you did for me. *Sergio* and *Camilo*, thank you for being such good friends in this lonely, and quite often tough journey. *Julie*, thank you for your help.

Jody, you are amazing, and there are not enough words to express all my gratitude to you. Thank you for being the wonderfully and transparent person you are. *Natalia*, what can I say? Besides the amazing role you played as my supervisor, I am blessed you have become one of the dearest people in my life. Thank you for your care, concern and trust. *Milo*, thank you for always placing a smile in my heart. All of you always made me feel like part of your family, and you are now part of mine. I love you guys!

I have an amazing family in Colombia. Thank you for your unconditional support all these years whenever I need it. You always kept my spirit healthy. *Mamá*, gracias por todo el cariño, la paciencia y en especial por las enseñanzas de vida que me has dado no solo durante estos años lejos de Colombia, sino también durante toda mi vida. Tu fortaleza y tus ganas de hacer siempre bien las cosas cualquiera sea el costo. Y quiero tener la oportunidad de recalcar una enseñanza que recién me has dado y que viene a lugar en este momento de mi vida: en un mundo en que todo esta en constante movimiento, se ha convertido en una habilidad el poder detenerse un momento y dejarse maravillado positivamente por las cosas pequeñas, grandes, bonitas y no tan bonitas que nos trae la vida. En un mundo de distracción en que ya no hay tiempo para detenerse porque toca estar listo para lo siguiente, no hay nada más importante que tener la capacidad de poner atención a los detalles. Esa habilidad y esa capacidad las tienes inherentes en tu espíritu. Eres mi punto de referencia, eres mi mejor ejemplo. Estoy muy orgulloso de ti y nunca será suficiente agradecer todos los sacrificios que tanto tú como mi *Papá* tuvieron que pasar para llegar al punto en el que me encuentro ahora. Gracias a Dios te puedo agradecer en vida. Mi *Papá* me estará escuchando en algún lugar. A él también le dedico todo este recorrido personal y profesional del cual hubiera estado muy orgulloso. A *Germán*, gracias por sus enseñanzas y fortaleza y por estar allí cuando lo he necesitado. Una charla, un abrazo o cualquier actividad juntos es increíblemente reconfortante. *Julián*, mi rol a seguir desde hace tantos años. Creo que jamás llegare a superar al maestro. Gracias por sus consejos, sus opiniones, su sabiduría y su cariñosa objetividad. Gracias por ser el polo a tierra en los momentos mas difíciles y por compartir conmigo los más felices. Esta tesis es de la familia *Jiménez García!* A mi tía *Graciela* y a mi tío *Eduardo*, gracias a ustedes por estar tan cerca a mi familia.

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Juan Jiménez Garcia was born on October 1st, 1976 in Bogotá, Colombia. He obtained his Bachelor from the Department of Industrial Design at Los Andes University in Bogotá. After some years working in the industry of office furniture and corporative image, he continued with a master program in Industrial Design Engineering at Delft University of Technology. In 2008, Juan received a honorific Cum Laude MSc. degree with the project “KITA” (Kinesiofeedback Toy for ADHD children), focused on reflective technology, Tangible User Interfaces and sensing technology.

After his graduation, Juan started his PhD research at the Department of Industrial Design Engineering in Delft University of Technology in 2009. His research focused on the design of supportive technology for healthcare. The application of his research adressed the recovery process of Total Hip Replacement patients (THR), and physical activity awareness and reflection for knowledge workers.

Currently, Juan works as a Post-Doc researcher at TUDelft with the 2ndSKIN project, within the Building Technologies Accelerator (BTA- Climate-KIC's project). His role is to explore and implement reflective mechanisms in the design of technology that supports energy consumption behavior.

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