Universidade de Aveiro Departamento de Comunicação e Arte
2014

CLÁUDIA SANTOS DA CONCEIÇÃO

REDESENHO DA INTERFACE DE UTILIZADOR DA APLICAÇÃO MÓVEL US'EM

REDESIGN OF THE USER INTERFACE OF US'EM MOBILE APPLICATION

Universidade de Aveiro Departamento de Comunicação e Arte
2014

CLÁUDIA SANTOS DA CONCEIÇÃO

REDESENHO DA INTERFACE DE UTILIZADOR DA APLICAÇÃO MÓVEL US'EM

REDESIGN OF THE USER INTERFACE OF US'EM MOBILE APPLICATION

Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Comunicação Multimédia, realizada sob a orientação científica do Doutor Pedro Miguel dos Santos Beça Pereira, Professor auxiliar do Departamento de Comunicação e Arte da Universidade de Aveiro.

Dedico este trabalho aos indivíduos com incapacidades físicas e cognitivas, em particular às vítimas de acidentes vasculares cerebrais, e aos que, de algum modo, os apoiam na sua reabilitação.

o júri

presidente

Luís Francisco Mendes Gabriel Pedro
professor auxiliar da Universidade de Aveiro

Miguel Fernando Paiva Velhote Correia
professor auxiliar da Universidade do Porto

Pedro Miguel dos Santos Beça Pereira
professor auxiliar da Universidade de Aveiro

agradecimentos

Gostaria de agradecer aos meus pais, irmã e irmão pelo apoio e incentivo incondicional durante o meu projecto de investigação.
Um agradecimento especial aos meus orientadores, professores Pedro Beça, Margarida Almeida e Panos Markopolos por me terem guiado neste trabalho e enriquecido o meu conhecimento.
Além disso, gostaria de agradecer às clínicas de reabilitação Adelante e Libra, na Holanda, e CPRG, em Portugal, e aos seus pacientes por contribuirem para a realização dos testes de usabilidade e pela sua inestimável contribuição para a minha investigação.
Além disso, gostaria de agradecer a Nikolaos Batalas, Robert van Vliet, Jamel, José Jordão, Pedro Neves e Jesus Muñoz pelo apoio antes e durante este projecto.
Por último, agradeço ao programa ERAMUS por ter financiado parte dos meus estudos na Universidade Técnica de Eindhoven.

acknowledgments

I would like to express my gratitude to my parents, my sister and brother for the unconditional support and encouragement during my research.
A special thanks to my research supervisors, Professors Pedro Beça, Margarida Almeida and Panos Markopolos for guiding me in this work and for enriching my knowledge.
In addition, I would like to thank the rehabilitation clinics Adelante and Libra, in the Netherlands, and CPRG, in Portugal, and its patients for contributing for the usability tests conducted and their priceless contribution in my research.
Furthermore, I would like to show my gratitude to Nikolaos Batalas, Robert van Vliet, Jamel, José Jordão, Pedro Neves and Jesus Muñoz for the support before and during this project.
Lastly, I would like to thank the ERASMUS programme for funding part of my studies in the Technical University of Eindhoven.

palavras-chave

Saúde móvel, acidentes cerebrovasculares, reabilitação, membros superiores, aplicações móveis, interfaces gráficas de utilizador, design centrado no utilizador, interação do utilizador.

resumo

O trabalho de investigação aqui apresentado objetiva o desenvolvimento de uma viável e adequada interface de utilizador de uma aplicação móvel (app). Esta app é um dos componentes do sistema Us'em, desenvolvido para promover a auto reabilitação após acidentes vasculares cerebrais (AVC). O sistema é baseado em tecnologia vestível, móvel e de monitorização através de sensores.

A app funciona como uma ferramenta de feedback, informando os utilizadores do sistema Us'em sobre a frequência dos movimentos dos seus membros superiores e sobre o seu processo de recuperação. A app objetiva aumentar a motivação dos pacientes em usar o seu braço ou mão debilitado ao longo do dia e, assim, promover a sua reabilitação através do treino autónomo em casa com feedback contínuo. O desenvolvimento da interface de utilizador é de grande relevância, pois determina se pacientes vítimas de AVC conseguem utilizar o sistema Us'em.

O estudo empírico parte da realização de entrevistas, questionários e observação de pacientes vítimas de AVC e fisioterapeutas Portugueses e Holandeses. Este estudo permite uma melhor compreensão do processo de reabilitação e das características e requisitos de vítimas de AVC no que respeita à reabilitação e à interação com dispositivos móveis.

A informação recolhida contribuiu para o desenvolvimento de um protótipo que concretizasse a app Us'em definida. O processo de prototipagem ocorreu ao longo de ciclos iterativos de desenvolvimento, implementação e teste de forma a verificar a adequação da interface de utilizador da app Us'em.

O protótipo final é o produto final deste projeto de investigação e foi testado através de testes de usabilidade com pacientes vítimas de AVC de ambos os países referidos anteriormente.

Os testes ao protótipo final revelam que poderá ser difícil desenvolver uma solução única para todos os utilizadores devido ao conjunto vasto dos seus requisitos. No entanto, o requisito chave da app Us'em é simplicidade: o número de elementos da interface de utilizador, a quantidade de informação e a complexidade das interações e funcionalidades da app deve ser o mais reduzido possível. Esta investigação também permite concluir que a interface de utilizador desenvolvida satisfaz a maior parte dos requisitos dos utilizadores e tem um impacto significativo na motivação de pacientes vítimas de AVC em movimentar o seu braço ou mão desabilitada de forma autónoma.

keywords

mHealth, stroke, reabilitation, upper limbs, mobile applications, graphical user interface, user centered design, user interaction post stroke rehabilitation.

abstract

The research presented here aims to design a feasible and adequate mobile application (app) user interface. This mobile app is part of Us'em system, designed to promote self-rehabilitation after stroke. The system is based on wearable, mobile and tracking sensors-based technology. The app works as a feedback tool, communicating Us'em system users about the frequency of their upper limb moves and about their recovery process. The mobile app aims increasing patient's motivation in using their arm-hand through the day and improving their rehabilitation through self-training at home with continuous feedback. The design of its user interface is of great relevance, because it determines if post stoke patients can use Us'em system.

The empirical part begins with interviews, questionnaires and observation of post stroke patients and physical therapists from Portugal and the Netherlands. It provides a better understanding of post stroke rehabilitation process and stroke victims' characteristics and requirements regarding rehabilitation and mobile devices interaction.

The gathered information contributed to the development of a prototype that materializes the defined Us'em app. The prototyping process ran through iterative cycles of design, implementation and evaluation to ascertain the adequacy of Us'em app user interface.

The final prototype is the final product of this research project and it was evaluated through usability tests with post stroke patients from both countries aforementioned.

Tests to the final prototype show it may be difficult to design a unique solution for all the users due to the wide range of their requirements. However, the core requirements of Us'em mobile app is simplicity: the number of user interface elements, the amount of information and the complexity of iteractions and functionalities of this app should be the lowest as possible. The research also allows to conclude that the user interface designed meets most of user's requirements and it has a significant impact on the motivation of post stroke patients in moving their impaired arm-hand autonomously.

Table of Contents

List of Figures

List of Tables

List of Abbreviations and acronyms

ADL	Activities of Daily Living
App	Application
CRPG	Centro de Reabilitação Profissional de Gaia
CSS	Cascading Style Sheets
E	East
EC	European community
eHealth	Electronic Health
epSOS	European Patients Smart Open Services
EU	European Union
GPS	Global Positioning System
HON	Organisation for Economic Co-operation and Development
HONcode	Health on the Net Foundation Code of Conduct
HTML	HyperText Markup Language
ICT	Information and communications technology
IT	Information Technologies
iOS	Mobile operating system developed by Apple Inc.
KP	knowledge of performance
Libra	Libra Revalidatie & Audiologie
mHealth	Mobile Health
N	North
NW	Northwest
OECD	The Health On the Net Foundation
PDS	Plataforma de Dados de Saúde
PEM	(portuguese) Prescrição Eletrónica de Medicamentos
PHA	Personal Health Application
S	South
SE	Southeast
SINUS	(portuguese) Sistema de Informação para as Unidades de Saúde (english) Information System for Hospital Units
SNS	Serviço Nacional de Saúde (in English, National Health Service)
SONHO	(portuguese) Sistema de Gestão de Doentes Hospitalares (english) Hospital Patients Management System
SVG	Scalable Vector Graphics
PDS-PP	(portuguese) Portal do Profissional (english) Professional Portal
PDS-PU	(portuguese) Portal do Utente (english) Patient Portal
SPMS	(portuguese) Serviços Partilhados do Ministério da Saúde (english) Portuguese health data platform
TU/e	Technical University of Eindhoven
UCD	User Centered Design
UI	User Interface
UML	Unified Modeling Language
W	West

1. Introduction

1.1 Framework

The main focus of this work is centered on Us'em project, developed at the Technical University of Eindhoven[1] (TU/e). Us'em project was initiated in 2009 and has been improved over the last years by TU/e students. In the beginning of the research project here described, Us'em system consisted of a set of two sensing wearable devices and a smartphone mobile application (mobile app). The main goal of the work described in this dissertation was the redesign of the user interface (UI) of Us'em mobile app.
Further information about this project's purposes is presented in the following sections.

1.2. Problem Definition

Nowadays, cerebrovascular diseases, such as stroke, represent one of the major public health issues worldwide (Di Carlo, 2009; Joubert, 2012; Sacco et al., 2013). Stroke incidents are the leading cause of death worldwide (WHO, 2014b). Although during the 20th century stroke mortality rates faced a decrease, stroke global burden increased (Di Carlo, 2009; Kunst, Amiri, & Janssen, 2011; Feigin et al., 2014). In addition, stroke is no longer regarded as a disease of old people, as its incidence in younger population rose (Feigin et al., 2014). In the future, stroke burden is expected to increase, including disability, illness and premature death (Timmermans, 2010). This is justified, for instance, by population's ageing, as age is a risk factor of stroke.
Stroke consequences include both physical and cognitive disorders, affecting the quality of life of stroke victims (Timmermans, 2010). These individuals concern about improving their abilities affected by the stroke event and so require treatment in order to recover them. The key for recovery is rehabilitation (Lövquist & Dreifaldt, 2006). Its purpose is making post stroke victims relearning skills and functions affected by the stroke.
It is a tough and long process, comprising different stages, contexts and participants, entailing high costs (Burke, McNeill, Charles, et al., 2009; Chen, 2013). Consequently, patients' motivation is difficult to maintain. Usually, after the stroke event, they go to the hospital, then to a rehabilitation center and after they are discharged to their home. There, most of the times, they are not provided by rehabilitation services neither supported by their families, and their motivation decreases. Thus, after discharged from the hospital, recovery is less efficient, mainly to its irregularity, and outcomes are more likely to decrease (Lövquist & Dreifaldt, 2006).
However, it is already known the relevant role that technological advances play in finding solutions to handle these problems (Willmann et al., 2007; Joubert, 2012; Deloitte Development LLC, 2014). Systems, devices and applications together with the Internet services and tools enable supporting and guiding rehabilitation patients at home with low costs. Rehabilitation will be more efficient leading to better outcomes, not only because patients continue training but also because they benefit to be at the enriched environment that is their personal context (Burke & McNeill, 2010).

[1] Retrieved September 17, 2014, from http://www.tue.nl/

Concerning arm-hand rehabilitation, patients' improvement is evaluated based on the quality and quantity of their upper limbs moves (in appendix *Interviews-Libra Therapists (results)*). Quality has to do with how properly they move their limbs (executing certain exercises) without worsening their disorders. Quantity, in turn, is related to the frequency they move their impaired arm-hand. Us'em system tracks and monitors the frequency (quantity) of patient's moves. In this regard (quantity), moving the impaired arm-hand the same amount than the good one, a ratio of 50% (moving both arm-hands with the same frequency), is the desired level (Boesten & Markopoulos, 2009). However, moving more does not mean improvement. To mean so, patients need to move more but also better (quality). Having information only about the frequency of their moves is, thus, not enough to assess them. However, this information is relevant information and contributes to assess the patients.

Measuring that data is, now, facilitated by the novel technological developments, such as tracking devices. These computing entities are becoming more and more ubiquitous, being scattered in different spaces, smaller and turning into wearable devices. These are the main reasons that support their introduction in healthcare and wellbeing fields.

Us'em system makes use of wearable (Figure 1) and tracking sensors-based (Figure 2 and Figure 3) technology and takes its advantages to provide a motivational and self-rehabilitation tool for post stroke patients with arm-hand impairments.

Figure 1: Us'em bracelets


Figure 2: Us'em bracelet with sensors technology


Figure 3: Us'em sensors technology

Us'em system purposes are to increase patient's motivation in using their arm-hand through the day and improving their rehabilitation through self-training at home with continuous feedback provided by Us'em. It comprises a set of two wearable bracelets with sensors, which can measure its user's upper limbs moves. This data can, then, be visualized through a mobile app on user's smartphone. Patients' awareness about their moves' frequency, and consequently their motivation, will be enhanced. The system is designed to enable post stroke patients to use it autonomously. It will, thus, promote their self-rehabilitation, increasing their autonomy and motivation. They will be more likely to continue their rehabilitation at home, enhancing their recovery outcomes. This approach invites patients to play a more relevant and participatory role, empowering them in their own rehabilitation. It is of great relevance to mention that Us'em system supports post stroke rehabilitation and cannot replace rehabilitation professional treatment.

The 2 components mentioned above – Us'em bracelets (devices) and mobile app - were developed in previous Us'em projects. User tests revealed that it is valuable and promising approach for rehabilitation at home of post stroke patients with upper limbs impairments. However, projects that focused on the mobile app showed that Us'em mobile interface design was not the best solution. In fact, Us'em target users have cognitive and physical disorders, addressing specific needs and requirements regarding their interaction with the mobile app. Hence, Us'em mobile app interface should be designed to meet these requirements, making possible to Us'em mobile app users interacting with it and perceiving its information. Us'em mobile app UI is, thus, of special concern for usability and interaction as it is an important factor on the decision to use Us'em mobile app and system.

1.3. Research Questions and Goals

The research question that supports this dissertation inquiry the possibility of redesigning a smartphone mobile app capable of providing feedback on upper limbs movements to post stroke patients within the context of Us'em use. To carry on the proposal, at least one mobile app prototype must be implemented and evaluated. Hence, it will be possible to determine which of its aspects should be maintained and improved. In addition, the mobile app should be able to encourage and motivate those individuals in training on their impaired arm and/or hand in daily activities, enhancing their recovery. The mobile interface should be usable, understandable and easy to use regardless their impairments. Furthermore, it should be connected to Us'em devices in order to get and use real values of user's upper limbs moves.

With respect to the questions that guided this research project, they were defined as follows:

- How can smartphones mobile app support home-based upper limbs rehabilitation of post stroke victims?
- Which requirements should an interface design of a mobile app (used as a support and motivation tool in home-based post stroke rehabilitation) meet?
- Considering Us'em system, which requirements should Us'em mobile app meet?

In order to answer the research questions mentioned above, research procedures were defined. They are listed below.

- Understand the stages of post stroke rehabilitation process;

- Understand the relationship between post stroke rehabilitation patients and therapists;
- Characterize post stroke rehabilitation patients and understand the differences between them;
- Understand post stroke victims' requirements and needs along their rehabilitation;
- Understand Us'em project, how it can be relevant in home-based rehabilitation and get to know the results of Us'em previous projects;
- Understand how post stroke rehabilitation patients interact with smartphones, bearing in mind their potential physical or/and cognitive limitations;
- Identify which features the mobile app should have to enable those individuals using it;
- Redesign Us'em mobile app;
- Validate Us'em mobile app.

1.4 Research Organization

In order to answer the defined research questions, the adopted research strategy is based on three components; 1) literature review[2], 2) empirical study and analysis of the post stroke victims' rehabilitation process, and 3) prototype design, implementation and evaluation. Further information is given in chapter *Research Methodology.*
In this dissertation, "older" refers to people aged over 60 year considering most of the sources of references.

1.5 Dissertation structure

The implementation and evaluation of the aforementioned research work is detailed in this document.
It is organized in thirteen chapters. The first 7 chapters have an introductory nature while the remaining chapters are directly related to the proposed to the prototype design, implementation and evaluation of the Us'em mobile app.
The first chapter – *Introduction* - gives a general overview of the motivation and objectives of this dissertation, as well as some of the main concepts. It also introduces the structure of this document.
The next chapter presents an overview of the link between the Information and Communication Technologies (ICT) and healthcare.
The chapter *Stroke accidents* explains the main concepts about this topic.
The next is referred to the rehabilitation of upper extremity after a stroke accident.
The *ICT and Rehabilitation* chapter is about the introduction of the ICT in the rehabilitation field.
The sixth chapter describes the main aspects concerning UI design of mobile apps.

[2] "*literature review is a systematic, explicit, and reproducible method for identifying, evaluating and synthesizing the existing body of completed and recorded work produced by researchers, scholars and practitioners*." (Fink (2005) cited in Blaxter et al., 2010)

In chapter *State of Art* there is a literature review regarding mobile apps. It discusses the current research trends on the field, as well as research projects and recent commercial mobile applications available on the market, including their functions, limitations, goals.
The Us'em system chapter introduces the Us'em framework: previous Us'em projects as well as the most current versions of Us'em mobile app and its UI.
The *Research Methodology* chapter describes the methodology on the basis of this research as well as the data gathering and testing methods. Furthermore, it presents the preparation and application of the instruments that were used to guide this research.
The tenth chapter focuses on the implementation and evolution of the proposed prototype. It presents the requirements regarding technical issues, mobile app's features and UI design. In addition, it describes the prototyping process from the first sketch to the final and tested prototype. Then, the conclusions for the whole research work are drawn, initial research questions are answered and the satisfaction of the goals is examined. In addition, the research development and contributions are discussed.
The penultimate chapter gives the recommendations for future improvements.
Finally, the bibliography is presented in the chapter *References* and the latest – *Appendices* – introduces some technical details of the implementation and detailed information that complements information given in this document.

In addition, there are documents (.pdf files) annexed to the CD of this dissertation. They are referred to throughout this document. They are as follows:
Principles of Fair Information Practices.pdf, Mobile Internet in the Netherlands.pdf, Guidelines to design software for older users (Phiriyapokanon).pdf, Interface Design for Impaired People (Flaten).pdf, User Stories.pdf, Use Cases.pdf, UML Use Case.pdf, Usability Software Defect Log (Constantine).pdf, Usability Test Libra (results).pdf, Usability Test CRPG (results).pdf, Usability Test Tasks.pdf, Interviews-Libra Therapists (guide).pdf, Interview with Jamel (results).pdf, Questionnaires Portuguese Therapists (model-PT).pdf, Questionnaires Portuguese Therapists (results).pdf, Observations Libra (results).pdf, Observations Adelante (results).pdf, System UML use case diagram.pdf, Test low-fidelity prototype (Jamel).pdf, UML Activity Diagram.pdf, Diagram Usem Mobile App Functionalities.pdf, Usability Tests Guide.pdf and *Worldwide Mobile Devices Users.pdf.*

2. ICT and Healthcare

"*This era of "hyper-connected" patients and citizens opens the door to a vast array of new opportunities for disease control and management*" (Claps & Giguashvili, 2014, page 1).
Over the last 25 years, our daily lives interactions have been dramatically influenced by the technology advent (Cunningham, Wake, Waller, & Morris, 2014). Current technologies and services became so commonplace that sometimes we deal with it without realizing it – in ubiquitous scenarios -, even if they have an important role in improving activities of daily living (ADL) (Cunningham et al., 2014; Feng & Winters, 2010).
The advances in technology did promote the widespread use of the Internet and the use of mobile technologies. This new era of ICT changed some fields, such as healthcare, leading to a better interaction alongside an easier access to the information, the improvement of services, information available and living conditions (World Health Organization, 2012). Given the challenges of growing population, shortage of doctors, the increasing incidence of chronic conditions and the rise of healthcare costs, technology will play an important role in wellbeing in healthcare (Rijpma, 2014). It will be a mean of engaging patients and helping health providers to manage their relationships and provide more efficient and effective services.
Nowadays, health data of individuals can be tracked, managed and recorded, enabling easier access to it (World Health Organization, 2012).

2.1 Old population and healthcare challenges

"*Aging of the population is a global phenomenon*" (Teng, Zhang, Poon, & Bonato, 2008, page 62).
According to the World Health Organization[3], world population over 60 years will duplicate from 11% to 22% between 2000 and 2050 (WHO, 2013). It is expected that over that period, there will be an increase from 605 million to 2 thousand million people aged 60 years and over. Moreover, people aged 80 years or older will quadruplicate, representing 395 million of world's population. These changes will affect more and faster low- and middle-income countries. In the Netherlands, for instance, old population will increase between 2014 and 2030[4].
Ageing will lead to an increasing number of unhealthy elderly people. They will have various health problems and many of them will have multi morbidities (Rechel et al., 2013). In European countries, mortality rates regarding older people have been decreasing since the 1970s due to the improvement of health care and health status of population, contributing to the aging of population.
As a sequence, "*the need for long term is rising*" (WHO, 2012, page 3). Indeed, by the year 2015 in developing countries, the number of older people who are not able to care themselves will be 4 times higher, comparing with 2012. They may be not able to live autonomously due to "*limited mobility, chronic pain, frailty or other mental or physical*

[3] Retrieved June 27, 2014 from http://www.who.int/en/
[4] Retrieved June 27, 2014 from http://www.cbs.nl/en-GB/menu/themas/bevolking/cijfers/extra/piramide-fx.htm

health problems", which leads to their need of long-term care such as "*home nursing, community care and assisted living, residential care and long stays in hospitals*" (WHO, 2013, page 1).
If on one hand the growing aging population represents advances in healthcare and medicine fields, on the other hand it triggers new challenges (Rechel et al., 2013). Age-related chronic diseases as a cause of death will increase to 69% in 2030 and its treatment may become the most expensive in our society.
Taking in consideration these factors – aging of the population, increase of healthcare costs, the impact of chronic diseases – healthcare professionals are considering a transformation of the current healthcare systems with a treatment focus shifting from the hospital-centered healthcare to an individual-centered healthcare system. In this new approach has been given relevance to "*early detection of risk factors, early diagnosis, and early treatment*" (Teng et al., 2008, page 1). Furthermore, these issues "*have prompted an unprecedented demand on health services*" and the need to find new solutions to cater the "*rising difficulties in supporting the constantly growing number of chronically diseased persons, older people, or persons with frail health*." (Wilkowska & Ziefle, 2012, page 1).

2.2 Use of Technology by older and young generation

In spite of being nowadays an important element in our daily living providing several services and devices to all age groups, technology is not broadly understood. Sometimes there is a lack of information, knowledge and literacy about the use of modern technology. Most of the current mobile apps and tools present new ways of interaction and UI, which poses challenges to its users (Rama, 2001; Böcker & Schneider, 2014). It is therefore important, thus, to develop strategies that enable users to get familiar with new technology. That is to say that is necessary developing user-friendly interfaces and systems which, in turn, require knowing the user. To achieve that a user-centered approach, such as the User Centered Design methodology (detailed in *User Centered Design* section, in *Research Methodology* chapter), should be used.
With the rapidly aging population and the technology development era, older individuals are facing new challenges in adapting to a modern society (Roupa & Nikas, 2010; Phiriyapokanon, 2011). While young segments can easier adjust to it, older generations have a lower process. This is due to their technological inexperience, health status and their human limitations such as sensory, physical and mental functioning constraint by their advancing age. Usually, older people have a lack of intention and confidence to accept and start to use a new technology they did not use before (Phiriyapokanon, 2011). In addition, as individuals' ability to learn relies on their former experience and as older people are not used to use technology, their ability to learn how to use present-day devices is lower than young people (Phiriyapokanon, 2011). However, these individuals do not like less new technology than other groups. In fact, technology rejection may be due to the low quality of its interface. Older people's acceptance fails when there is not an adequate training period either a good support service, or when user needs are not considered. The ageing of the population forces, thus, technology market to offer products that accommodate elderly requirements.

2.3 Change of traditional home healthcare

"The result of technology's evolution may be a funda*mental change in the delivery and* operating model for traditional home health care." (Deloitte Development LLC, 2014, page 4)

"Home care aims at satisfying people's health and social needs while in *their home by providing appropriate and high-quality home-based health care and social services, by formal and informal caregivers, with the use of technology when appropriate, within a balanced and affordable continuum of care.*" (World Health Organization, 2008, page 1)

Home care offers various relevant services and it is expected to increasingly become part of health systems development and emerge as a promising option for health and social care providence (World Health Organization, 2008). Especially elderly, disabled and chronic ill individuals will benefit from home care potentials. Among others, the factors that drive the need and demand for home care are the "*demographic trends, changes in the epidemiological landscape of disease, the increased focus on user-centered services, the availability of new support technologies and the pressing need to reconfigure health systems to improve responsiveness, continuity, efficiency and equity*" (World Health Organization, 2008, page vi). In addition, home care promotes healing, gives to the patient more freedom and provides tailored services.

The new technologies facilitate and allow providing better services of home care comparing to the traditional means of care. It decreases costs, allow a more frequent and unobtrusive monitoring and allows providing services regardless the distance between the care provider and receiver, improving healthcare outcomes.

In the United of America, healthcare organizations are setting new care strategies for reducing costs and meeting healthcare consumers' demands (Deloitte Development LLC, 2014). Technology is seen as good tool to provide care in people's homes and care models that engage patients. The increased chronic disease prevalence, patients' preference to receive care at their home, the purpose of reducing hospital readmissions and, for instance in the United States, a decrease of costs due to payment arrangements, represents drivers for home care services. It is known too that future care costumers will desire more and have a greater commitment to be provided by chronic and long-term care services at home.

European countries have different patterns of home care (World Health Organization, 2008, page vi). While in Portugal, Italy, Spain, Italy, Belgium and the United Kingdom home care is part of the healthcare system, in other countries, such as the Netherlands, Denmark, Finland and Sweden, health matters are usually regulated within the framework of a national social insurance system. In the Netherlands, there are social insurance organizations that provides home healthcare.

2.4 eHealth

Healthcare services and information were not always available as they are now. Before, "*the delivery of healthcare has been based around paper case notes (e.g. health records, discharge summaries, etc.)*" (Cunningham et al., 2014, page 16). Because of that, sometimes, there was a lack of information about the patient. But now, the combination between technology and health field had led to a new way to deliver health care and the reduction of inefficiencies (WHO, 2014c). This did lead to the creation of a new term: eHealth[5]. It is one powerful tool to boost health care promotion and communication in society, due to its interactivity, the availability of information as well as its users' privacy. Due to these web-based technology and services that have emerged, exchanging information and providing services are now easier (Feng & Winters, 2010).

Indeed, technological developments and eHealth approaches are responsible for the modification of the care intermediation model and configure a new scenario of *apomediation*: patients access relevant care information using intermediaries such as care professionals, but also networks and collaborative groups on the internet, relying less on traditional experts and authorities (Eysenbach, 2008).

2.5 Information mobility and portability: mHealth

Due to the (r)evolution with respect to the combination of technology communications and healthcare sector, healthcare data gained a new dimension: mobility (Feng & Winters, 2010). Thereby, a new concept, a growing sub-segment of eHealth, did emerge: mHealth[6] (World Health Organization, 2001a; World Health Organization, 2012). It is taking advantage of the mobile technologies emergence[7] - mobile devices are increasingly becoming common property and used daily – to cover medical and public health practice providing, for instance, news methods to transfer health information. Consequently, patients' information becomes portable, closing distances and making possible monitoring patients remotely and in real time, and accessing their data from different locations. There is no longer a geographic boundary, which thereby minimizes the overall healthcare costs. Portability of information enables, in addition, healthcare professionals to do timely detection and a faster treatment of the patient (Demiris, 2006; World Health Organization, 2012). Consequently, complications can be avoided and readmissions can be prevented.

In this sense, recently, in June of this year (2014), there was a strategic partnership between Royal Phillips Electronics and Salesforce.com to create a cloud-based platform for healthcare[8]. Its purpose is to offer a new way of managing relationships between patients and care providers, so they can interact closer. It supports connectivity, collaboration, interoperability of medical devices and information from multiple sources around the world, data collection and analysis. In turn, this leads to optimization of

[5] "*eHealth is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies*." (Eysenbach, 2001).

[6] According to WHO, mHealth or mobile health is related to "*the use of mobile technologies for data* collection about individuals and interactive information services" (World Health Organization, 2012) (World Health Organization, 2001a).

[7] For further information about the trending use of mobile devices see document *Worldwide Mobile Devices Users* annexed to the CD of this dissertation.

[8] Retrieved June 27, 2014, from http://www.newscenter.philips.com/nl_nl/standard/about/news/press/2014/20140626-Philips-en-Salesforce-com-kondigen-strategische-samenwerking-aan-om-cloud-technologieen-en-diensten-voor-de-zorg-te-leveren.wpd#.U6wRx_mSxHX (This information source is non-scientific.)

decision-making by professionals and a more active role of patients who will become able to manage their own health. Is also comprises a built-in privacy protection and data security. This system is seen as great progress in the development of real time solutions for digital healthcare.

In Portugal, ALERT®[9] provides software solutions for healthcare units, such as hospitals and acute care settings, to support clinical professionals' activity (ALERT, 2014). With regard to the mobile component, ALERT designed applications for both care providers and citizens, in general. The former can use mobile app to manage their activity at the hospital or even during home visits. Individuals can use ALERT mobile products to search and share information, to create and manage their own personal health record, and to study medicine.

In addition, the Portuguese national health service (in Portuguese *Serviço Nacional de Saúde*) developed the Portuguese health data platform (*Serviços Partilhados do Ministério da Saúde,* in Portuguese)(SPMS) (Serviços Partilhados do Ministério da Saúde, 2014). For further information see section *Portuguese Healthcare system*, in this chapter.

At a European level, the European Patients Smart Open Services (epSOS) (2008-June 2014) is a transnational eHealth initiative in Europe and it is a reflex of data mobility and portability (EpSOS, 2014). Its intention was testing the implementation of cross-border eHealth services. This project aimed for improving healthcare quality and safety for European citizens while traveling abroad, through exchanging health data, and accessing patient health data from different healthcare systems in Europe. Portugal made part of the epSOS network through the Portuguese Health Data Platform. The results show this network, with the commitment of stakeholders is of great relevance for healthcare of European citizens.

Yet, to harness the aforementioned advantages of mHealth, it is needed to establish communication and interoperable data standards such as the Electronic Medical Records (World Health Organization, 2012). Only then it will be possible to make care process more effective, safety and qualified.

Although eHealth and mHealth have a big potential to enhance healthcare, theirs real benefits can only be fully achieved depending on patients' present health and digital literacy (Rechel et al., 2013). The former has to do with patients' ability "*to obtain, process, and act appropriately on health information*" (CECS - Centro de Estudos de Comunicação e Sociedade, 2012, page 226). It is critical and it is one of the most relevant driving factors to better results of healthcare promotion in a population. Health literacy correlates directly with and is a predictor of one's personal health: low levels of health literacy are associated to high hospitalization rates and low prevention practices. Thereby, it is required to develop technology taking in consideration different literacy levels so not only people with technology literacy can use eHealth. However, health literacy has been approached not just with regard to patients and their knowledge and care, but also considering prevention, diagnose, support, counseling and knowledge dissemination. Thus, research is still needed to inform people with low health literacy as well as to develop others' literacy and help them find, understand and use properly health information.

[9] Retrieved 26 September, 2014, from http://www.alert-online.com/

In the current year, 2014, the first study in the health literacy in Portugal shows negative findings: the majority of the inquiries have a problematic or inadequate level of health literacy (ENSP-UNL, 2014). The study shows that not only the vulnerable groups of citizens have inadequate levels of health literacy, but also the Portuguese population overall. In addition, the research allows the researchers to conclude that people aged over 76 have low levels of literacy, while aged 25 or younger have high levels. Comparing to the same study conducted in other 8 European countries, Portugal ranks low. On the contrary, the Netherlands takes one of the top places in the table with a higher level of health literacy among its population.

In addition, regarding digital literacy, the reaction to the emergence of new technology-based tools and services is relevant. It explains the success (people's acceptance) or failure (people's resistance) of these new technologies on the healthcare field (Ketikidis, Bath, & Lazuras, 2011).

Patients' health literacy and education is under responsibility, in part, of public health professionals – someone who is "*educated in pub*lic health or related discipline" and is "*employed to improve health through a population focus*" (Hernandez, Rosenstock, & Gebbie, 2003). A public health system, to be effective, requires well-educated public health professionals who, in turn, educate their patients. In this sense, the ICT diffusion and the emergence of eHealth and mHealth services requires instill also to health professionals technology skills and competencies to develop a proper attitude in eHealth (Stepánková & Engová, 2006; Ketikidis et al., 2011; Barakat, Woolrych, Sixsmith, Kearns, & Kort, 2013). Health care professionals' competence involves skills for using technology and hardware in general but also in the context of eHealth, so they will become educated and competent to deliver efficient, improved and optimized health care services. This is a requirement for healthcare professionals as healthcare systems are introducing technological solutions for health services delivery and replacing traditional tools. Healthcare professionals are, thus, obliged to adapt to and learn how to use these new tools. So, despite being hard to accept these changes for some of them, mainly for older professionals, technology literacy end up increasing.

In Portugal, this can be exemplified by the *Prescrição Eletrónica de Medicamentos* (PEM), a computer tool for healthcare professionals for electronic prescription and respiratory home care services, *Professional Portal* - *Portal do Profissional*, in Portuguese - (PDS-PP) (Portal da Saúde, 2011; Serviços Partilhados do Ministério da Saúde, 2014) (See more information about this digital tools in section *Portuguese Healthcare System*, in this chapter. Both digital tools required training healthcare professionals in order to educate them in using these tools properly and, thus, to achieve better results in healthcare delivery. Moreover, healthcare professionals' acceptance was relevant for the implementation of these tools. Yet, the success of their implementation was not achieved yet due to technological and software problems.

On the other side, as technology affects our lives, rolling out on a daily basis, the acceptance of the new technology-based artifacts and services in healthcare field by both professionals and patients is likely to increase (Feng & Winters, 2010; Cunningham et al., 2014).

Health and technology literacy becomes, thus, "*imperative for all who are involved in healthcare delivery*" to derives benefits from eHealth and mHealth services (Stepánková & Engová, 2006).

2.6 Tracking and Sharing Personal Information

"*Web and related technologies have changed attitudes and the culture in health care*" (Eysenbach, 2008, page 4).

Currently, there is an increasing desire of *self-tracking*: tracking personal health data (Health Data Exploration Project, 2014). People are more and more engaged and more motivated to track, collect, store and analyze their data in fitness or health monitoring - see some examples of these mobile apps and devices, in chapter *State of art*. Although for many people tracking this data might be a result of their curiosity, for others it may be a means of their health and lifestyle improvement (Pfarr, McColgin, & Jordan, 2014).

This trend has been given an increasing number of opportunities thanks to wearable and mobile computing devices and mobile apps with focus on healthcare. Individuals are now using this technology to collect, store and analyze their personal health data (Health Data Exploration Project, 2014). They can track activity, diet, mood, sleep, blood pressure, among others. Consequently, *self-tracking* is no longer limited only to medical and athletic domains, but is also being integrated in societal considerations (Pfarr et al., 2014). These procedures make them more aware and knowledgeable about their healthcare and incentive them using that data to intervene in their behaviors and activities.

Engaging people in *self-tracking* is easier when they are chronic individuals and as they are "*more likely to update their data more regularly*" (Pfarr et al., 2014, page 11).

As individuals track their personal data, they are more likely to care themselves – *Self-care* (Rechel et al., 2013). This concept is related "*with general living conditions, sense of coherence, perceived health, and nutritional state*" (Rechel et al., 2013, page 1317). More specifically, *self-care* is related to the execution of activities that "*maturing or mature persons initiate and perform, within time frames, on their own behalf in the interests of maintaining life, healthful functioning, continuing personal development, and well-being*" (Proot et al., 2002, page 461).

For old people who manage their life in their homes, being able to do this is, in fact, a key health resource (Rechel et al., 2013; Peeters, Wiegers, & Friel, 2013). Specially, chronically ill individuals benefit from *self-management* as their disease management is a lifetime task. They become able to manage their chronic condition autonomously from home and more engaged in their care. Thus, they do not need to go to a clinical environment or to receive professional assistance directly. This capability of people with a chronic condition in controlling themselves over their lives with the disease and its treatment is termed as *self-management* (Duijvendijk & Idzardi, 2013). It is relevant to enhance patients' motivation, treatment and active lifestyle and it can be facilitated by monitoring patients' activity (van der Weegen et al., 2013). These possibilities suggest that, nowadays, rehabilitation process can shift to home, emphasizing patient's central role in managing his condition, becoming more responsible and actively engage in their healthcare. However, it is required that patients are decision-making skilled, independent and capable to care themselves (Proot, Abu-Saad, Van Oorsouw, & Stevens, 2002).

Self-track and, thus, self-management, are facilitated by the current technological developments: sensors are being improved, mobile phones have new features and functions, and devices are becoming smaller and ubiquitous (Duan & Canny, 2004). These new opportunities arouse, thus, an increasing interest in linking technology, which enables self-monitoring with a coach or a health care professional. In addition, this increasing trend of *self-care* and its use of technology can be expressed by the pathway of technology markets. Mobile apps and devices markets are facing a new growing: these new mobile applications allow tracking health parameters and provide information about healthier ways of living (Kofler, 2013). For instance, "*By 2017, around 50 % of mobile users would have downloaded mobile health (mHealth) apps*" (Kofler, 2013, page 1). In fact, "*The European mHealth sector is booming*" (Kofler, 2013, page 1). In March 2014, fitness and medical reference mobile apps were the largest mHealth app categories (HIMSS Europe, 2014). In this category, the number of published mobile apps doubled in 36 months.

Those products, as well as wearable devices, are part of an ecosystem oriented to the consumer where health parameters can be captured with a purpose of self-reflection and self-acknowledgement - Personal Informatics Systems (Li, Dey, & Forlizzi, 2010).

Actually, even the European Commission purposes to make Europeans use mobile apps to manage their health, based on statistics which show that "*In 2013, the top 20 free sports, fitness and health apps already accounted for a total number of 231 million installations worldwide*" and that "*by 2017 3.4 billion people worldwide will own a smartphone and half of* them will be using mHealth app" (European Commission, 2014a, page 7). Another reason is because using mobile apps will lead to a decrease of health costs in European Union in about 99 thousand million euros. Despite the advantages of these new trends, there are some concerns about privacy, consent, data access and security.

Besides being able to do it, now, people are also devoted to sharing its insights with others with similar health conditions in online communities (Health Data Exploration Project, 2014). More and more people are now interested and willing and have the opportunity to share data online about their personal health with others, aiming to learn more about it.

In Portugal, there is the Citizen Portal (launched in 2012) - *Portal do Utente*,[10] in Portuguese – a personal health record area that offers online services such as ebooking, eordering and health education (Portal da Saúde, 2012) (for further information see section *Portuguese Healthcare system*, in this chapter).

This paradigm of sharing information is possible due to the emergence of a new and dynamic paradigm of the Internet - web 2.0, Social web or Social Networking (Pestana, 2011), or People-centric Web (Kamel Boulos & Wheeler, 2007). It promotes an active participation, enabling sharing and discussing ideas, exchanging knowledge and interacting with other individuals. (Eysenbach, 2008; Pestana, 2011). Patients become informed, involved and interested in their own health condition. It happens in virtual communities for different stakeholders (patients, health professionals, public, …) where they meet to share information and insights about their tracked activities, biology and health and to compare findings – Quantified Self movement (Eysenbach, 2003; Health Data Exploration Project, 2014). Data is transformed into actionable insights, helping people to manage themselves and, consequently, improving the outcomes of long-term

[10] Retrieved 03 September, 2014, from https://servicos.min-saude.pt/utente/portal/paginas/default.aspx

wellbeing and health. Internet connected mobile apps in fitness field, for instance, enable its users sharing their information via social networks such as *Facebook* or *Twitter*. This shift heralded, thus, significant changes of the use of the web in healthcare, including attitudes and culture. Now, users/patients have a more active role (Eysenbach, 2008; Pestana, 2011). Just like tracking data, sharing personal information also concerns about data privacy and quality matters. *Patients like me*[11] and *Kaiser Permanente*[12] are examples of virtual communities focused on healthcare sector.

As a consequence, there is a new growing trend termed *Patient Empowerment,* a condition for self-management (Duijvendijk & Idzardi, 2013). This means a different and more important role of the patient regarding his own health (Demiris, 2006). According to Feste (1995), this it brings "*self-awareness, personal responsibility, informed choices and quality of life*" to the patient (cited in Demiris, 2006). Patients become entitled to manage and control their health, making their own care choices independently. Indeed, medical data is no more just a sole custodian of health care providers, but the patient has also an important role and participation. Although, they still need to receive support and be coached by caregivers (Duijvendijk & Idzardi, 2013).

With patients' empowerment and their possibility to track and manage their own health data - *Quantified Self movement* and *Self-tracking* – care systems are now personalized: *Personalized Care Systems*. They may be helpful to chronic ill people in monitoring and managing their condition as well as supporting them to make decisions in real-time and in-context (Pfarr et al., 2014). Hence, it leads to a health and lifestyle improvement.

These issues rise, yet, a lot of discussion concerning how competent are patients to make right decisions with respect to their health.

The focus of *Quantified Self* on people with chronic conditions' needs, requires particular attention on the design of services and mobile app (Pfarr et al., 2014). Monitoring and data management by this population may occur in different settings such as home, outdoors or public spaces. So, products that are intent to be used in clinical environments may meet hospitals staff's needs but not patients' needs. In this way, as care may be at the responsibility of patients and family caregivers, who are not experts as doctors, it is need to design solutions that can be understandable and usable by these individuals. Moreover, they may be influenced by their interactions and knowledge about mainstream consumer technological products, and interact with medical devices with a similar approach. Finally, design requirements include the need to enable different medical practitioners to keep being up-to-dated about patient's status. In order to provide this information to a care team, for example, *Qualified Self* models should be flexible (Li, Dey, & Forlizzi, 2010).

2.6.1 Ubiquitous Technology

Technological trends present technological and computing identities that serve people without their awareness. In other words, novel smart phones and wearable devices are increasingly ubiquitous. The essence and goal of ubiquitous computing environments –

[11] Retrieved June 5, 2014, from http://www.patientslikeme.com/

[12] Retrieved September 16, 2014, from https://healthy.kaiserpermanente.org/html/kaiser/index.shtml

"*Information Technology (IT) embedded in artifacts, infrastructure and environments of daily life*" -, is to be everywhere, serving people without their awareness (Langheinrich, 2001; Feng & Winters, 2010; Singh, 2014). In these contexts, there are computers, sensors and actuators that disappear from people's views, thanks to the "*shrinking form factor of computing and communication devices*" (Langheinrich, 2001, page 6). In addition, and because of the increasing processing power, sensors can perceive aspects of the environment. Sensors are already able to sense temperature, light or noise.

These are also useful tools to collect people's data (Duan & Canny, 2004). They can be connected to wearable devices, which can be used by people in their daily routine as a normal device, enabling them to collect their own data. In 2001, Langheinrich stated that next generation of sensors would allow the sense of human emotional aspects, such as stress, and would be embedded in people's clothes and environment (Langheinrich, 2001). Nowadays, in fact, technologies can be embedded, sensors and devices are getting smaller, so things, people and systems can be connected (Duan & Canny, 2004; Jara, Fernandez, Lopez, Zamora, & Skarmeta, 2013). Wearable technology plays, thus, a relevant role as it extends the possibilities to track and collect personal data as it is explained in section *Wearable technology* in chapter *ICT and Rehabilitation*. Simultaneously, prices of computing and storage technologies have been decreasing which enables the use of these technologies by more individuals.

In spite of almost all legal systems allow data collection without omitting it to the subject who is being monitored, ubiquitous devices may become a mean of illegal monitoring, as their characteristics enable them to be unnoticed. This fact entails discussion about data privacy.

2.6.2 Wearable Technology

Wearable devices are making computing and connectivity very pervasive in our day-to-day lives and, in 2013, there were nearly 22 million wearable devices (CISCO, 2014).

In the last few years, industry and scientific community have been considerate designing and developing wearable biosensor systems. They expect these systems, as well as wireless technologies, may open new horizons and transform health care in the future, enabling a ubiquitous monitoring of patients' health status and individuals managing their personal health (Winters et al., 2003). Their motivations are related to advances in technology (including "*biosensing devices, smart textiles, microelectronics, and wireless communications*") as well as increasing costs in healthcare (Pantelopoulos & Bourbakis, 2010, page 1).

These technologies are considered beneficial to health care area, due to its possibility to monitor the patient, to communicate to patients and/or healthcare specialist and to be aware of an adverse condition (Teng et al., 2008; J. Burke & McNeill, 2010; Wang, Chen, & Markopoulos, 2014). These are important issues, given the ageing of world population will require (J. Burke & McNeill, 2010). In addition, prevention will be significantly less costly than patients' treatment (Park & Jayaraman, 2003).

According to Lymberis (in Teng et al., 2008, page 69), a scientific officer of the European Commission's Information Society, wearable monitoring systems have "*the potential to significantly reshape the provision of health care, assigning new responsibilities for the medical-device maker, the health practitioner and the patient*".

Mainly, the first prototypes of wearable medical systems were based on body-worn devices, which collect data through its sensors.
Since the beginning of the development of wearable devices, user needs and the context of use need must be addressed in order to implement the more valuable features to the end-users. So, issues such as 1) telecommunication, 2) data storage, 3) human technology interface, 4) patient safety, 5) standardization and interoperability, 6) biomedical sensors and 7) security and privacy should be considered. An optimal wearable system must be developed with a consumer-centered approach in order to meet users' needs (Winters, Wang, & Winters, 2003). Sensors should be "*light in weight and have low power consumption, reasonably low in cost, easily accessible by an* inexperienced user and able to maintain a network connection" (Lymberis (2003) cited in Feng & Winters, 2010, page 8).
Nowadays, wearable devices are already being developed to target different groups of end-users such as chronic patients using home telemonitoring (Feng & Winters, 2010). These systems may have smart health wearable devices attached to clothes, jewelry or wristwatches or devices which are not wearable, for instance a chest belt to monitor the heart-rate or a set of headphone[13]. They may be used to sense cardiac activity, blood pressure, blood oxygen saturation, respiration and biochemical measurements (Teng et al., 2008). However, technology progress so fast that it will be even in human's eye[14].
Wearable systems have been considerate for rehabilitation purposes, with particular emphasis to upper extremity in multiple scenarios, since they might be a means to achieve rehabilitation goals (Wang et al., 2014).

2.6.3 Home-based applications

There are also home-based care web applications which can be used to record and transmit monitoring data to a web server (Demiris, 2006). There is a private entity, which owns and maintains the server, "*that allows providers to login and access their patie*nts' *data*" (Demiris, 2006, page 184). Although this possibility promotes several improvements and opportunities to healthcare, it also has implications related to data privacy and ethics.
As the term "Home-based applications" implies, healthcare services are specific and customized to the individual healthcare needs and, so, truly effective for him/her (Feng & Winters, 2010). This approach also enables proactivity, preventing and detecting a disease in an earlier stage, rather than focusing on diagnosis and treatment.

---

[13] In the current year, 2014, a patent for a biometric headphone system enabled to detect metrics such as temperature, heart rate and perspiration levels was announced by Apple[13]. A common and daily tool to listen to music, headphones, was integrated in a fitness monitoring system. Users do not need to use or carry extra equipment, but just the headphones that most of them are already used to use while working out. The collected data may be then transferred wire or wirelessly to a host device such as an iPhone. Retrieved from Retrieved March 5, 2014, from http://appleinsider.com/articles/14/02/18/apple-patents-sensor-packed-health-monitoring-headphones-with-head-gesture-control

[14] Google is prototyping an eye lens that monitors blood sugar levels through user's tears. They are read and that information is, then, sent to a handheld device via wireless. Thus, users can avoid traditional blood sugar tests which require prick the finger. Retrieved June 20, 2014, from http://health.howstuffworks.com/human-body/systems/eye/10-crazy-contacts.htm#page=9

HealthVault[15] application is an example of a Personal Health Application (PHA). It aims to improve personal health, making individuals more informed and helping them to make better decisions about their health and healthcare spending. Users may insert, keep, manage and share health data with other groups online, being more aware of their personal health condition and gaining more knowledge about health care issues.
With regard to chronically ill patients, Royal Philips has developed a home medication dispensing service - *Philips Mediation Dispensing Service*[16] - with a dedicated web-based IT (information technology) connection between patients and their caregiver organization and pharmacist (EHEALTHSERVER, 2014). The system was developed to increase medication adherence by seniors and chronic patients and, thus, improve their health and quality of life. In addition, "*hospital stays, adverse events and healthcare costs*" could be decreased (EHEALTHSERVER, 2014). To achieve that, it monitors and provides prescribed medication at the right time, remind patient to take it, check if he is taking the right ones and it "releases and opens individual pouches according to the patient's *prescribed regimen*" (EHEALTHSERVER, 2014). This monitor and support provided to patient decreases the risk of wrong intake of medication or dose and it enhances his motivation to adhere to personal medication plans. In turn, nursing staff is informed when patient does not take medication. Currently, this service is being applied in Benelux, Luxembourg and it is also rolling out the Netherlands and Belgium.
However, these systems and applications address concerns with respect to the population graying[17]. Applications designers need to consider this users group (WHO, 2014c; Demiris, 2006). On one hand they need to consider that, in most cases, this target group has minor technological literacy, that is to say less experience with technology. On the other hand, their potential functional limitations and accessibility requirements must be address as well. Usability and User Experience are important dimensions related with this issue. They are important concepts as refer to the easy use interface, so the communities members are able to communicate with each other, learn rapidly, get skilled and minimize errors rate (Preece in Demiris, 2006). Thus, they must be considered when designing the applications in health field as well.

[15] Health Vault, by Microsoft, is a web tool to gather, store, use and share health care data of family's members. It can be connected to certain devices such as cholesterol monitoring device or a fitness wristband and store its data. Hence, it makes possible keep tracking and have a better overview of all the family's health. In addition, it enables data sharing with medical professionals, receiving medical exams results, goals setting and checking user's progress. Retrieved September 15, 2014, from https://www.healthvault.com/pt/pt

[16] Retrieved April 28, 2014, from http://www.managemypills.com/content/

[17] According to WHO, "between 2000 and 2050, the proportion of the world's population over 60 years will double from about 11% to 22%. The absolute number of people aged 60 years and over is expected to increase from 605 million to 2 billion over the same period." (WHO, 2014c)

2.7 Data Quality and Privacy

2.7.1 Data Quality

Despite the advantages of data mobility and portability, issues about data privacy and quality have been raised.
Some data is ensured by authorities that are not connected with the mainstream of traditional health care, public health or health research. Devices, mobile apps and services are owned by start-ups, telecommunications and social network corporations that are not integrated in the healthcare systems. Thus, quality of information may be lower comparing to traditional health data sources such as clinical trials, even though it has lower costs.
Because of the liberation and freedom that the web 2.0 offers to everyone to create content, there is a concern with the veracity, security, reliability, quality of the information and ethics (Pestana, 2011; Ferreira, 2006).
Since the Internet provides an extensive and volatile data, some aspects with regard to the quality of the exchangeable information must be considered. The information in healthcare sector must be reliable since it has an impact on the quality of the decisions (Pestana, 2011). In this area, an untrue information result in very negative consequences.
These issues are important regarding to the online information available for everyone but also to that information shared between a patient and a clinician (Ferreira, 2006; Pestana, 2011).
Information must be certificated and there must be given a help to make sure readers to know the source and the purpose of the information, so it can be used to manage and control their health well.
Researchers, governments, healthcare authorities, authors, citizens and others have proposed a set of guidelines in order to promote the deployment of useful and reliable online health information and its efficient use.
In a European context, the EC (European community) in 2002 – currently EU (European Union) - did define quality criteria for the web sites related to healthcare such as honesty and transparency, authority, privacy and personal data protection, data update, responsibility and accessibility. There were other groups, such as the HON[18] (The Health On the Net Foundation) foundation, that have discussed these questions. Furthermore, it was concluded that the users trust more in the websites with the HONcode[19] logo and those with the ".org" ending. There were other initiatives such as American Medical Association, health Summit Working Group and eHealth Code of Ethics.

---

[18] Retrieved April 23, 2014, from http://www.hon.ch/

[19] "The Health on the Net Foundation Code of Conduct (HONcode) for medical and health Web sites addresses one of Internet's main healthcare issues: the reliability and credibility of information" (HON, 2013).

2.7.2 Data privacy

Online communication and social networking enable sharing a wide range of information. In most of the cases, people, mostly the new generation, do not considerate privacy settings. Young individuals, already born during the digital era, have different approaches with regard to privacy, social and online sharing.
Online systems involve data privacy[20] issues that, if not well addressed, may be a reason of users' abandonment, for instance if they are asked too much information (Hong, 2012). Hence, it is important to offer to users different ways to set their privacy preferences, instead of providing them a fixed set of policies that they need to accept or reject.
Assess a system's privacy varies depending on temporal, social and cultural factors (Iachello & Abowd, 2005). The fast technology development is addressing new challenges to healthcare field. Digital data in this field requires security requirements, as it is impacting individual privacy rights.

Fair Information Practices address issues related to information collection and use regarding the subject's consent, and to the application needs (Iachello & Abowd, 2005).
These principles, codified in the OECD (Organisation for Economic Co-operation and Development) guidelines in 1980, based in Langheinrich (2001) are detailed in document *Principles of Fair Information Practices* annexed to the CD of this dissertation.

The *Principle of Proportionality*[21] advocates the need of any application, tool or process to balance "*its utility with the rights to privacy (personal, informational, etc.) of the involved individuals*" (Iachello & Abowd, 2005, page 92). It is similar to the *Fair Information Practices* and resembles to *Data Quality* practice. However, on one hand, *Fair Information Practices* address issues related to information collection and use regarding the subject's consent, and to the application needs. On the other one, *Proportionality* reflects on "*the balance between the usefulness of the considered application and its effects on privacy*", and on how technology and its impact on their daily life might be accepted by people (Iachello & Abowd, 2005, page 92).

Based on Proportionality concept "*between utility of data collection and its burden on privacy*", the *European Union* set out a regulation of data protection the European Union's Directive 95/46/EC[22] or "The Directive" (Langheinrich, 2001; Iachello & Abowd, 2005). It intends to regulate the processing and free movement of personal data[23] in European

[20] "Information privacy is the patient's right to control the use and dissemination of information that *relates to them.*" (Demiris, 2006). Privacy also Privacy is also "*the claim of individuals, groups, or institutions to determine for themselves when, how, and to what extent information about them is communicated to others*", according to Alan Westin (1967) (Cate, 2006).
[21] "*Proportionality is a straightforward principle widely used in the legal community for judging upon the merits and trade-offs of privacy-sensitive IT applications*" (Iachello & Abowd, 2005).
[22] Retrieved September 15, 2014, from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31995L0046:en:HTML
[23] According to the European Commission, "*personal data is any information relating to an individual, whether it relates to his or her private, professional or public life. It can be anything from*

Union's countries, being on the basis of data protection laws for all them. This directive defends that "personal data may be processed only if … processing is necessary for the *purposes of the legitimate interests pursued by the controller or by the third party or parties to whom the data are disclosed*" (Iachello & Abowd, 2005, page 92). Indeed, considering the benefits of data collection should be equal to consider the interest of those from whom data is collected in controlling that process and the exposure of their personal information.

In addition, collectors of information are also required to receive an explicit consent that might be a written contract, from the individual who provides information.

Also in Europe, there is the European Health Insurance Card (European Commission, n.d.). This card, free of charge, allows European citizens to access "*medically necessary, state-provided healthcare*" while staying in the 28 European Union countries, Iceland, Lichtenstein, Norway and Switzerland., and healthcare is provided under the conditions and costs of the care system in that country. This card is personal: its data includes a number that identifies the individual. Hence, the patient can receive treatment outside his country in privately.

However, this directive does not address globalization and technological developments issues. Hence, to reform "The Directive" (the current EU Data Protection Directive 95/46/EC), the European Commission intents to implement a single law in the EU to unify data protection: the General Data Protection Regulation (European Commission, 2012; European Commission, 2014b). This proposed law will comprise new guidelines for data protection and privacy that consider the new technologies, extending the scope of the current European Union data protection law. In addition, it ensures protecting data that is transferred to the outside of the EU.

Data privacy in Healthcare

When online systems are related to healthcare – eHealth systems – users/patients should be able to decide which, to whom and for what purposes their personal information will be exposed in accordance to privacy legislation and regulations. Medical information requires special attention regarding to its privacy, security and data handling, as it is directly related with social living and ethical issues (Wilkowska & Ziefle, 2012). In addition, it is individuals' private information which is shared with doctors and, sometimes, with relatives or friends confidentially.

In the scope of eHealth and medical technology, and in its design and use, these issues must be considered. They require even more attention in environments where those technologies are used because data is processed and transferred electronically. Thus, it is necessary to examine electronic devices and systems with regard to their security properties - especially medical monitoring systems to assist elderly, as this group of individuals is particularly vulnerable.

Medical technologies are more likely to be accepted by users, and so successfully adopted and implemented, if they meet their needs and requirements. eHealth products and technologies need, thus, to be designed taking in consideration its value to

---

a name, a photo, an email address, bank details, posts on social networking websites, medical information, or a computer's IP addr*ess*" (European Commission, 2012a).

healthcare, technical feasibility as well as human factors and its user's perceptions, including their privacy. For instance, despite their positive effects in improving medical treatment, real time monitoring and tracking technology, which also involve ubiquitous technology, address discussion about personal intimacy limits related to privacy and security.

Even if Wilkowska & Ziefle (2012) study's findings cannot be generalized, they showed people less healthy do not pay much attention to security aspects, as they find more important the value of good health than the need to protect and self-determine digital data. They need frequent medical examinations, so it is also relevant medical staff to quickly access medical data. With regard to privacy, this group pf people have lower demands.

On the other hand, data protection is more relevant to healthy individuals as they "*do not need, or are simply not accustomed to*" a transparency of this information (Wilkowska & Ziefle, 2012, page 196). In addition, they demand higher confidentiality, anonymity and intimacy, without sharing their eHealth usage and results of its measurements with others.

Data security and privacy is given less relevance by less healthy people. Indeed, chronic patients require and give more importance to their need to get fast help and to be continuously monitored, so they have less concern about security and privacy loss.

2.8 Mobile Technologies and Mobile Internet

"*The recent globalization of mobile technology and its overwhelming presence on everyday life through various societal groups and activities has raised its importance to unprecedented levels.*" (Sá, Carriço, & Duarte, 2014, page 191).

Smartphones are increasingly becoming common property and its users are becoming reliant of their devices, using them every day (Google, 2013). For some of those, these devices are indispensable to their daily activities and are changing some of their daily behaviors. For instance, 75% of them use their smartphone while multi-tasking (for example, driving or watching TV at the same time).

According to CISCO[24], in 2013, there was an increase of 81% in global mobile data traffic. Indeed, it was "*18 times the size of the entire global Internet in 2000*" (CISCO, 2014). In addition, mobile devices and connection have also increased globally about half a thousand million in 2013, of which 77% of that growth was related to smartphones and 21% represented smart devices (with 88% of the mobile traffic).

In 2018, mobile network will face a significant rise. It is envisioned a big increase in both global mobile data traffic and the number of mobile-connected devices. In fact, regarding the latter, it is expected that it will exceed the world's population by 2014 and, by 2018, there will be 1.4 mobile devices per capita (CISCO, 2014).

Smartphones usage will increase and, consequently, they will represent 66% of mobile data traffic by 2018.

Smart devices, in turn, will represent 50% of all mobile network connected devices.

If on one hand the number of information technology devices and services is increasing, the audience that is using them is also broader than before.

[24] Retrieved April 23, 2014, from http://www.cisco.com/c/en/us/index.html

Information about Mobile internet use in the Netherlands can be found in the document *Mobile Internet in the Netherlands* annexed to the CD of this dissertation.

2.9 Dutch Healthcare system

Every country has a different way of providing health care for its residents (National Institute for Public Health and the Environment, 2010). Yet, improving health is the main goal of a health system as well as one of the main goals of health care. Thus, a care system is considered fair when there are good levels of health care and distribution, without inequalities.

The Dutch health care system is considered a “*work in progress*” due to the reforms that have been introduced in the past few decades (National Institute for Public Health and the Environment, 2010). Despite the economic crisis that has been affect it, the Ministry of Health defends a qualified, effective and affordable system, accessible to all Dutch citizens regardless their age, health status, income or lifestyle (National Institute for Public Health and the Environment, 2010; Verónica & Geppaart, 2010; Nictiz & NIVEL, 2013).

Although the system has a mostly “*excellent*” accessibility, a quality that overcomes the average in some areas, and its costs that do not differ from neighboring countries, new challenges are being faced. There are several reasons to this need such as the aging of the population, the increase of chronic patients, the increase of the scarce human resources and the increasing healthcare costs. Yet, since 2006, there were no substantial changes in quality or accessibility. In order to face these changes, new treatment modalities are being developed; however its price makes them not affordable.

“*How can we maintain our strong position in the next few years? Working more efficiently is the best way to cut costs.*”, Ab Klink, the Minister of Health, Welfare and Sport in Netherlands in 2010 (National Institute for Public Health and the Environment, 2010, page 4). Informal contacts established during the internship allowed us to verify that Dutch people are used to be supported by the government. However, due to crisis, this situation is changing and government is less capable to support them. People are now wondering about until when the government can handle this situation.

Dutch healthcare sector comprises three interlinked submarkets: 1) a healthcare delivery market, 2) a healthcare purchasing market and 3) a healthcare insurance market. The Healthcare purchasing market provides services to insurance companies. These aim buying good-quality and reasonably priced services in that market and, in turn, provide them to consumers. Consumers, then, choose a healthcare insurance company and a policy option that suits better their needs. According to this selection, they may choose and use a set of services in the healthcare delivery market.

Dutch patients are living longer and their health gains are justified by disease prevention and health care (Verónica & Geppaart, 2010). Furthermore, their relationship with doctors is changing: patients have a more active role in care process, in contrast to the past when they were hesitant to ask information to medical specialists.

Despite rating well their health care system, some Dutch citizens are dissatisfied about accessibility in some areas (National Institute for Public Health and the Environment, 2010). Additionally, this system has other drawbacks, such as poor co-operation and coordination between people involved in the care process, leading to a lack of information, unnecessary duplicated tests and conflicting advice to the patients.

Chronically ill individuals represent a quarter of Dutch citizens and caring them requires high expenditures (Nictiz & NIVEL, 2013). In recent years, expenditures in their personal health care have not changed, yet there is shift in the types of expenditures (Verónica & Geppaart, 2010). Extra costs for aids and appliances and for home adaptations were reported. Three percent of the Dutch population with a chronic illness (including people have had or have a chronic illness, had surgery and/or were hospitalized in the past two years) forewent a visit to the doctor (National Institute for Public Health and the Environment, 2010).

Currently, the Netherlands does not have a healthcare system capable to provide care services to citizens with a chronic condition (Duijvendijk & Idzardi, 2013). Its system first focus is the acute care services, which are also needed by chronic patients. However, they need more than that: they require a planned support, control and guidance. Hence, a more integrated approach is necessary that focuses on care for citizens with chronic disease, encouraging self-management and a more important role in their care. There is, thus, a new strategy in which responsibility by care is shared by the various parties. In the Netherlands, this shift to integrated approaches can be exemplified by the Chronic Care Model. It proposes giving patients a central role as well as new responsibilities to caregivers. More than treatment and care, now they provide support on the physical and/or psychological, and social effects.

In 2009, in the Netherlands, innovations in long-term care, which included eHealth, were being slowly adopted and with great progresses (National Institute for Public Health and the Environment, 2010). On the basis of it there is the use of digital records by general practitioners (Nictiz & NIVEL, 2013). However, there are still relevant aspects that need to be overcome. For instance, exchanging data electronically between healthcare providers is quite established, but it still needs a lot of improvement.

Integration of eHealth in the Netherlands is occurring in a small scale (although still growing), so people think that is not being using yet but just being experimented. In turn, the slow progress is justified by the fact that both healthcare users and providers are not fully aware about eHealth and its issues related to legislation, privacy and information security. Healthcare providers think, thus, that introducing eHealth is a long-term process and expectations should be moderate to a certain extent (Nictiz & NIVEL, 2013).

Despite the number of Dutch citizens who have access to the internet (94%) and the high percentage of the population that use the internet as a source of information for healthcare issues (66% search for information with respect to diseases or treatment), there are not many eHealth applications being used (Nictiz & NIVEL, 2013). The number of self-management applications' users is reduced, as well as of those who desire to use them in the future. Currently, only 6% use applications that enable carrying out self-diagnosis via online, 4% use application which male possible updating medical data online and 2% use a telephone as a reminder for taking medication (Nictiz & NIVEL, 2013).

2.10 Portuguese Healthcare system

The Portuguese National Health Service (in Portuguese, Serviço Nacional de Saúde (SNS)) was settled in 1971 (Cardoso, Espanha, & Mendes, 2007; Governo da República Portuguesa, 2014). In the following decades, special attention has been paid to the right to health of all Portuguese citizens (including promoting and monitoring their health, disease prevention, diagnosis, treatment and medical and social rehabilitation), to the integration of health services and, among others, to a central functioning approach. At present, the SNS comprise the services and public entities that provide healthcare services.

In Portugal, the use of ICT in health field did start in the nineties (Simões, 2010). The goal of its adoption were the need to account the productivity, establish a new information system which could enable the control and management of patients, as well as to enhance the communication between hospitals and health care centers, standardize clinical data and compile statistics (Cardoso et al., 2007; Simões, 2010).

In turn, it did lead to the emergence of electronic data transfer and so, to eHealth. Thus, a new patient card and different operative systems to health data were developed.

One of the most important implementations of ICT in healthcare in Portugal was the "*Rede de Informação da Saúde*", in English *Health Information Network*, which enabled connecting several local networks and the computers of an institution. The SINUS ("*Sistema de Informação para as Unidades de Saúde*", in English *Information System for Hospital Units*) and SONHO[25] ("*Sistema de Gestão de Doentes Hospitalares*", in English *Hospital Patients Management System*) are other examples of systems developed at that time.

In this scope, it was possible to set a point of care where all the information could be accessible. It was valuable to minimize clinical errors, maximize the number of care givers and control costs, time and assignments.

However, at that time, there was still no integration and standardization of health services in the Portuguese health system. It was just between 2004 and 2008 that Portugal faced a considerable mind shift: there were more hospitals connected to the internet and some of those using telemedicine. In addition, among others, there was an increase of available data about health prevention and care.

At present, the Portuguese healthcare system has technological solutions that aim to improve its quality and services delivery.

For instance, there is the *Portuguese health data platform* (in Portuguese, "*Plataforma de Dados de Saúde*" (PDS)), a central registration and sharing system created by the SNS (Portal da Saúde, 2012). Healthcare professionals can access PDS platform and the information about their patients through the PDS-PP (Serviços Partilhados do Ministério da Saúde, 2014). It is expected that, in this way, services delivery will be faster and it will be more secure for healthcare professionals to get to know the patient and diagnose them. Regarding Portuguese citizens, those who have a SNS patient number can also access the platform, register health information, use online health services and manage the access to their information stored in PDS. Accessing this service is free for all the

[25] Retrieved September 15, 2014, from http://portalcodgdh.min-saude.pt/index.php/SONHO

Portuguese citizens and it is through the *Citizen Portal* (launched in 2012) – "*Portal do Utente*" (PDS-PU), in Portuguese -, part of the PDS (Portal da Saúde, 2012; Governo de Portugal - Ministério da Saúde, 2014). It is a personal health record area that offers online services such as ebooking, eordering and health education. This platform is based on centralization, integration, personalization[26] and it provides information that patients understand, fulfilling their needs. It has 2 types of services: information services and electronic services. The latter requires patient authentication and his active role in maintaining, promoting and improvement of his health condition. Patient can register information about his health condition, medication, diseases, schedule a clinical appointment, access health information, among others. If allowed by the patient, SNS healthcare professionals can access patient information on the portal (through PDS-PP) and, thus, improve the delivery of healthcare services. However, according to *Público*, a Portuguese newspaper (non-scientific source of information), only 838 000 patients have registered in the platform, contrary to expectations of 2 million this year (2014). One of the reasons is the requirement to patients to of have an identification card reader to use the *Citizen Portal* (Público, 2014).

The *Prescrição Eletrónica de Medicamentos* (PEM) is other technology-based solution that is currently being using in Portugal (Portal da Saúde, 2011; Serviços Partilhados do Ministério da Saúde, 2014). It is a computer tool for healthcare professionals for electronic prescription and respiratory home care services, designed by the SPMS and is mandatory for professionals of the SNS.

[26] Personalization has to do with the changes based on implicit data. A personalized system/service/product fits user's requirements (abilities, preferences and needs) (Feng & Winters, 2010). This is the definition of personalization that was considered to this research project.

3. Stroke Accidents

3.1 Stroke Burden

"*Stroke is a costly disease from human, family and societal Perspectives*" (Di Carlo, 2009 page 4).

Nowadays, stroke accidents are the leading cause of morbidity worldwide and are the first leading cause of death worldwide: stroke mortality was estimated to be in excess of 150.000, in 2004 worldwide (Di Carlo, 2009; Joubert, 2012; Sacco et al., 2013). Feigin et al (2014) stated that, in the last two decades (1990-2010), stroke deaths rates have decreased worldwide, although stroke accidents in younger people did increase. Indeed, this is no longer regarded as a disease of older people. Young and middle-age people experience one-third of all strokes and, between 1990 and 2010, stroke incidence in people aged 20 to 64 did rise 25% (HealthDay, 2013). In fact, the stroke incidence among people aged 20 and younger is 0,5% of all strokes worldwide and 83.000 people of them experience a stroke each year. Furthermore, the second cause of disability in individuals older than 60 years worldwide are the cerebrovascular diseases, such as stroke (Freitas, Bezerra, Maulaz, & Bogousslavsky, 2005). Besides, stroke is the main cause of chronic disability in adults, which make it a major public health issue worldwide (Di Carlo, 2009; Joubert, 2012; Sacco et al., 2013). In the Netherlands, stroke accidents represent the third cause of mortality (Evers, Engel, & Ament, 1997; Struijs et al., 2005).

Over two decades, between 1990 and 2010, a global stroke burden faced a rise: the number of people experiencing a stroke for the first time did increase 68% to 16,9 million. There were 33 million stroke survivors, an increase of 84%, and illness and disability because of stroke affected 102 million people, an increase of 12%[27]. Indeed, in terms of disability-adjusted life years there are 72 million of cases worldwide each year (Di Carlo, 2009).
Nonetheless, during the 20th century there was a decrease on stroke mortality rates as well as in incidence and case-fatality rates among men and women (Kunst et al., 2011). These facts may be explained by lifestyle improvements, "*environmental exposures in different phases of life*" and the current progress in "*secondary prevention and treatment of stroke*". The "*combination of improved lives, prevention, and treatment*" and that the improvement in health care delivery might have been also a relevant factor to decrease old-age mortality during the 21st century (Rechel et al., 2013, page 1312 and 1313).
Globally, the average of stroke patients did increase, but people age 74 and younger were the ones who did face an increase of illness and death caused by stroke events[25].
Between 2000 and 2025, in European Union countries stroke accidents may increase 30% (Timmermans, 2010). Some findings also show that if this increasing trend will persist, in 2030 there will be 12 million of stroke deaths, 70 million of stroke survivors and 200 million of stroke disability and illness. In fact, is projected that stroke burden - disability, illness and premature death - will double by 2030 worldwide (HealthDay, 2013).

---

[27] Retrieved September 15, 2014 from http://consumer.healthday.com/circulatory-system-information-7/blood-pressure-news-70/stroke-young-people-lancet-release-681368.html

Furthermore, the world population is aging and those aged 60 and over are prospected to be about 1.363 million in 2030, an increase of 180% since 1990 (Di Carlo, 2009). As age is one of the stroke risk factors, the number of individuals at a stroke risk is increasing.
In the Netherlands, until the year of 2020, rates of stroke will increase continuously (Struijs et al., 2005). This expectation is based on population's graying (population changes in size and composition), smoking and hypertension rates that are expected. It is also known this increase is larger for woman (40%) than for men (18%), what might be explained by past smoking behaviors among the two genres.
Regarding to stroke, cerebral hemorrhagic or myocardial infarction and are in-hospital case-fatality rates within 30 days, in an international level, the Netherlands presents numbers above the European average. Comparing to other European countries, the Netherlands scores poorly with a high rate (5,9%) of in-hospital case-fatality within thirty days for ischemic stroke patients. However, over the past few years this percentage has decrease. In regard to hemorrhagic stroke accidents, 25% of those who were admitted to hospital died within 30 days, in 2005, which contributes to make "*the Netherlands one of the countries with the highest 30-day mortality rate*" (National Institute for Public Health and the Environment, 2010).

3.2 Stroke Accidents

The *stroke* term classic definition is mainly clinical and refers it as a consequence of a vascular problem which causes an acute focal injury of the central nervous system (Sacco et al., 2013). However, the term "*is not consistently defined in clinical practice, in clinical research, or in assessments of the public health*." (Sacco et al., 2013, page 2).
A stroke, or cerebrovascular accident (CVA), is caused by the collapse of the blood supply to the brain, that is to say the blood is interrupted or stops moving through as artery (WHO, 2014a; National Stroke Foundation - Australia, 2014b). Usually, there are two stroke accidents causes: a burst of blood vessels (Hemorrhagic stroke) (Figure 4) or a clot block (Ischaemic stroke) (Figure 5).

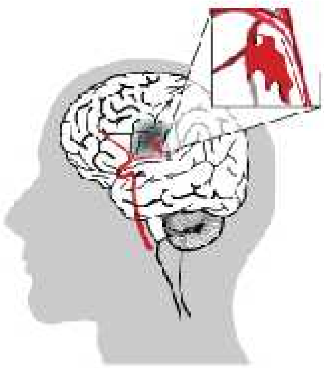


Figure 4: Hemorrhagic stroke bleed in the brain[28]

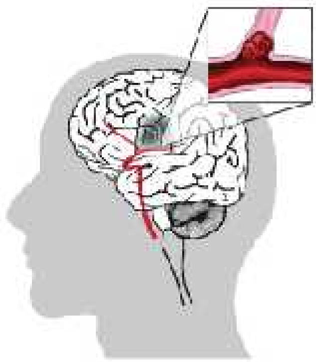


Figure 5: Ischaemic stroke blocked artery[29]

[28] Retrieved March 06, 2014, from http://strokefoundation.com.au/what-is-a-stroke/types-of-stroke/haemorrhagic-stroke-bleed-in-the-brain

The supply of oxygen and nutrients for the brain cells is cut off and too much pressure is put on the brain, causing cells to die. Consequently, it causes a disturbance of the brain tissue and its function. This brain damage area is called a cerebral infarct (National Stroke Foundation - Australia, 2014b).

Even if both are equally common, hemorrhagic causes 61% of stroke-related disability and nearly 52% of stroke deaths[30]. Just as stroke incidence is higher among younger than 75 aged and in low- and middle-countries, hemorrhagic strokes rates have increased in those groups.
Stroke accidents depends on local environmental, cultural, socioeconomic and genetic variables (Freitas et al., 2005). Furthermore, the causes of stroke accidents can be related to the race and ethnic origin, family history, gender and other health conditions (Freitas et al. 2005; National Health Service, n.d.; van der Weegen et al., 2013; Hall, 2014; National Stroke Association, 2014).
As a result of a stroke accident, the brain of stroke victims is damaged making them gain mental and/or body functions problems and lose some basic skills (Willems, 2013).
About half of stroke victims gain some physical or cognitive impairment (Di Carlo, 2009). Their gained impairments can include "*loss of balance, attention and concentration deficiencies, pain, weakness and paralysis*" (J. Burke & McNeill, 2010, page 1). Cognitive disorders and consequent symptoms might be "*confusion, difficulty speaking or understanding speech; difficulty seeing with one or both eyes; difficulty walking, dizziness, loss of balance or coordination; severe headache with no known cause; fainting or unconsciousness*" (WHO, 2014a).
In relation to the specific brain part is damaged, stroke consequences also affect the control of the different human functions such as the way to move the body, think, use of language or receive sensory messages like touch, sigh or smell (National Stroke Foundation - Australia, 2014a). Usually, when the left side of the brain is affected by a stroke, the patient has problems on the right side of the body, and if the stroke happens on the right side, the patient's left side is affected. When a stroke occurs at the base of the brain, some activities such eat, breath and move can become difficult to execute by the patient. Thus, each post stroke patient has a different outcome according to the brain location where the stroke takes place but also how big the stroke is (Wingen, 2013). Thereby, each of them will have different problems and so different needs. Furthermore, the pre-stroke conditions, like the general health and the level of activity, are also important on the effect and recovery process of a stroke.
Consequently, they face new challenges in their daily activities, wellbeing and quality of lives, just as their life plans which are suddenly interrupted (Di Carlo, 2009; Proot et al., 2002). 30% of stroke victims become permanently disabled and 20% require institutional placement at 3 months. These individuals require support during their daily routine as well as in the acceptance of the new condition. Moreover, there is also an impact on patients' families and society (Di Carlo, 2009; Joubert, 2012). The damage of a post stroke victim

---

[29] Retrieved March 06, 2014, from http://strokefoundation.com.au/what-is-a-stroke/types-of-stroke/ischaemic-stroke-blocked-artery

[30] Retrieved March 06, 2014, from http://consumer.healthday.com/circulatory-system-information-7/blood-pressure-news-70/stroke-young-people-lancet-release-681368.html

can be widespread and long-lasting, so recovering their former independence may be a long process (National Health Service, n.d.)[31].

3.2.1 Motor Impairments

Mainly, strokes accidents can affect up to 80% of the patient and result in motor impairments[32], that is to say in deviation or loss of the body functions or structure (Langhorne, Coupar, & Pollock, 2009; World Health Organization, 2001b). In a multiethnic population, this type of deficits is the most commonly reported one week after onset first-ever stroke accident (Askim, 2008). They are defined as a sudden weakness or numbness of the face, arm, leg of most often on one side of the body which provokes the loss or limitation in mobility and body's control (World Health Organization, 2001b). 70%-80% represent the victims with upper limb problems (World Health Organization, 2001b; Pang, Harris, & Eng, 2006). 66% of stroke survivors can remain with weak upper limb (J. Burke & McNeill, 2010). Approximately 80% suffer from acute hemiparesis, a motor deficit of one side of a person's body (Timmermans, 2010). In addition, 40% of all stroke patients have chronic upper extremity due to that type of deficit. Some patients can acquire, for instance, reduced balance and some of them cannot stand without a support (Askim, 2008). Consequently, when the patients have motor impairments, they have a lower self-perceived health, so a poor quality of life, being affected in their daily life activities and engagement in social life (Askim, 2008; Langhorne et al., 2009; Timmermans, 2010).

Upper Limb Impairments

After 6 months, 5% to 20% of stroke patients have recovered their arm-hand function, and 33% are independent (Timmermans, 2010). In addition, while posture and gait tend to improve (85% of the patients are able to walk independently in indoor setting), the arm-hand function does not. In fact, 33% of them did "*need help with feeding, 31% need help* with dressing and 49% need help with bathing." (Table 1).

Table 1: Percentage of post stroke victims with upper limb impairments

	After 6 months	After 4 years
100% arm-hand function	5%-20% patients	
Independent patients	33%	
Patients enable to:		
Walk	15%	
Help feeding	33%	
Dressing	31%	
Bathing	49%	
Non-use/disuse affected arm		67%

[31] Non-scientific data source

[32] Impairment is a loss or abnormality in body structure or physiological function (including mental functions). Abnormality here is used strictly to refer to a significant variation from established statistical norms (i.e. as a deviation from a population mean within measured standard norms) and should be used only in this sense (World Health Organization, 2001b). It can be temporary or permanent; progressive, regressive or static; intermittent or continuous.

Pang et al. (2006) also add that 25 to 33% of the patients are dependent in at least one ADL task 6 months after stroke (Pang et al., 2006). Further, the major problem of 67% of the stroke patients, four years after the accident, is the non-use or disuse of the affected arm (Timmermans, 2010).

Since the impairments caused by a stroke accident can affect victims ability to perform daily activities and have a tremendous impact on his participation in everyday life situations and on the rehabilitation process, stroke victims can also be considered disable[33] (Langhorne et al., 2009). Because of that, post stroke rehabilitation involves physiotherapy and motor training.

3.2.2 Recovery

After a stroke event, stroke victims have gained physical and/or cognitive impairments and, consequently, lost some of their functions and skills (Langhorne, Coupar, & Pollock, 2009; World Health Organization, 2001b).

Therefore, they aim recovering their skills and functions affected by the accident and, thus, improving their abilities and daily lives (Lövquist & Dreifaldt, 2006; Kemna & Culmer, 2009; World Health Organization, 2011; Willems, 2013). To that, post stroke patients require a recovery plan and process – rehabilitation (detailed in next chapter) that support and guide them regaining the affected functions.

Respecting to how long an individual have experienced a stroke, stroke survivors "*may be classified as being in an acute, subacute or chronic stage*" (Timmermans, Seelen, Willmann, & Kingma, 2009). Acute patients are those who had experience a stroke accident until thirty days ago, subacute experienced the accident between thirty days to six months and chronic suffered a stroke more than six months ago. In turn, according to patient's stage, different restorative process may occur, as shown in Figure 6.

[33] "*In the context of health experience, a disability is any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being*" (World Health Organization, 1980, page 28).

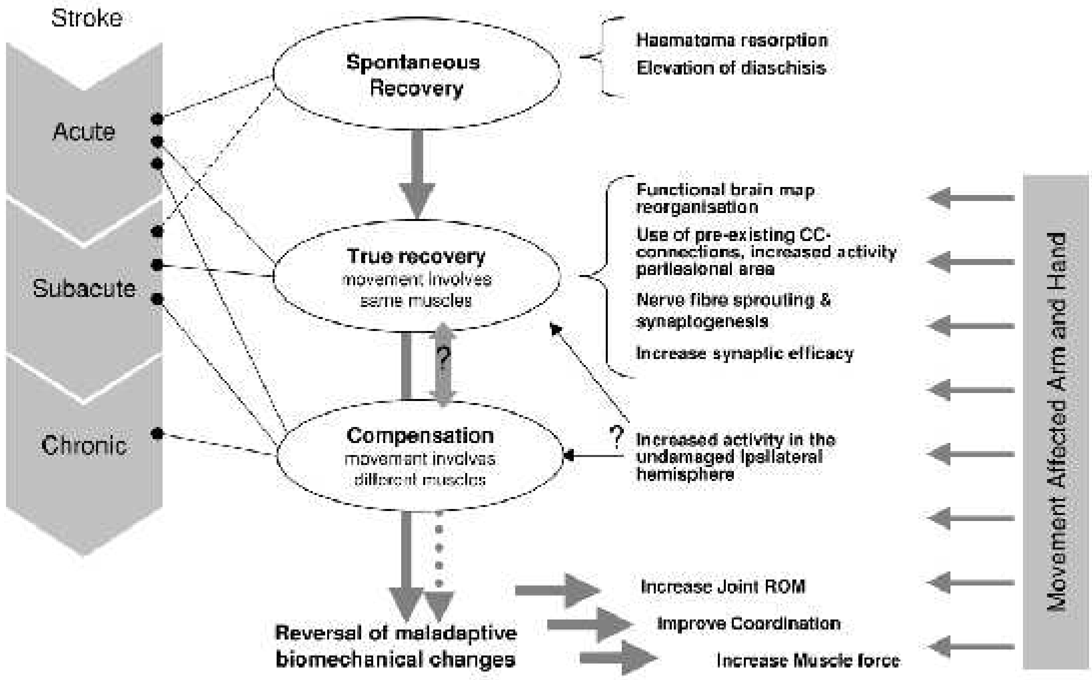


Figure 6: Declarative model of motor recovery after stroke. (CC = corticortical)[34]

[34] Source: Timmermans et al., 2009

4. Post Stroke Upper Limb Rehabilitation

"*Approximately 50% of persons who have suffered from stroke face arm-hand performance problems that may last for the rest of their lives.*" (Timmermans, 2010, page 68)

The main concern for a post stroke victim is improving (Lövquist & Dreifaldt, 2006). Stroke rehabilitation is a key for recovery, aiming to help stroke victims relearning skills and functions which were affected due to the brain damage they sustained, and help them to become able to live and to perform activities more independently (Lövquist & Dreifaldt, 2006; Kemna & Culmer, 2009; World Health Organization, 2011; Willems, 2013). In addition, it intends to trigger and help patients in the transition from dependence to independence, giving them the opportunity to become as independent as possible after an accident, and improve them physically, cognitively, emotionally and socially (Di Carlo, 2009; Proot, Abu-Saad, Van Oorsouw, & Stevens, 2002; Talbot et al., 2004; Johansson & Wild, 2011; Hochstenbach-Waelen & Seelen, 2012).

To describe rehabilitation and care goals and the requirements to achieve them, Proot et al (2002) presents 5 main concepts: 1) *self-care*, 2) *self-care* limitations and dependent care, 3) restoration of autonomy, 4) privacy, authority and independence, and 5) attentiveness and responsibility. For patients, during the first rehabilitation phase, *self-care* is the dimension more relevant, while self-determination and independence are concerned later on.

It involves one or more interventions, different participants and is characterized by 1) its repetitive nature, which can decrease patients' motivation, 2) using mechanical devices with little or without computerized sensing, fostering data evaluation errors, 3) its one-to-one communication approach in which patients interact with one or more therapists and 4) its high costs (Burdea, 2002). Furthermore, traditional rehabilitation does not enable monitoring patients when they train at home, which can influence rehabilitation results.

It has to be performed daily, and the sooner the intervention starts, the more effective it is (Lövquist & Dreifaldt, 2006; Johansson & Wild, 2011). Commonly, there is a specific period to proceed with rehabilitation and it can start from the acute or immediately after the recognition of the health condition.

Rehabilitation success may depend on different factors such as 1) stroke severity, 2) rehabilitation team skills and 3) the co-operation between patients and their families (Di Carlo, 2009; Proot, Abu-Saad, Van Oorsouw, & Stevens, 2002; Johansson & Wild, 2011). Moreover, it should address each patient's needs and preferences and provide them tailored exercises.

Four main domains influence rehabilitation patients' experience: 1) system (where patient is treated), 2) services, 3) staff and 4) decision process. The system is responsible to provide services that in turn are provided by staff. Decision Process has to do with the decision, which results from the interaction between patients and staff.

The recovery of movements after stroke is often achieved through two mechanisms (Willems, 2013): 1) "*when the same muscles for a certain activity are once again used as before the stroke*" – true recovery, and 2) "*alternative muscles are used as a strategy, different than before the stroke, to perform an activity*" – compensation. As both required a

learning process, rehabilitation must approach different methods to achieve certain goals instead of only repeating the same moves.
As mentioned before, patient's impairment depends on how strong the stroke was and in which part of the brain it took place. Therefore, each patient requires a different rehabilitation process that targets his/her individual needs. Stroke rehabilitation treatment sessions are, thus, tailored to the patient according to his impairments: therapeutic activities match patient's abilities (Ma et al., 2007). No individual treatment is likely to be applicable to every post stroke victims.
In this way, prior to the rehabilitation process, there is a diagnosis. Therapist(s) assess the patient's conditions and needs through standardized tests and its relation to personal and environmental factors can be identified. In doing so, it is possible to define a suitable challenging rehabilitation plan and goals. Along the rehabilitation process, the patient is monitored constantly by his/her therapist(s), who ensures that the treatment sessions and exercises remain adequately challenging to the patient.

4.1 Motivation in Rehabilitation

Rehabilitation is "*a long and a tough process*", therefore, maintaining motivation of people undergoing therapy is challenging (Burke et al., 2009; Chen, 2013).
Patients' motivation may be increased when they are aligned to the aims and methods of rehabilitation professionals. And when they share what they think about rehabilitation, which, in turn, made rehabilitation professionals give them more attention.
Patient's motivation and involvement are relevant to improve rehabilitation outcomes and success (Maclean, Pound, Wolfe, & Rudd, 2000; Willems, 2013). Regarding to independence specifically in a home context, some patients did see motivation as a goal to success. However, patients with lower motivation levels were more likely to not have this goal, comparing to high motivated patients.
Motivation increases when: 1) professionals provide information about rehabilitation to patients, 2) stroke patients are favorable compared and 3) patients desire to leave hospital (Maclean et al., 2000). Indeed, when patients get information, they are aware about rehabilitation process, goals and procedures, so they know when they are progressing. Thus, it leads patients to keep focus and determined in their recovery. Also, when patients know about their rehabilitation process and progress they become more motivated and confident.
"*If it was easier for patients to see their progress immediately then they would be more motivated to keep on doing their exercises*." (Lövquist & Dreifaldt, 2006, page 309).
At clinic Adelante[35], patients' motivation takes origin from feedback and information about the exercises they receive from the therapists (Willems, 2013). To make them feel involved, they participate in goals-setting, reflect on their performance and plan home-based training together with their therapist. In practice, motivation increases when patients perform activities which are meaningful and rewarding (Lövquist & Dreifaldt, 2006).

[35] Adelante is a center that provides an extensive range of services to disable persons and it is involved in scientific research and educational and retraining programmes for professionals within rehabilitation. Retrieved September 15, 2014, from http://www.adelante-zorggroep.nl/

Finally, the desire to leave hospital as soon as possible leads patients to higher levels of motivation for exercise more. Still, sometimes hospital environment is not stimulating.
In particular, high motivated stroke patients believe rehabilitation is beneficial to recovery (Maclean et al., 2000). They find important to have an active role in their rehabilitation, believing that rehabilitation is even the most relevant fact to recover. They also think that is important to know how rehabilitation exercises should be performed and they understand more about this process as well as the role of the nursing staff. These patients express independence as a goal, defending that rehabilitation progress has to do with being independent in daily activities.
On the other hand, low levels of motivation are caused by: 1) "*overprotection from family members and professionals*", 2) "lack of information or the receipt of 'mixed messages' *from professionals*" and 3) "*unfavorable comparisons with other patients*" (Maclean et al., 2000, page 1051).
During the recovery process, there are some potential problems (Burke et al., 2009). Patients are commonly depressed and so they cannot be focused and concentrated on the training program. Exercises can also become boring and routine due to its repetitive nature. The therapy can also have high costs since it is one-to-one based treatment administrated or because patients need to travel to attend a clinic. In traditional therapy, there is also a possibility to interpret evaluation data with errors when there is a lack of computational sensing and measurement.

4.2 Stakeholders

Stroke severity, rehabilitation team skills and the co-operation between patients and their families are constraints to rehabilitation success (Johansson & Wild, 2011). Post stroke rehabilitation involves three different stakeholders: the stroke patient, the health professionals/rehabilitation team and the patient's family (Boesten & Markopoulos, 2009).

4.2.1 The stroke patient

In this study, the term "stroke patient" is used to refer an individual who experienced a stroke event and is still being monitored and served by rehabilitation and clinical services. However, people who had a stroke are patients for specific period. Hence, and to refer people who happen to have had a stroke but are not anymore receiving rehabilitation services, they are used the terms "stroke survivor" and "stroke victim" in this document.
As mentioned before in *Recovery* section, in chapter *Stroke Accidents*, there are three different categories of stroke patients according to the time after the accident (Timmermans, 2010): acute (patients who had experience a stroke accident until thirty days ago), subacute (those who did experience the accident between thirty days to six months), and chronic (those who did suffer a stroke more than six months ago).
Each person has his/her own needs, which means that needs are subjective (Talbot et al., 2004). They depend on individuals' factors and environment, organizational factors and factors related to the services providers, so they may be also multilevel.

In rehabilitation field, patient's needs are related to the difference between patient capacities and the different factors of patient environment. Apart from having exclusive needs as a human being, each post stroke patient is unique, with his specific impairments and so personal goals and therapy programs (Ma et al., 2007; Burke et al., 2009). In this way, what can be trivial for some of them can be difficult or impossible for other. For instance, for some elderly individuals with greater rehabilitation potential, a less intense rehabilitation may lead to in unnecessary disability, but it may be appropriate for other patients (Kramer, Fuhrer, Keith, & Materson, 1997). Therefore, it is required to plan patient's treatment towards targeting his individual needs, matching therapeutic tasks and his abilities (Ma et al., 2007). For that reason, a pre-therapy assessment is needed.

Apart from the physical and cognitive impairments, stroke burden extends to the emotional level. Indeed, patients' awareness of their inability to participate in society as before and the challenge to deal with and accept their new condition, affect them emotionally. Thus, although rehabilitation is focused on the disability of the patient and his improvement, there is an important role in educating them to self-help, care, management and decision-making (World Health Organization, 2011). In particular, older post stroke patients may have needs such as (Talbot et al., 2004): 1) acceptance of their health problem, 2) accessibility to physiotherapy and occupational therapy services, 3) adapted means of transportation, 4) medical follow-up, 5) home visit, domestic help and encouragement from healthcare personnel, and 6) motivation by their caregiver.

Added to this, the recovery process, including using and training their impaired arm-hand, demands physical and mental efforts. The length of this process depends on each patient but, in most of the cases, it is a long process of "*small steps where significant improvement may take some time*" (in appendix *Interviews-Libra Therapists (results),* page 2).

4.2.2 Health Professional(s) / Rehabilitation Team

The rehabilitation process always involves a patient and a health professional, who cares and monitor him/her (World Health Organization, 2011). But, in fact, along all their recovery process, patients contact with various clinicians (Boesten, 2009; Chen, 2013; Willems, 2013) (see appendix *Interviews-Libra Therapists (results)*). Each patient is supported by a multidisciplinary rehabilitation team according with their disorders, demanding costs and human resources. This team may include physiatrists, rehabilitation doctors and/or specialists, expertise in Rehabilitation Medicine[36], increasing the effectiveness of the process (World Health Organization, 2011). They define, after a diagnosis, patient's rehabilitation plan under specific stroke rehabilitation guidelines based on scientific evidence or on the rehabilitation expert judgment (Winters et al., 2003). The goals they set are based on different factors including "*patient's age, gender, culture background, usual handedness, and his or her medical condition*" (Ma et al., 2007, page 683). In addition, a rehabilitation team may provide information about these issues to patients' families and carers, helping them with the supporting strategies to make the patients regain autonomy.

---

[36] Rehabilitation Medicine aims to diagnose and to treat health conditions in order to improve the functioning (World Health Organization, 2011).

Rehabilitation plan and goals are defined in accordance between therapist and patient, in order to approach patient's desires and needs (Chen, 2013). There is, thus, a patient-centered approach in setting and conducting the rehabilitation treatment. But rehabilitation team's purpose is not only to support patients recovering their physical and cognitive impairments, but also to take care and ensure their emotional well-being.
The relationship between therapists and patients is crucial in this process (Chen, 2013). On one hand, the former have to know in detail the patient and, thus, define a proper and suitable plan for him/her. On the other hand, he also needs to be able to motivate and engage him/her in the process, which can be very challenging. For instance, during therapy sessions, apart from the explanation about how to perform the exercises and the adjustments to the plan that may be needed, therapist must incentive the patients.
Therapists' value in rehabilitation requires them to provide proper services, acting towards the best results. For that, for instance, the Dutch Health Care System has a legislation which requires therapists a number of obligations (National Institute for Public Health and the Environment, 2010).

4.2.3 Patient's family

In this dissertation, "carer" and "caregivers" are terms used to represent those who care about a stroke victim when they move home.
The consequences of a stroke event have enormous effects on patient's family: if on one hand it has a crucial role on patient's rehabilitation, on the other hand, it is greatly affected by it (Anderson, Linto, & Stewart-Wynne, 1995; Freitas et al., 2005; Chen, 2013).
Since about 50% of stroke accidents lead to some physical or cognitive problem, their ability to perform daily activities may decrease (Di Carlo, 2009). Hence, they require daily support, which is frequently offered by their family members or friends, informal caregivers.
The ability of stroke victims to live at home, for instance, is related to the support they get from their caregivers. In fact, the more adequate support they receive, the better quality of live they get (Anderson et al., 1995). Thus, patient's family should be supported and informed to provide better assistance to patients. The more partnership exists between carers and patients, the better health and functioning they both have (World Health Organization, 2011).
They also support the patient indirectly, providing patient's personal information, such as his/her history and background, to therapists, which is crucial to define the rehabilitation plan (Silverman, 2011).
As families are involved in patient's care and recovery, they are required to adapt their lives according to patient's needs. This may lead to great psychosocial burden and a lower quality of life, as they feel a heavy and constant responsibility of caring, believing the patient relies only on their care (Anderson et al., 1995; Hochstenbach, 2000). The role of patient's family also extends to the transitions of their relatives across care settings, supporting them to ingress in a different context (Silverman, 2011).
Lastly, patients' families and friends may support them watching them over, reminding them about treatments and medications, assisting personal care at home and reporting to health providers.

4.3 Contexts and Stages

The recovery process after a stroke accident may be divided into separate phases according to the setting where rehabilitation takes place, for most of the patients (Kramer, Fuhrer, Keith, & Materson, 1997; Lövquist & Dreifaldt, 2006; Burke et al., 2009; Boesten, 2009; Timmermans, 2010; McAdam et al., 2013). Rehabilitation can take place at both public and privet settings (World Health Organization, 2011).

According to Kramer et al. (1997), rehabilitation settings include inpatient, outpatient and home care (Kramer et al., 1997). Thereby, rehabilitation requires patients to move from on healthcare setting to another one - defined as care transition -, where the unique common factor is the patient and his/her carer (Coleman et al., 2004; Silverman, 2011). Transiting across a variety of care settings influences the rehabilitation experience of patients (Kramer et al., 1997). Indeed, they represent a high-risk time for turning rehabilitation into a disruptive process and for fragment care services, especially for elderly people. When poorly executed, it may address negative consequences and outcome to rehabilitation progress, and a greater use of hospital services which, in turn, will increase health care costs (Coleman et al., 2004).

When a stroke event occurs, a doctor examines the patient and, according to his diagnosis, contacts a hospital or clinic. The first stage takes place at one of these locations where the stroke victim is diagnosed, treated and followed by a professional expert. Then, the patient remains at the hospital receiving initial treatment, to restore his functions as fast as possible to enable returning to community (Kramer et al., 1997). At an appropriate moment, patient is discharged to a specialized unit where is provided by supervised outpatient therapy.

The discharge from the hospital is important on the care pathway and it does not mean the end of care (National Institute for Public Health and the Environment, 2010). In this transition phase, information is given to the patients and it is very important to make aware of provided follow-up care. The Netherlands has more patients who had a good experience in this field, comparing with some other countries where appointments with health care specialist after discharge were done less often (Berg & Heijink, 2011). On other hand, better results have been achieved in United States where is more common to patients to receive written follow-up care information. Usually, most of motor and functional rehabilitation takes the first three months after stroke. However, the stays at the hospital have decreased and some patients are discharged before their full recover (Duncan et al., 2003). This happens, especially, to those who suffer arm-hand impairments and are recovering its functions (Feys et al., 1998). In fact, the majority of stroke patients (78%) return home alone or with a carer who requires support their rehabilitation needs (McAdam et al., 2013). However, formal therapy like seeing a physiotherapist is given to less than 30% of those stroke survivors. Hence, rehabilitation after hospital discharge may lead to inadequate and insufficient training possibilities, and so to patients' dissatisfaction. Two reasons of that may have to do with unavailable therapists and to the geographic distance between them and their patients (Timmermans, 2010). Yet, the training after rehabilitation at the hospital is valuable and patients should keep exercising.

Then, when they are able to live at home, they are discharged. Yet, they still need to visit the clinic from time to time, according with their rehabilitation plan (in appendix *Interviews-*

Libra Therapists (results)). During these visits, the rehabilitation training purposes include gaining mobility, not feeling pain and taking care of the impaired hand-arm, regaining the ability to perform basic and daily activities, and recovering arm-hand functions as much as possible.

In other cases, patients might continue with home-based programs, receiving professionals' visits, and so be able to develop skills at their personal context and enhance their recovery. There are, although, some patients who find themselves at home without receiving rehabilitation services, which have significant negative effects on their recover (Kramer et al., 1997; Lövquist & Dreifaldt, 2006). However, if patients do not train or use their affected arm-hand in their daily lives, out of therapy period, its skills deteriorate.

Despite some patients are still provided by services when they are already at home, their recovery usually slows down. They may get less motivate, whether because they are bored or because they are not provided by family or friends support.

4.3.1 Home-Based Rehabilitation

Current physiotherapy rehabilitation for those patients who are not at the hospital or clinic full-time is typically provided 2-3 times per week. However, the increase of training frequency leads greater improvements of patient's performance and rehabilitation outcomes (Timmermans, 2010). For better results, rehabilitation should continue, thus, at home, after discharge, as patients may be not fully recovered when discharged from the hospital (Willmann et al., 2007). Those who stop their recovery process at the hospital may still suffer from affected functions, becoming not able to reach their full potential. In addition, just as the early start of rehabilitation and the intensive training, an enriched environment, such as the patients' personal setting, increases upper limbs rehabilitation (J. Burke & McNeill, 2010). Indeed, the context of training should be as close as possible to real life context of patients, as it is more meaningful and more likely to improve exercising (Hochstenbach-Waelen & Seelen, 2012). That is another reason what stroke rehabilitation is one of the fields in which a shift toward outpatient and home visits have been considered (Winters et al., 2003; Feng & Winters, 2010). Although with a great potential, it requires an appropriate support system (Feng & Winters, 2010).

Home rehabilitation is meaningful during all the rehabilitation process, "*from the initial planning to the end of rehabilitation*", in order to continuously support the patient (Wottrich, von Koch, & Tham, 2007, page 782). It may be a worthwhile, feasible and effectiveness approach (C. Anderson et al., 2000). In fact, there are advantages to perform the rehabilitation training at home, such as: "*satisfying patient choice, reducing the risks associated with inpatient care through reductions in length of hospital stay, the home setting being more focused toward rehabilitation outcomes, and savings in direct costs.*" (Anderson et al., 2000, page 1024).

However, comparing with rehabilitation in a clinic with experts, it is less efficient, mainly due to its irregularity (Lövquist & Dreifaldt, 2006). The fact that patients in home context do not training frequently enough may be explained by the way they find the exercises – boring and not stimulating – and the lack and unsatisfactory feedback from the clinics.

Patients have a great desire to return home, justified by privacy issues and accessibility to friends and family, and therapists did appreciate the opportunity to be part of home rehabilitation program (Kramer et al., 1997; Wottrich et al., 2007). If collaboration between patients and the same therapists start at the hospital and continue at patients' home, it will enable therapists to "*see how continuity could be regained*" and to get to know patients' pre stroke activities. Thus, they can help patients to become capable to perform those activities or other meaningful alternatives with which they could connect. Indeed, it is scientifically proved that home-bases rehabilitation with guidance prevents patients from: 1) "*deteriorating in their ability to undertake activities of daily living*", 2) "*may lead to functional improvement*", 3) "higher social participation", and 4) "*lower rates of depression*" (Timmermans, 2010, page 17). Furthermore, knowing patient's life story, enable therapists to better understand of how to support continuity.

The shift of stroke rehabilitation to patients' home is also positive bearing in mind decrease of hospital funding and the increase in healthcare demand (Lövquist & Dreifaldt, 2006).

4.4 Rehabilitation therapy of the upper limbs

"*The rehabilitation of the upper limb is a challenge.*" (Feys et al., 1998, page 2).

Stroke patients in the scope of this project are those with upper limbs impairments, particularly arm-hand problems. These patients can be classified, in terms of impairment level, in severe, moderate or mildly impaired (Lum, Burgar, Shor, Majmundar, & Van der Loos, 2002).

Nowadays, there is a range of methods which can be used in rehabilitation.

The primary focus of traditional therapies of post stroke upper limbs rehabilitation are "*unilateral strengthening exercises and functional training of the paretic limb*" (Ma et al., 2007, page 686).

Therapy term is related to the capacity to restore and compensate a function loss and preventing or slowing deterioration in functioning in individual's life and it includes training, education, support and counselling and resources provision, among others (World Health Organization, 2011). Therapy can improve the rehabilitation outcomes as far as it has contributed to increase strength, endurance and flexibility of joints and functional mobility.

In rehabilitation therapy, goals are set towards a patient-centered approach and based on patients' difficulties (Hochstenbach-Waelen & Seelen, 2012). They are "*prioritised, individualised and coordinated for the different medical and paramedical disciplines that work with the patient*", emphasizing a patient-tailored rehabilitation and promoting their motivation and self-regulation. Actually, it was found out that, "*patients felt that physical issues of their condition and basic care needs had been addressed*" when health care professionals did consider their best interests to set their treatment goals (Langhorne et al., 2009). In the same way, their training should be oriented to patients' ability to achieve their personal goals. Thereby, it should be patient-and goal-tailored. With a more client-centered training approach patients are allowed to choose the skills they want to train on (Langhorne et al., 2009). They might choose those who are more relevant and meaningful according to their personal daily life. Their motivation and self-regulation increase, so the chances to get more benefits in motor learning and exercise compliance.

Although in research environments, there are already several therapeutic techniques implemented for upper-extremity stroke rehabilitation which presented significant improvements in limb use, such as the intensive Constraint-Induced Movement Therapy, where "*patients perform repetitive, behaviorally relevant arm movements with short intertrial and intertask rest periods for 6 to 7 hours daily for at least 2 consecutive weeks*" (Taub et al., 2000).

The upper limb therapy which involves robotic support is also seen as a potential approach in rehabilitation (Feng & Winters, 2010).

Often, these therapy approaches require one-to-one supervision and, some of them, an extensive amount of daily training or involve expensive equipment, increasing rehabilitation costs (Pang et al., 2006).

To face these drawbacks, and as an alternative to upper limb post stroke rehabilitation, community-based groups' approaches have been proposed and it has led to positive outcomes. Its advantages respect to providing accessibility to a larger number of people, to avoid of one-to-one supervision and to reduce costs. Moreover, it was found out this approach may promote social interaction which is, according to Pang et al. study's participants, an enjoyable aspect.

4.4.1 Physical therapy

Most of the times, when rehabilitation and recovery are considered, functional recovery is the most addressed aspect (Hochstenbach, 2000). It is also a fact that physical impairments and disabilities are aspects considered when speaking about stroke. Rehabilitation has to do with functional recovery but neuropsychological and psychosocial aspects also play an important role. These two latter are important not just in improving the quality of life but also in the functional recovery.

Rehabilitation is a learning process aiming to enable patient gaining new skills or regaining those lost or affected in order to be functionally independent. Thus, patient's learning capabilities, such as memory, attention or even motivation, are relevant and determinant for his/her capability to recover functionally. Indeed, cognitive impairments may limit patients' ability to recover from physical problems (Hochstenbach-Waelen & Seelen, 2012). Hence, rehabilitation must approach both physical and cognitive abilities.

Training should have different exercises because patients will be more motivated, challenged and because it "*improves generalizability of treatment effects*" and retention of effects (Hochstenbach-Waelen & Seelen, 2012; Chen, 2013).

The motor rehabilitation after stroke related to arm-hand function has been addressed differently over the last decades (Timmermans, 2010). The first approach had to do with joints and ligaments and muscles, or with muscles strength, or both, targeting the function level. However, a new approach was addressed when Butefisch C, Hummelsheim H, Denzler P, Mauritz KH (in Timmermans (2010)) did confirm that there were improvements in arm-hand functions when training repetitive hand and finger movements using loads to hemiparetic patients. Consequently, different training approaches, such as task-oriented training[37], mental practice and constraint-induced movement therapy, were considerate and explored.

---

[37] Task-oriented training is "*a repetitive training of functional, i.e. skill-related, tasks that are* relevant to the patient" and it "includes the use of real-*life objects in a natural environmental context*" (Timmermans, 2010).

But, despite having a healing effect, repeating the exercises may cause boredom and, consequently, a negative effect (Chen, 2013). In addition, exercising too much can lead to fatigue or injuries. In this way, patients should be encouraged to complete exercises, but also remind them to rest properly, in order to avoid the decrease of training's effect and consequently patients' anxiety.

The post stroke motor recovery ("*recovery of impairment and associated function*") is complex and confusing (Langhorne et al., 2009). There is a range of different perspectives about the motor recovery after stroke among researchers and clinicians (WHO, 2014c).

In accordance with WHO International Classification of Functioning, Disability and Health framework, recovery in rehabilitation is related to 1) regaining a lost function in neural tissue, 2) regaining the ability to perform movement in the same way as before injury, and 3) completing a task successfully like those who are not disabled do.

Since upper limb impairment is related to reduced self-perceived health, its rehabilitation process is strongly connected with motor training and physiotherapy (Askim, 2008).

4.4.2 Task-Oriented exercises

The motor arm-hand rehabilitation approach has been changing over the last years. A shift from spasticity reduction approaches to new ones concerning paresis and impairment motor control have led to new training approaches: mental practice, task oriented training and constraint-induced movement therapy (Timmermans, 2010).

The use of rehabilitation methods that include repetition of meaningful and engaging movements are now advocated by researchers, as it induces motor recovery (Timmermans, 2010).

Task and upper limb movements' performance are the basis of arm and hand basic functions such as coordination and muscle force.

Skill learning occurs along a sequence of increased difficulty: 1) *Cognitive phase*, 2) *Associative phase*, and 3) A*utonomous phase* (Timmermans, 2010). It starts with cognitive activity to set the most effective strategy to perform a new task. Once it is set, skill performance is adjusted and improved. After a long period of training, in the autonomous stage, the learned skill may be performed "*with less or no interference from other simultaneous activities*" (Hochstenbach-Waelen & Seelen, 2012). As this process progresses, exercising levels of difficulty should be increased in order to improve skill learning. For instance, exercises may start with "*a light object and progress to a heavy object*".

In the Netherlands, traditional exercises are still being used in large scale. However, task-oriented training was proven to be faster and better.

The findings of Van Peppen's (2004) systematic review support that task-oriented exercise training, rather than, for instance, muscle strength training, influences positively post stroke rehabilitation (Van Peppen et al., 2004). And, when training with intensity and in an early stage after the accident, there are larger effects. In fact, training effects are specific, so the movements or tasks that the training does not include are less likely to improve (Timmermans, 2010). Indeed, repetitive practice of specific tasks - task-oriented exercises -, including meaningful and engaging movements with high-intensity, enhances motor recovery (Langhorne et al., 2009; Timmermans, 2010).

On task-oriented training different plans have been used: while in some of them simple movements such as reaching or pointing are used, in other the train include movements related to object manipulation in real life environments and the practice of task-related problem solving strategies (Timmermans, 2010). When there are similar skills, patients tend to transfer what they learned in one exercise to one another.
However, task-oriented training methods demands costs, time and efforts to therapists in supporting and monitoring patients during all the training (Boesten & Markopoulos, 2009).

4.4.3 Training preferences

A Timmermans (2010)'s study showed that sub-acute and chronic patients have similar training preferences after a stroke accident, in relation to arm-hand skills. The skills' categories or the combination of some of them that were preferred were very much related to manipulation and grasp and so fine motor skills. Although, the patients' preferences in skill training was also to do with gross motor arm function, when the category "positioning" was referred.
Both patients' groups have mentioned as preferred skills to train on:

- eating with knife and fork;
- holding an object while walking;
- PC-keyboard use;
- taking money from purse;
- opening/closing clothing;
- grooming;
- handling broom, rake or spade;

The sub-acute group has also added the following skills as preferred:

- 'bringing cup to mouth;
- handling a telephone;
- using a car's steering wheel;

In addition, chronic patients have also mentioned:

- hand writing;
- washing/frying body; and
- sewing.

In relation to patients' motives to choose certain training skills as their most preferred, it was found out that the patients did emphasize the improvement of "*their participation level*" instead of "*their impairment and activity levels*" (Timmermans, 2010). Their motives were: 1) "*hope* on transfer to other activities", 2) "*avoid frustration*", 3) "*avoid embarrassment in public*", 4) "*independence*", 5) "*not to be a burden to others*", 6) "*pride*", 7) "*joy*", 8) "*back to work*". All of those motives relate to participation, except the first one which is related to improve the activity level. Furthermore, any of the patients was motivated by the improvement of his/her impairment when did choose a preferred skill to train on. Thus, the motives of patients were driven by their need to optimize their participation in society.
Finally, it was found out that patients are more likely to prefer to train on skills already with a level of use and proficiency, "*rather than to train on their most impaired skills*". For that

reason, it was said that patients' training preferences differ from the goal priorities set by their therapist. In fact, the goals setting by the therapist is influenced by their propensity to consider the physical independence and mobility and by economic factors. In this way, this study also did address another question about how the patients' needs are considerate when rehabilitation goals are set and so, how the patient-centered approach is considerate. In fact, therapists set goals based on the outcome of body functions, activities and quality of life of the patient assessment. Thus, this process of goals setting should be given for the patients, but also with them. It should focus on a client-centered assessment, so therapy goals might match their motivations. When using a client-centered approach during rehabilitation, patients are more likely to be active and to have a meaningful treatment outcome related to self-management (Wressle, Eeg-Olofsson, Marcusson, & Henriksson, 2002).

4.4.4 Feedback

Providing feedback to patients during a training period may help them to learn and improve their motor skills (Willems, 2013). Feedback is also important to make patients feel that there is no problem if they do not perform well a task and they can explore their capabilities.
The type of feedback is provided depends on each patient - type of stroke he/she experienced and the impairments stroke event have caused – and his/her stage of learning, leading to a further improving in motor learning (Timmermans et al., 2009). Thus, feedback on patient's performance should be patient-tailored (Hochstenbach-Waelen & Seelen, 2012). In addition, therapist' experience also affects the feedback patients are given (Timmermans et al., 2009). Hence, there is no systematic approach to provide patients feedback.
With regard to motor skill learning, there are two types of feedback: intrinsic or task-intrinsic feedback and extrinsic or task-extrinsic feedback (or augmented feedback) (Timmermans, 2010; Willems, 2013; Kemna & Culmer, 2009). The main difference between them is their source. While intrinsic feedback requires the use of the senses of the individual who is performing the activity, extrinsic feedback is usually received from an external source, complementing the intrinsic feedback. The task performer may receive intrinsic feedback through "*visual, tactile, proprioceptive and auditory cues*". Extrinsic feedback is provided in the form of "*verbal encouragement, charts, tones, video camera* material, computer generated kinematic characteristics (e.g. avatar)." (Timmermans, 2010, page 22).
Motor learning benefits from the two types of feedback. However, stroke compromises intrinsic feedback system of its victims, so they may not know how to improve their performance. Consequently, extrinsic feedback will be the one through which they will know how to do it, and so it is the one which rehabilitation technologies should provide
Extrinsic feedback provides two types of content: 1) knowledge of results and 2) knowledge of performance or kinematic feedback (Timmermans, 2010; Willems, 2013) (Figure 7).

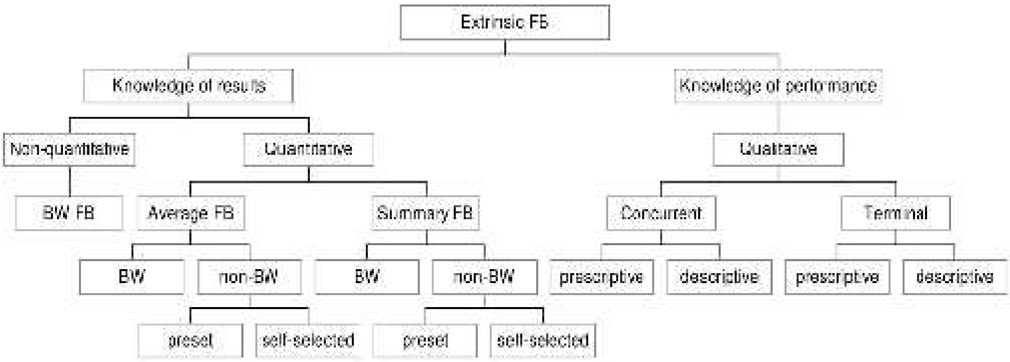


Figure 7: Schematic presentation of extrinsic feedback components for motor performance (FB = feedback, BW = band-width)[38]

Knowledge of results provides information with regard to the performance's outcome relatively to the environmental goal. Usually, it is transmitted as summary feedback – "*a result overview of previous trials*" - and average feedback – "*the average result of previous trials*".
The knowledge of performance (KP) type of feedback provides information about the characteristics of the movement performed. This feedback has two types: 1) prescriptive KP – "*information about the error and how to correct it*" and 2) descriptive KP – "information about the error alone" (Willems, 2013). Prescriptive KP was considered the most effective feedback in health contexts, but according to Timmermans (2010) that type is more beneficial for novices, while more advanced people benefit from descriptive feedback.
Feedback can be provided while exercising - concurrent feedback - or after it - terminal feedback (Willmann et al., 2007; Timmermans et al., 2009).
Exercises performance can be enhanced if feedback is provided concurrently (Timmermans, 2010; Willems, 2013). For instance, visual feedback provided concurrently to the training, triggers an external focus of attention which, in turn, enhances the performance and learning. However, when that feedback is withdrawn, performance and learning are retained. Concurrent feedback for motor skill acquisition should not always be provided. Indeed, patients cognitively affected may not be able to receive a big amount of information beneficially. As a solution, terminal feedback may be used, so they will be more likely to retain and use it.

Individuals are strongly dependent on their performance's feedback when they received it after they end their performance. Consequently, they might be not able to evaluate it because their intrinsic feedback system may be affected.
According to Winstein (cited in Willems, 2013), even though immediate feedback may affect positively the performance while training, it may be negative for learning and retention. A more effective learning can also be achieved through a delayed feedback because it allows processing information, which is important to enable motor learning.
An example of a system which provides both concurrent and terminal feedback is The Stroke Rehabilitation Exerciser system, by Phillips (Willmann et al., 2007; Phillips, 2014).

[38] source: Retrieved June 05, 2014, from Timmermans (2010)

While exercising, patient may be provided by animated figures, verbal cues as text presented on a screen or as speech output. An animated figure representing patient's movement and charts and plots providing information about the exercises are presented as terminal feedback, provided after exercise's performance. In this system, to visualize the training progress and so, to enhance patient's motivation, the current performance was compared to the results of previous sessions and to the expected performance. Further information about Phillips' Stroke Rehabilitation Exerciser system can be seen in section *State of Art*.

According to Adelante's therapists (in Willems, 2013), during rehabilitation sessions, therapists from Adelante provide feedback which should primarily concern movement's quality and, normally, they use verbal and encouraging feedback. In addition, according with an interviewed therapist, feedback is also important to make patients feel that there is no problem if they do not perform well a task and they can explore their capabilities (see appendix *Interviews-Libra Therapists (results)*). During rehabilitation sessions, patients receive verbal and encouraging feedback.

A self-selection or self-controlled feedback – when someone can choose when he/she is provided by feedback – is also valuable when exercising. It leads to "*more enhanced learning, active involvement, increased motivation, and increased investment in the exercise*" (Willems, 2013). People who are able to do it ask for feedback after their performances that they think were good, which indeed has been shown that enhances learning. According to Timmermans (2010) patients are more involved and motivated and invest more effort when they are able to choose the timing for receiving feedback, which facilitates their learning.

Usually, in motor learning settings, visual feedback is provided through information about the result of the performance on a screen, a video which presents the movement that must be learned or a visual representation of the activity's performance while executing it.

Providing information feedback through audio can be effective and it can reduce the one's attention on visual feedback. If so, and if the auditory information is incorrect, performance and learning may be affected. However, in the right conditions, this type of feedback is a tool to achieve better performance and learning.

4.4.5 Patient's assessment

"*Rehabilitation is an outcome-orientated field*" (Kramer et al., 1997, page 54).

To assess the rehabilitation process, professionals consider functional outcomes measuring "*restoration of function, recovery of speech, and return to independent living in the community*", rather than focus on patients' interests. But, there should be a shift to standards and quality assessment based on a patient-centered approach.

Moreover, before setting rehabilitation goals and in order to understand how rehabilitation process must be approached, therapists must know how patient's previous lifestyle was and what they think is important to recover and to do in their changed lives after stroke. For example, old people prefer to restore speech and language skills rather than physical function in view their lifestyle.

The result of the process is calculated by the rehabilitation outcome measures which are related to the impairment level of the patient as well as to the individual activity and participation outcomes (Timmermans, 2010). The latter can be measured by the

performance in activities like communication, mobility, *self-care* and quality of life, by programmers such as the independent living rates or by the changes in resource use like the support needed hours per week.
For patients, physical functioning is mainly measured by the difficulty in performing activities: the more difficult, the worse they are (Kramer et al., 1997). Usually, rehabilitation therapy is related to restore abilities, so patients find their success in accordance to their success in regain a previous ability.
After a stroke accident, patients may be not able to interact socially and to participate in recreational activities, so their recovery in this respect is also relevant. Their social participation has to do with their daily activities, context and how they spend their time. Elderly people, for instance, may work, perform physical activities, or have less active activities such as reading or conversing. Since many of them live alone, these activities are important to experience social interaction. Thus, regain the ability to read and/or speak and/or converse may be an outcome indicator.
One other outcome to assess patients' rehabilitation is the reintegration into a previous context (Kramer et al., 1997). It depends on the availability of an able caregiver and it is more relevant to those who experienced a debilitating event who were living in the community, rather than those who were living in a long-stay nursing home.

Rehabilitation can also be assessed taking patients' satisfaction in consideration. It has to do with "*perception of benefit, manner of service delivery, and level of accommodation and amenities*" (Kramer et al., 1997, page 56). In addition, patients' perspectives on independence, self-direction and personal autonomy are very important. Indeed, recover their ability and independence in making choices and in controlling their personal lives may be more important than their physical functions.

5. ICT and Rehabilitation

Due to the demographics' changes, to the increasing stroke incidence and to the results related to the patients' improvements of motor rehabilitation, issues about the capacity of health services are arising (Timmermans, 2010). In addition, it is expected that, in the future, therapy demand will increase.

Technology advances offers novel opportunities "*to support the ageing and ailing population in maintaining independence and mobility for as long as possible*" (Wilkowska & Ziefle, 2012, page 1). These solutions allow patients self-training, or to decrease the time of therapist's participation in rehabilitation (Timmermans, 2010). With the use of technology, patients become more independent and more likely to train more often. Consequently, their rehabilitation will be faster and with better results.

Rehabilitation outcomes may be enhanced by technology as a training support. On one hand, it enables patients training more often, leading to a better and faster recovery. In addition, technology also triggers a larger and different training input. According to Page et al (in Timmermans (2010)), motor recovery might slow down when there is no variety in the exercises and its conditions, so should be offered a set of different practices and ways to do it to increase the results of the therapy. Thirdly, due to the expected technology development, home-based rehabilitation training will be possible, without the therapist help. And finally, there will be a decrease of the paramedical staff work flow and, consequently, costs for health care services will be reduced.

Furthermore, new rehabilitation tasks may emerge and increase patients' motivation, engagement and immersion in their rehabilitation which, in turn, may lead to better performance and better outcomes (Burke et al., 2009). For instance, a technological system can create a virtual environment, which enables patient training safely and with exercises tailored to his/her personal characteristics. Moreover, it can provide performance monitoring as well as encouragement.

In this way, once a system can be installed in home context, therapy can take place at the patient's personal environment, increasing therapy outcomes. Data with regard to the training sessions, for instance, can then be sent to a remote clinical site where can be analyzed by a therapist.

However, some of these systems require high costs and a specialist expertise to set it up and operate, and have a structure that is difficult to move. Hence, although valuable, they are not accessible to everyone. To face these drawbacks, video capture systems, video games software and console platforms are used in home-based motor rehabilitation. Some examples of these are Microsoft Xbox, Sony Eye Toy and Nintendo Wii, which are more detailed in the section *State of Art*. They are regarded as low-cost systems, making it affordable for most of the people, without the need of a technical expert or an operating system to install or maintain. Because of that, they are referred as good solutions with respect to home rehabilitation.

However, integrating technology in upper limb therapy after stroke cannot only consider the potential of it (Timmermans et al., 2009). In fact, it needs to be aligned with the rehabilitation field "*towards functionally oriented approaches that influence function level,* activity level and participation level." (Timmermans et al., 2009, page 13).

5.1 Telerehabilitation

"*A telerehabilitation link makes possible better and more frequent sampling of the health and functional status of the person*." (Feng & Winters, 2010, page 25).
Even if over the past two decades there have been developed evidence-based treatments to acute stroke, some barriers such as distance and lack of expertise have been faced, mostly in rural areas (Joubert, 2012). The limited access to care units and/or services because of, for instance, geographical distance, may decrease the quality of recovery process. So, in this regard, telemedicine has been focused as a potential tool in stroke treatment. The use of telemedicine in cerebrovascular diseases is called telestroke.
One of the reasons of established telestroke networks is to ensure availability of expertise. Effective telestroke collaboration can be achieved through different types of network organization involving communication via audio and video or internet. In addition, it can be done aiming to improve the treatment of acute stroke patients, in the acute, subacute, rehabilitation phases as well as in the long term prevention of recurrence of stroke accidents. Furthermore, using telestroke methods enhance stroke management and care access and quality (Feng & Winters, 2010).
These technological systems play an important role as versatile tools, connecting services and hubs of stroke to remote, underserved regions and hospitals areas (Joubert, 2012). Support can be given by stroke specialists via the internet, telephone or real-time consulting and, consequently, one other of its potential is related to the decrease of general costs and the increase of patient care (Feng & Winters, 2010; Joubert, 2012). For instance, videoconferencing and the possibility to visually confirm stroke diagnosis by stroke experts can support interventions and consultations after a stroke, regardless the geographic distance. Telestroke networks models may vary, but they share common goals: 1) improving the treatment of acute stroke victims and 2) connecting specialist stroke services to under-serviced hospital centers (Joubert, 2012).
In the same way eHealth and telestroke enables expert treatment and support from any location, rehabilitation support should also be possible to people who is in remote areas.
A solution that addresses the barrier of access due to distance and enabling the provision of distance rehabilitation services and support can be beneficial for rehabilitation (Feng & Winters, 2010; Winters, 2002). This method is called telerehabilitation and it has used "*video and teleconferencing technologies in accessible formats; mobile phones; remote data-collection equipment and telemonitoring*" (World Health Organization, 2011, page 118). It may allow patients living at home and still receive rehabilitative therapy from a remote provider, being a home-based therapy approach to treat disabled people (Piron, Tonin, Trivello, Battistin, & Dam, 2004).
Although there are advantages to individuals with impairments, the use of telerehabilitation may also guide and help the clinicians. It enables a more frequent sampling of patients' health and functional condition data (Feng & Winters, 2010). For instance, in using the proper interventions, or even providing a way to share information and communicate with other experts (World Health Organization, 2011, page 118). One of telerehabilitation advantages is related to saving costs. By an early discharge from the hospital followed by home-based treatment, patients can train at home without the need to use clinical spaces or the face-to-face support of an expert (Piron et al., 2004).

However, when home therapy requires the preparation of the equipment, it also requires costs and time. It requires ensuring that the virtual connection between professional and patient is not interfered (Piron et al., 2004). In addition, the fact that older patients may not be able to use this type of equipment needs to be considered.

Telerehabilitation services delivery differ according to different conceptual models (Feng & Winters, 2010). It may include 1) *Teleconsultation*, in which there is an interactive videoconferencing support; 2) *Telehomecare*, when service delivery is coordinated by a tele-nurse; 3) *Telemonitoring*, when patients' data can be monitored and possibly assessed remotely; 4) *Teletherapy*, in which patients can exercise in home-based settings and, according to their performance, their therapists can change settings remotely; and 5) *Telecooperation*, that enables the cooperation between people who participate in the rehabilitation process. Thus, it promotes team-work, enhancing their motivation and, consequently, optimizing rehabilitation outcomes.

The number of novel telerehabilitation applications is likely to increase due to the promise of the growth of telecommunication technology, the increasing use and capability of wireless networks and the novel mobile tools, including wearable technology (Piron et al., 2004; Feng & Winters, 2010). For instance, the Smart Shirt, with wireless and sensor technologies, enables to monitor user's physiologic vital signals (Park & Jayaraman, 2003). Taking also in consideration the emerging 'smart home' and in order to make healthcare a consumer-responsive, it is important to ensure a connection between technology and in-home environment embedded sensors or products, so the user's data can be transferred between them (Winters et al., 2003).

"For example, (…) the *home patient can use some exercise devices, the setting of which can be remotely set by telepractitioner; Web services can intelligently adjust the exercise* plan of the patient." (Feng & Winters, 2010, page 4).

Several telerehabilitation studies on post stroke care with different approaches were done and they reported positive outcomes to rehabilitation.

For example, in order to reach stroke caregivers in rural areas, the internet and a customized educational care website were used to provide educational information and share experiences. Moreover, a hospital and a community center for seniors were connected and, by using a real time videoconsulting system, a physiotherapist was given patients education information, psychological support as well as physical exercises. Specifically for motor function therapy, there were studies in which patients' exercises were monitored by sensors and sent to a hospital-based server. Then, therapist could access that information and have a videoconsultation with the patients, providing them support in real time.

Indeed, post stroke telerehabiliation was well accepted by health professionals and they find out it as valuable. It may be promising in improving stroke patients and caregivers' health. Overall, telerehabiliation in stroke field can be used to: 1) monitor patients' health status by health professionals, 2) identify conditions that require improvement, 3) educate and support caregivers of those patients who live at home, and 4) upper limb exercising and recovery, enhancing patients' motor and physical health.

The introduction of telecommunication tools in the rehabilitation training is valuable, even more when it is related to a home-based setting (Winters et al., 2003). While it enables the researchers to timely access to adaptive rehabilitative processes, it also decreases the constraints to assess and to take action in the therapeutic process.

The consumer-centered mobile telerehabilitation, including wearable sensors, interfaces and embedded computing, has been considered regarding to its vantages such as convenience, efficiency and cost-reduced (Winters et al., 2003). However, it requires the address of optimization on multiple levels. Winters et al did (2003) propose three main challenges: "*Optimization of rehabilitation Strategies*" and "*plan for assessements*", "*Optimizing Human-Tecnology User Interfaces*", so the user can accomplish the set tasks, and "*Optimizing Compliance and Lifestyle Modification*" to understand interpersonal communication.

The intelligent telerehabilitation assistants approach aims to reduce the distance and time of the rehabilitative healthcare process. Thus, it considers the "timely remote assessment, local personal and remote in a simple, timely remote assessment, local personal and remote assistance, telesupport, and telecoaching" (Winters et al., 2003). Furthermore, they interact with the users and assist them to realize tasks at home, remotely assessed. Thus, the geographic location turns to a non-barrier to the therapeutic intervention. These technological assistants have an interface, which enables teleconferencing and communication, and so the patients remote assessment and treat, and an embedded computing component. Since it involves interaction between humans and machines/technology, it requires the study of interfaces and its features of usability, design, user performance, etc. They also need to include specific sensor technologies because the rehabilitation process is related to function and activity.

5.2 Rehabilitation Technologies

Alternative rehabilitation approaches often make use of technologies based on tools from the robotics and virtual reality fields that help automate aspects of the therapeutic process (Feng & Winters, 2010). Studies using the most notable of these approaches have shown positive results. Yet the technologies are expensive and access is currently limited to small geographic regions of the country.

Some research groups are now actively exploring alternative approaches that strive to reduce access barriers such as cost and distance by taking advantage of emerging trends and advances in mass-market telecommunications and information technologies. The trend is also toward more home-centered approaches. But, currently, an individual with, for instance, stroke-induced disability lacks access to more personalized interventions (Feng & Winters, 2010).

The therapy strategy needs to be developed and implemented taking in consideration the consumer and in order to be adaptable to home environment (Feng & Winters, 2010).

The HoneyBee rehabilitation system have been developed in order to solve the problematic situation when patients are left alone exercising, which leads to less effective process (Chen, 2013). Hence, it was aimed to design a system which could be able to make patients exercise more efficiently without therapists' aid.

It is related to an interactive board which can recognize real objects and how they are moved by the users. It was designed to support stroke victims regaining arm functions, making them perform tasks based on daily activities, as it has been proved rehabilitation benefit from exercising real-life activities. The project had three main initial aspects set: 1) "*to design a personal planning system that can pre-assign and record exercises*", 2) "*to optimize the existing exercises to be more engaging and motivational*" and 3) "*to create new exercises for better rehabilitating quality*" (Chen, 2013, page 5).
In this project, literature studies on stroke rehabilitation were conducted and lectures with the therapists were attended, which have enabled the authors to found out that therapists consider engagement and "*patient-tailored and task-oriented arm training in natural environments with feedback that supports learning of motor skills*" as criteria for designing rehabilitation technology. Some key principles were also found out in this project:

1) "*Setting personal goals that are self-selected, well-defined, individually meaningful and wi*thin the patient's capability";
2) "*Exercising with real-life objects. Learning by solving task-specific problems, e.g. drinking water with a cup, cutting sandwi*ches with a knife";
3) "Stimulating patients' motivation by empowering the*m with the control of exerc*ises"
4) "Making exercises engaging. *Creating proper feedback during training session*s";
5) "*Setting milestones throughout the rehabilitation period. Sufficient support from friends/family*";
6) "*Variabili*ty and flexibility of exercises".

However, some rehabilitation methods require equipment or products to increase, maintain or improve the functional capabilities of disabled individuals, so called assistive technologies. There are several of them but, especially for people with upper limb or/and lower limb impairments there are prostheses (Figure 8), orthoses (Figure 9), and wheelchairs, among others. They can be provided by the national health care system in some countries or by the governments. It was proved that these technologies are powerful tools in increasing the independence of brain injuries victims and also in decreasing the care costs and support services.

Figure 8: Arm-hand prosthesis[39]

Figure 9: Foot Orthoses[40]

[39] source: Retrieved March 14, 2014, from http://www.technobuffalo.com/2012/11/25/terminator-tech-cool-robotic-arm-types-ties-knots-and-cracks-eggs/
[40] source: Retrieved March 14, 2014, from http://www.podiatrycpd.com/foot-orthoses

5.3 Wearable Technology

"*Personalized mobile information processing means that sensors are integrated to meet the specific needs of the individual being monitored, and the information is transmitted wirelessly so as not to interfere with th*e person's mobility." (Park & Jayaraman, 2003, page 589).
In a study about wearable systems in upper rehabilitation, conducted by Wang et al., (2014), wearable systems were divided in three sections taking in consideration its function. Thus, the systems might 1) monitor and track posture, 2) be related to therapy rehabilitation with integrated interactive games and 3) be related to therapy rehabilitation with visualized feedback.
Wearable systems which aim monitoring and tracking the posture use multiple sensors and technologies and their combination. Various systems of this type require wiring communication. Sensors collect data about users' posture that is, then, sent to another unit where is analyzed and/or stored.
Some systems are based on a gamification approach. They involve interactive games, making rehabilitation a funnier and more engaging experience. Others, apart the rehabilitation enhancement, provide feedback to its users. Usually, they have 2 components: one related to the wearable sensing and central controller, and one another with respect to data communication and feedback.
Given that, Us'em system, and the scope of this dissertation, pertains to this wearable systems category. The first Us'em prototypes comprised a wristband with sensors and watch-like device with a graphical display to provide users information (Figure 10) (Markopoulos, Timmermans, Beursgens, van Donselaar, & Seelen, 2011). More information about Us'em projects is given in chapter Us'em system.

Figure 10: Us'em prototype comprising a wristband with sensors and watch-like device with a graphical display

The most recent prototypes have a slight difference. Although they still include a sensor-based wristband that collects users' data, information is now displayed in a graphic interface of a smartphone.
Philips' Stroke Rehabilitation Exerciser, detailed in *State of Art*, is another example of a sensor-based system that focus on the home-based rehabilitation process (Willmann et al., 2007). It includes a wearable set of motion sensors that measures, records and

analyzes patient's movements. Both patient and therapist are then provided by proper feedback through a computer graphic interface.
It was estimated that, in the Netherlands, in 2014, wearable computing, such as smart glasses and smart watches, would loom (Deloitte, 2013). However, at that time, the desire to purchase those technologies was low, yet expected to rise. In fact, people were not aware of these devices which are still limited available. Nevertheless, these factors were expected to change, according to the estimated future marketing campaigns.

5.4 Rehabilitation Games

"*Considering its high availability, low cost and associated large and motivated user populations with existing accessible communication technology and standards, gaming technology can readily be used as a tool for home rehabilitation, especially using approaches such as Computer-Assisted Motivated Rehabilitation (CAMR), since research shows that therapy that proactively considers motivation is more likely to be effective in* functional restoration." (Feng & Winters, 2010, page 10).
Frequently, video gamers are so engaged in games so they do not realize passing of time. This games' ability to highly engage gamers made health care and rehabilitation communities embrace the gamification concept (Burke & McNeill, 2010; Deterding & Dixon, 2011). Gamification offer relevant aspects to health care and rehabilitation turning those processes into a funnier, more relaxing and more efficient experience.
Games' engagement features can be valuable in rehabilitation games, boosting patients' motivation and engagement, which are relevant factors to adhere them to their rehabilitation therapy program, and so fostering greater therapeutic outcomes (Burke & McNeill, 2010; Burke, McNeill, & Charles, 2009; Cameirão, Bermúdez, & Verschure, 2008). In addition, its ability to make that process more motivating and fun justifies the use of computer games to train upper-limb movement (Lövquist & Dreifaldt, 2006).

It is proposed to use these games in both home or hospital settings (Burke et al., 2009). If, on the one hand, patients may play them outside therapy sessions, increasing their training, on the other hand, at the hospital, games may be used by patients when therapist are working with one another.
Cost issues are also addressed when it comes to different settings. While medical centers can afford more expensive systems, gaming-based rehabilitation in home-settings becomes viable due to low-cost devices and "*off-the-shelf*" technology.
Despite being beneficial, rehabilitation gaming systems do not replace traditional therapy, as therapists are still responsible by patients' support, assess, monitor and goals setting.

Virtual environments have been part of rehabilitation applications towards upper and lower limb motor function (Burke & McNeill, 2010). They include virtual reality technology in order to immerse the user, standard display technology like computer monitors and technology which allows tracking its users' moves. The system can then use these data to graphically represent the user, or part of he/she, in that environment. In this way, user will be more likely to control and have a bigger impact on it. Virtual games activities vary between simulated real life activities (such as grasping), simulated everyday tasks (such

as shopping), "*conventional functional-based tasks*" and game-based tasks which are learn in the specific games' context (Ma et al., 2007; Burke & McNeill, 2010).
This type of gaming systems enables configuration with a user-centered approach. It is possible to programme and modify its environments and its levels of difficulty of tasks in order to meet its users' capabilities and goals. Thus, patients are given a more tailored solution and their dependence on human therapists may decrease. Though, this requires a pre analysis and assessment of patients.
Virtual games can use different virtual reality hardware which, in turn, can be used by different patients and in different exercises (Burdea, 2002). This is called economy of scale and it is considered the major advantage of virtual rehabilitation. There are other advantages such as the interactivity and motivation, the possibility to transfer data to computer, avoiding patients' or therapists' actions and so, evaluation errors and costs saving.
An example of a virtual reality game for rehabilitation after stroke is "Whack-a-mouse", developed by Ma et al. (2007). It aimed to improve accuary and speed of upper limb movement of its users, requiring user to hit a virtual mouse.

In addition to virtual games, upper limb rehabilitation therapy approaches have been considerate valuable incorporating video games (Wang et al., 2014).
Frequently, video gamers are so engaged in games so they do not realize passing of time, one of the reasons why healthcare and rehabilitation communities embraced the gamification concept (Burke & McNeill, 2010; Deterding & Dixon, 2011).
Interactive video has ubiquitously become part of the rehabilitation process with an important role in promoting and motivating the user in intensive task-based therapy (Deutsch et al., 2011).
Typically, rehabilitation gaming systems include an input device, such as a joystick, an output device like a monitor, and a computer. For instance, in the Bubble Trouble game user must burst virtual bubbles presented on the screen, making him/her move, especially his/her upper limb (Burke & McNeill, 2010).
These systems may be customizable built. However, as a less costly approach, commercial game consoles are also already used in the type of systems. This is exemplified by Nintendo Wii console (see chapter *State of Art*).
Normally, it is easy and simple to play, which is an advantage to patients who either have not experience playing it or have cognitive impairments. However, some of them enable patients to configure it, so different gamers have the chance to engage effectively.
Its gamers perform real upper-limb therapy similar moves such reach, grasp, manipulation and release. Nonetheless, games provide a "*more challenging and rewarding*" perform repetitive moves. Reaching function could be translated in a game which goal would be touch a target on the screen.

5.5 Gamification

"*We are already well on our way to a fully engaged gamification world. Our buying patterns, our health care, our communications, and our recreating and entertainment all* *have built-in gamification already—whether people recognize it or not!*" – stated by an anonymous respondent in (J. Anderson & Rainie, 2012, page 11).

The gamification concept, coined in 2002, has become popular in several contexts (HIMSS Europe, 2014). It meaning is not defined but, based on the definitions of Deterding & Dixon (2011) and Hamari & Sarsa (2014), it refers to inserting design elements characteristic for games in non-game contexts, services or activities, invoking "*game*ful experiences and further behavioral outcomes" (Hamari & Sarsa, 2014, page 2).
Yet games were being developed to entertainment, they are now considerate in healthcare setting where, typically, gamification refers to "*transforming patient behavior* and building up healthy habits" (HIMSS Europe, 2014, page 46). The concept is present in the fit market, such as Nintendo Wii Sports (see more in chapter *State of Art*), as well as being approached in the management of chronic illnesses and in home-based rehabilitation systems (Hamari & Sarsa, 2014; HIMSS Europe, 2014). In rehabilitation context, exercise games are called "*Exergames*" and it was proven they have a positive effect on the mobility, balance and strength of the patients who play them.
Since games are not being developed particularly to stroke victims, it could be assumed that they would not fit these groups of end-users (Hamari & Sarsa, 2014). However, it was found out that actually they may be suitable. For instance, a study with both healthy and stroke users, using Eye Toy games, made clear that although stroke gamers face some limitations, there is a potential in these games to improve upper limb motor functioning.
Other study's findings showed that games that are specifically designed for stroke victims are more effective that those developed for entertainment or exercise for use by the general population.
In addition, gamification elements are powerful motivational and challenging tools, benefiting rehabilitation patients (Hochstenbach-Waelen & Seelen, 2012; Lövquist & Dreifaldt, 2006). In fact, patients' motivation should be maintained during all the rehabilitation process and its training should be motivating and challenging (Burke et al., 2009; Hochstenbach-Waelen & Seelen, 2012). The more rehabilitation exercises can encourage, stimulate and engage patients, the more effective they will be. However, it but it may be difficult to meet these requirements since rehabilitation must start early and be intensive and repetitive. Hence, games and its motivational effects will provide a funnier and more enjoyable experience, increasing the outcomes. Given games characteristics, defining a game-based rehabilitation system involves addressing issues such as Rewarding system, Difficulty, Multimodal feedback and, among others, Intuitive task. Indeed, patients are more likely to keep interested in exercises when they are provided by an efficient reward system. In addition, if they feel achievement and encouragement because of the exercise, rehabilitation becomes more interesting. According with each patient's impairments, exercises must have different levels of difficulties, considering that if the exercises are too easy, it may have no challenge, but if it is too hard, patients may give up to play it. With regard to multimodal feedback, it is considered important the possibility for the patients to be provided by "*real time task-specific feedback when interacting with the interface*". Patients can also obtain feedback about their progress instantly when provided by a scoring system and get more motivated. Moreover, exercises which require patients a long time to understand and to get used to perform it or a long explanation may make patients get disinterested.

Patients' motivation when playing rehabilitation games can be influenced by "*difficulty level of the motor task, the awareness of the performance obtained and the quantity and quality of feedback presented*" (Burke & McNeill, 2010, page 196).
Other positive fact of gaming-based rehabilitation is the greater attention on the outcome of the movement rather than focusing on the movement itself (Lövquist & Dreifaldt, 2006). While playing a game, patients have an active participation, which also increases their motivation, facilitating the rehabilitative process.
Given this valuable effect of gamification in rehabilitation, its systems design benefits from analyzing the principles of game design (Rizzo et al, 2005). In particular, designers should consider three main principles: 1) "*meaningful play*", 2) "*handling failure*" and 3) "*setting an appropriate level of challenge*" (Burke et al, 2009).

6. UI design of mobile applications

6.1 Mobile Interfaces and people with disabilities and elderly

Designing UI involves knowing Human-Computer Interaction principles[41], used to improve interaction between humans and computers, and to provide a richer user experience for computer systems' users (Myers, Hollan, Cruz, & Al, 1996; Flaten, 2006; Phiriyapokanon, 2011). Nowadays, they are being used to improve experiences of mobile devices users, making these services more inclusive. However, usability for people with disabilities is usually not approached, because HCI-principles have rarely intent to accommodate their disabilities.

A system's interface is very relevant to make users use a system, which involves considering human factors such as "*limitation of working memory*", that "*people make mistakes*", "*people are different*" and "*people have different interaction preference*". Designing an application interface requires, thus, knowing who are the end-users and characterizing them (needs, requirements, preferences, abilities, limitations…), in order to match user's experience, needs and expectations (Flaten, 2006).

This is closely related to *Usability*, the "Extent to which a product can be used by specified *users to achieve specified goals with effectiveness, efficiency and satisfaction in a* specified context of use"[42] (Seffah, Donyaee, Kline, & Padda, 2006; Myers et al., 1996; Phiriyapokanon, 2011). Generally, usability measures the usefulness of a system from the point of view of its users. For instance, individuals with disabilities may have problems interacting with technology because of touchscreen interfaces (Lippincott, Morris, & Mueller, 2011).

Due to their specific condition, disabled and elderly users require specific attention and a deep understanding of accessibility principles and guidelines.

Disability does not just mean having a severe impairment. It has also to do with a lack of functionality or ability an individual can have during a specific period. Stroke victims also gain impairments that may be recovered after a certain period or become permanent.

Due to their exclusiveness, Us'em mobile app users are more likely to have greater limitations and more diverse requirements (Seffah et al. (2006); Flaten (2006)). They may have visual, hearing, physical and cognitive/language impairments which may address constraints in using Us'em mobile app. And, in addition, most of all of Us'em app users are older people who have specific requirements regarding mobile app (Phiriyapokanon, 2011; Lippincott et al., 2011).

In order to design Us'em mobile app that accommodates users' impairments, Flaten's (2006), Phiriyapokanon's (2011) and Lippincott et al.'s (2011) work was considered.

---

[41] "*Human-Computer interaction (HCI) is the study of how people design, implement, and use* interactive computer systems and how computers affect individuals, organizations, and society." (Myers, Hollan, Cruz, & Al, 1996, page 1).

[42] This definition of *usability* is part of ISO 9241, a multi-part standard from the International Organization for Standardization that aims to standardize the ergonomic requirements to Human-System interaction.

Us’em mobile app end users’ cognitive impairments may have great impact on their memory and in perceiving information, leading to more errors when interacting with the mobile app. Bearing in mind users’ characteristics, Us’em mobile app was designed to be simple and clear, so users spend the shortest time to understand it. Nonetheless, depending on the severity of their impairments, some of them may require an explanation before use the mobile app.
Regarding other potential of impairments of Us’em mobile app users, using a mobile app or a smartphone may have constraints that exclude users from using the mobile app.

Based on Flaten’s work (2006), the main disorders of each impairments category, the problems they address when interacting with software and mobile phones, and potential solutions were analyzed and are described in the document *Interface Design for Impaired People (Flaten)* annexed to the CD of this dissertation*.* The solutions implemented in Us’em mobile app are described in Table 2, below.

Table 2: Design solutions of Us'Em mobile app interface according to different impairments

Impairements	**Design solutions**
Visual	- large size buttons - big text size - text size can be increased and descrease (3 different sizes)
Physical	- large size buttons
Cognitive/language	- large size buttons - simple and clear graphics - simple language

In relation to older users, it was concluded they require more than a simple interface and bigger size buttons, contrary to common beliefs. In particular, software usage may be affected by the main age-related cognitive declines: eye vision, color, sound, attention and simplicity, memory and motor decline (Phiriyapokanon (2011)). In this sense, Phiriyapokanon (2011) defined the following interface design guidelines with regard to elderly: 1) Reduce complexity, 2) Design tasks with clear structure, 3) Provide consistent information, 4) Provide rapid and distinct feedback, 5) support the user and 6) Enable customization[43]. See document *Guidelines to design software for older users (Phiriyapokanon)*, annexed to the CD of this dissertation, where these and more guidelines of this author are detailed. For instance, UI colors are relevant factors that can enhance user experience. However, colors’ perception varies with users’ background and culture, so the same color may have different meanings. Because of that reason, a color, by itself, should not be used to represent a meaning. In Us’em mobile app, vivid colors are used to represent relevant information, but they are also associated to text or the form of a UI element. Hence, a UI element may be perceived by its color, form and/or text. Yet, two colors of the app, orange and blue, are an exception. These represent both right and left Us’em devices data, respectively. Other solution to represent this information was not

[43] Customization is related to the ability of users to modify the page layout or specify what content is displayed (in a user interface) or define certain aspects of a service. It is a means of meeting users’ specific needs (Feng & Winters, 2010; van der Weegen et al., 2013). This definition of customization was used in this research project.

found, but it might be beneficial to found other method to do it, enabling more patients to understand it.

In general, Us'Em mobile app was designed with familiar, clear and well-differentiated icons and graphics, as well as proper and comprehensible feedback, to make it more easy-to-use and intuitive. In addition, considering that mobile app responses to user's input may affect him, Us'em mobile app was coded (*HTML*, *CSS* (Cascading Style Sheets) and *JavaScript*) to make time response be the shortest as possible. Added to this, there is the fact that touchscreen resistance of the used smartphone is high, which also influences the interaction and users' experience. As spontaneously re-orientation may also affect the user, Us'Em mobile app was designed to be used only vertically.
Furthermore, enlarged fonts were used to make information readable. But, bearing in mind the variety of users, the mobile app enables users to increase and decrease the size of the text. Given user's potential cognitive disorders, and to assure they will know how to act after the first activities, functions and interaction types along the mobile application are similar.
Us'Em mobile app also comprises mobile invitations[44] to improve users' experience. In particular, a tour and a persistent pattern were used. The first one provides users relevant features of the current screen; the other is present in some buttons with text that indicates its function.

Constantine & Lockwood (1999) and Seffah et al. (2006) work was also relevant to design Us'em mobile app. It provided elements that must considered when designing usable software: Learnability, "*rememberability*", efficiency in use, user satisfaction, usefulness and trustfulness.

6.2 Cross cultural UI design

"*Making good user-interface design should acknowledge the value of culture and take into account the intrinsic ne*eds and preferences of the user" (Evers (2002) in Shen, Woolley, & Prior, 2005, page 826).
The way users perceive and use products and services is significantly influenced by their culture. Hence, in addition to consider users' needs and requirements, UI design must also account for user's cultural dimension (Sears & Jacko, 2007). Indeed, users are different in terms of their demographics, education and experience, among others. In turn, each of them has different needs, goals, group roles and tasks. Their needs are met, thus, when these factors are taking in account, what is done by user-centered design approaches. Cultural concerns affects several UI elements and content, from language translation, navigation complexity, choices of input techniques, to graphics, colors, sound, vibration, and others.

[44] Mobile invitations "*are helpful tips that are displayed the first time a user opens an application or arrives at a new place*" and that may affect mobile users experience (Neil, 2012). The can be: 1) Dialog, 2) Tip, 3) Tour, 4) Demo, 5) Transparency, 6) Embedded, 7) Persistent and 8) Discoverable.

Designers' role is, hence, to create more usable and appealing interfaces that can support users and make their experience simpler, more transparent and natural in accordance with their contextual environment (Shen et al., 2005; Sears & Jacko, 2007). UI must be adjustable and sensitive to deal with cultural factors and have certain values that will provide users a richer and more meaningful experience. In turn, they will find effortlessly and pleasurable to use the products.
Besides the need to meet user's needs, designing for different cultures has also to do with economic reasons. With a global UI design that approaches different cultures, products and services will require fewer changes when introduced in different cultural contexts. That means a decrease of costs of production, maintenance, distribution and user support for business.
Globalization, "*a worldwide production and consumption of products*", influences communication mediated by computers, "*which, in turn, affects user interface design*" (Sears & Jacko, 2007, page 357). It relates to international, intercultural and local levels. The intercultural one covers people's humanistic factors such as religion, history, language and aesthetics, among others. For instance, culture may be reflected on terminology used for colors and signs. Internationalization relates, thus, to the creation of a design that can be adapted for different international markets (Shen et al., 2005). Localization, in turn, relates to customization of data, including, among others, language translation, graphics, colors and icons/symbols, adapting it for a certain international market. In that way, users are able to use it in "*their own language and appropriate cultural* context." (Shen et al., 2005, page 823).
In the view of the relevant role of cultural issues in UI design, two new terms did emerge: *culturability*, a combination of culture and usability, and *Culture-Centred Design*, a designing approach with a particular focus on the target user and their cultural characteristics (Shen et al., 2005).
The influences of culture in UI users' needs also did lead Sears & Jacko (2007) to report the need to modify or create new practices and tools. They exemplified with testing in accordance to the cultures involved. UI design methodologies that approach cultural issues are even more relevant given the technology progress that increases "*the number and kind of functions, data, platforms, and users of computer-based communication media*" (Sears & Jacko, 2007, page 376).

In this project, a comparison study between Dutch and Portuguese rehabilitation practices patients and therapists was done. It had the purpose to characterize those individuals and evaluate the main differences between them. It was concluded that rehabilitation services and patients' needs vary between the two countries which, in turn, influences their interaction with UI of Us'Em mobile app. However, this study did show that that difference, apart from healthcare and rehabilitation services, is also justified by cultural differences. Given this intercultural group of end-users, it was needed to analyze both Dutch and Portuguese patients and understand their specific needs regarding Us'Em UI. These were, then, considered in the redesign process with the aim of improving the likelihood that they would be more satisfied and engaged with Us'Em mobile app.
Overall, designing Us'Em mobile app required, thus, considerations of:

- Difference between rehabilitation practices between the Netherlands and Portugal;
- Difference between the Netherlands and Portugal with respect to UI design;

- User’s needs among post stroke individuals regarding to age groups, cognitive impairments and technological literacy.

This project compared both groups of end-users, Dutch and Portuguese, regarding their culture and its influence on UI design preferences in terms of:

- users’ languages (Which languages were appropriate for users – possibility of multiple national languages within one country);
- way of perceive mobile app’s graphics, colors and icons;
- symbols’ meaning (if the same symbol convey the same meaning);
- character-coding schemes and date formats;

These aspects provided relevant information for designing Us’Em mobile app. For instance, users’ language were important to decide which font should be used (as it needed to support language character-coding schemes) and to considerate a variation of text length.

It is simpler to define a pattern of UI design’s elements and interaction regarding cultural issues. In fact, even though not every individual “*in a society fits the cultural pattern precisely*”, there is still a possibility to identify a trend (Sears & Jacko, 2007, page 375). Contrary, stroke victims may gain so broadly types of impairments that is more difficult to find a pattern that suits the needs of a high number of them. This fact did pose a great challenge in this research.

6.3 Mobile device users hand choice

Designing a mobile device interface requires attention to several aspects such as usage scenarios where there is a possible hand use variation (Karlson, 2006). People can interact with mobile phones in three different ways: 1) one handed (49%), 2) cradled (“*using two hands to hold a mobile phone*”) (36%) and 3) two handed (15%) (Steven, 2013). Single-hand usage benefits the user in the way that provide him/her a freeing hand (Karlson, 2006).

Even though small and light phones may be easy to use with only one hand, they address negative aspects to thumbs because of small buttons and crowded keypads.

Current interaction patterns are based on the use of one hand and it is predictable that will still be the basis of mobile devices interaction behavior. So, interface design should consider the way mobile devices are used to meet its users’ needs.

The use of certain hand influences user interaction as his/her fingers may hide parts of the screen. In that way, they might not see some content. Hence, the interface should be designed in a way that its users can visualize the relevant information regardless the hand they are using to interact. Furthermore, with regard to thumb interactions, task performance and perceived difficulty are affected by device’s areas: those that the thumb can easily reach had meant a fastest and most comfortable interaction. Moreover, it is easier to access mid-device areas and lower right corners of the devices were difficult to reach. As solutions for both left and right handed users, interface’s interactive elements should be positioned centrally and the display should be configurable.

Interaction performance is less affected when considering device size rather than “*the position of a target with respect to the thumb*”. Right-handed users find

NW(northwest)↔SE(southeast) movement difficult regardless the size of the device, which also is degraded with movement distance. On other hand, using the opposite movement would present a barrier to left handed operation. Hence, repetitive movements to N(north)↔S(south) and E(east)↔W(west) directions should be avoided.

Even if these findings should be considered to interface design, each individual has different hand size and thumb length so there will be a range of different users to take into account.

Mainly, one hand users hold a mobile phone in two different methods that differ in terms of how high users position their hand.

Those who use both hands, use their thumb or finger. With this method of usage, users have more support, as they use one hand to stabilize the device, and may interact more freely than one-handed users.

Two-handed use might be related to the orientation of the device: 1) vertical (portrait), or 2) horizontal (landscape).

These questions were concerned on this research project. Most of Us'em mobile app interactive elements (buttons) are placed in the central part of the screen. Furthermore, interface elements were arranged in a way that areas with relevant information are less likely to be obscured by users' fingers when they interact with other elements.

Nevertheless, mobile devices usage and interaction raises other questions about left- and right-handed users. Each person has a dominant hand that is mainly used in everyday activities. Hence, there will be mobile users using left hand and others using right hand. In this way, according to how they do it, the interaction with the device and its will be different.

This question is particularly relevant to this dissertation considering Us'em mobile app users' characteristics. They have arm-hand impairments that influence their way of interacting with a smartphone. On one hand, they could be used to use it with both hands before stroke. Now, they concern about the interaction, as they can only use the one that did not lose its function. On the other hand, they can be affected in their dominant hand with which they used to interact with the smartphone. Hence, they are required to learn how to use the other hand to be able to interact with it.

However, research about these issues is little. Indeed, there are some studies with regard to how users hold mobile devices, thumb interaction and screens areas that are more easily reached. But, they do not address specifically which hand they use. Thus, there is also a lack of understanding about which factors, and how, influence the decision of users to use one hand or another to hold these devices.

There are several blogs and forums where people discuss about these issues. Most of the cases, they are users who have bad experiences using mobile devices due to the inadequate interface regarding to the hand they use to interact with it. In other cases, they are designers or developers seeking to understand how they can design an interface or an application to meet users' needs related to this question.

In conclusion, there is no possibility to assume a default pattern of how mobile users are hold. It can be done with one or two hands and, in both methods, there are also variations. Thus, even comparing two users who use the same hand to interact with a mobile device, findings may be different, so a different design of the interface might be required. Factors such as the tasks that being performed and the context of usage are relevant to make users change their way to hold a mobile device.

In this dissertation it was not possible to design Us'em mobile app interface considering these questions, given the lack of research in this field. However, it is a relevant topic that must be addressed in the future. After literature research and some reflections, and with the respect to the scope of this work, a main question did arise: Should the layout of Us'em mobile app be customizable according to the hand its users use to interact with the smartphone?

7. State of Art

After literature review, a closer look to projects and products already on the market should be taken. This chapter deals, thus, with some relevant questions such as follows: 1) What mobile apps are currently available?; 2) What are the functionalities of those mobile apps?; 3) What are those mobile apps user's needs and requirements?; 4) What are their limitations and benefits?

The chapter starts with a closer look at Healthcare management tools and mobile apps, then Sports and Fitness mobile apps, Rehabilitation systems and products are presented. After, it presents Mobile apps and Games for rehabilitation. It ends with a summary part.

Each subsection comprises a description of a product or a project followed by an analysis of its characteristics that were relevant to design Us'em mobile app.

7.1 Healthcare management tools

Microsoft HealthVault

Microsoft Health Vault[45] is a web tool to gather, store, use and share healthcare information. It can be connected to certain devices such as a cholesterol monitoring device, blood pressure monitors, weight scales or a fitness wristband, and store this devices' data. Microsoft HealthVault can also be connected to many apps which information can be managed through this tool. In addition to user's data, records for other people, such as a parent, a child, or other family member can also be added, enabling the user managing their health. In addition, this tool enables data sharing other people including with medical professionals, receiving results of medical exams, goals setting and checking user's progress.

At a functional level, this platform presents various characteristics that were relevant to the design of Us'em mobile application. The possibility of communication and data sharing between medical professionals and users make them better informed and may improve their relationship. As seen in previous sections of this document, rehabilitation process of a post stroke patient requires a great patient's support and guidance by their therapists. The more informed they are, the better they can play their role. In this way, implementing this feature in Us'em mobile app is beneficial. Data collected by Us'em system, because it concerns patients' rehabilitation progress, is important for therapists as they will gain a greater understand of patients' condition. In this way, they will be able to easier meet patient's needs and to better define his rehabilitation plan. Us'em users will, thus, take advantage of data collected because they will be better supported. Other possible situation for Us'em mobile app users is sharing information with others than therapists, such as family members or friends. However, if in the first case there is a very specific purpose to share Us'em data, in this one, there is no certainty of how and for what that data will be used. Nevertheless, in both cases, privacy, security and ethics issues involved sharing healthcare data were considered.

[45] source: Retrieved June 30, 2014, from https://www.healthvault.com/de/en

Monitoring data and setting goals are other important features of this Microsoft tool that were implemented in Us'em mobile app. They are a means of motivating users towards achieving their objectives and, thus, training in their own contexts.
Microsoft tool's UI has a simple, flat and clear design (Figures 11 and 12).

Figure 11: Microsoft HealthVault menu[46]

Figure 12: Microsoft HealthVault dashboard of cholesterol tracked data management[47]

On its basis there is a grid structure that clearly arranges the interface in different and meaningful components. In that way, information is organized and easier to understand. Its buttons and text (with a sans-serif font style) are legible, readable and the text is not long. Mainly, the colors are soft and light, but there are also vivid colors used to highlight relevant information in text, buttons, background or charts. Some screens present a main title that informs what it is about. Next to it there is also an icon that represents the same information graphically. Icons used have a simple design, are not detailed and only have two colors. These aspects, in particular the font style, colors and the simple and flat design, were taken into account to design Us'em mobile app UI.

Wellframe

Wellframe system[48] is a management tool for chronically ill patients. It guides and supports patients in managing their health condition and enables therapists providing better care services. Its mobile app, for iPhone and Android phones and tablets, makes possible the connection between patients and therapists between visits. Through it, patients are provided with a to-do list (Figure 13 a.) with, among others, their medication and tasks and with medical information, and they obtain feedback about their progress (Figure 13 b). Furthermore, it has a private social network where patients can share their progress with their care provider and obtain social support.

[46] source: Retrieved June 02, 2014. from http://apps.microsoft.com/windows/en-us/app/healthvault/728f1c88-7e2f-4b40-95c1-74fc09983689
[47] source: Retrieved June 30, 2014, from http://apps.microsoft.com/windows/en-us/app/healthvault/728f1c88-7e2f-4b40-95c1-74fc09983689
[48] Retrieved June 02, 2014, from http://wellfra.me/

This platform, for clinicians use, aims to improve efficiency and effectiveness of care management resources. For instance, it alerts therapists of patients that require help or support and enable them to view and analyze patients' care plans in real time.
Wellframe mobile app's UI has as main colors orange (buttons, some graphics), white (background and some buttons) and black (menu background, text). Black text in a white background, a sans-serif font and an appropriate text size makes text readable. Text is short, so it does not require much time to read it. Icons are simple and only have one color. The bottom menu only has 3 simple buttons. Overall, screens have empty and white areas between interface elements which enable its users to perceive well the information. Feedback and alert boxes emerge over a darker background (Figure 13 c.) focusing user's attention. Regarding Us'em mobile app, Wellframe interface aspects that were considered are: 1) sans-serif font style; 2) the space between elements; 3) simple and clear buttons; and 4) design of feedback and alert pop-ups. Regarding the system as a whole the features regarded were: 1) the communication between patient and therapists through the mobile app; and 2) the possibility for therapists to view and analyze patients' data in real time.

Figure 13: Wellframe mobile app screens[49]

7.2 Healthcare mobile apps

This research project aimed the development of a mobile app related to healthcare field, thus, it was important to get to know some of mobile app already on the market. This subsection presents some examples.

WebMD mobile app

WebMD mobile apps for the iPad and its mobile website optimized for smartphones - Android and iPhone -, by WebMD LLC company[50], are tools for searching healthcare

[49] source: Retrieved June 02, 2014, from http://wellfra.me/
[50] WebMD LLC company provides information, support communities, reference material and managing tools for health care. Individuals can access the WebMD online content and services to

information. User can search approved information about drugs, treatment, symptoms and, among others, first aid essentials and get information on demand (Figure 14). Its symptom and treatment tracker (Figure 15) enable users to monitor their pain. Although Us'em does not include a searching information feature, these mobile website and mobile apps were considered regarding its UI.

Figure 14: WebMD Android mobile app[51]

Figure 15: WebMD iPhone mobile app[52]

In general, WebMD mobile app has a defined color palette: blues, greens and greys. Each button, icon and text element have, in maximum, two colors. There are, yet, some graphic elements with more than two colors and with gradients. Important information is highlighted with more vivid colors like red and orange. Text elements have different sizes but all of them are legible and short, which makes them more understandable for users. Interface elements that enable user interaction and new functions are well-perceived due to its design or tips provided to users.

WebMD Pain Coach mobile app™

WebMD Pain Coach mobile app™ [53], available for *Android*[54] and iPhone[55], is designed for people with chronic pain. Users can use this mobile app to review personal patterns and access healthcare content. This tool provides an individual user experience according to

---

find solutions when faced with healthcare decisions. Retrieved June 30, 2014, from http://www.webmd.com/ retrieved

[51] source: Retrieved June 06, 2014, https://play.google.com/store/apps/details?id=com.webmd.android

[52] source: Retrieved June 06, 2014, https://itunes.apple.com/us/app/webmd-trustedinformation/id295076329?mt=8

[53] Retrieved June 02, 2014, from http://www.webmd.com/webmdpaincoachapp retrieved

[54] Retrieved June 02, 2014, from https://play.google.com/store/apps/details?id=com.webmd.paincoach

[55] Retrieved June 02, 2014, from https://itunes.apple.com/us/app/webmd-pain-coach/id536303342?mt=8

the specific patients' conditions. Each of them inserts information about their own condition and the mobile app offers them physician-reviewed tips, articles, videos and slideshows, provides quizzes, recommends goals, and shows personal reports. This information is organized into four main sections: 1) Journal (Figure 16); 2) Goals (Figure 17); 3) Library and 4) Tips.

Figure 16: WebMD Pain Coach *Android* mobile app[56]

Figure 17: WebMD Pain Coach *Android* mobile app[57]

The Journal section provides a new screen by day so the user can record his day and see his history later on. If the mobile device turns sideways, it is possible to see a chart report with the well-being and pain levels and a list of the most common symptoms, triggers and treatments. There is also the possibility to export this report to a .pdf file and send it by email for the patient or his physician. In the second section, it is possible to set goals and its duration (one day to one year), browse and select them, which are previously approved by his physician. These goals can be related to 5 pre-defined lifestyles categories like food, rest, exercise, mood and treatments. According with each goal, the mobile app gives the user specific tips. Relevant information about user's condition and pain management can be founded in the library section. It is present in the form of articles, videos, slideshows and quizzes and can be accessed in offline mode. The personal library can also be shared via email, Facebook or Twitter. The last section presents tips organized into the same 5 lifestyles categories that match user's goals.

Though this mobile app and Us'em mobile app have different purposes, both target chronically ill people. Some characteristics of WebMD Pain Coach mobile app, described next, benefit Us'em mobile app users. First, WebMd Pain Coach mobile app users are provided by information that suits their needs and are related with their condition. This is important given the specificity of post stroke patients' needs. So, it was considered that offer that to Us'em mobile app users will be relevant. It enables customization, providing a more effective user experience tailored to user's needs. WedMd Pain Coach allows users setting goals which are, then, approved by their therapists. This approval is important as chronic patients may be not capable to make the right decision when setting a goal.

[56] source: Retrieved June 06, 2014, from http://www.webmd.com/webmdpaincoachapp
[57] source: Retrieved June 06, 2014, from http://www.webmd.com/webmdpaincoachapp

Hence, a goals-based feature was also implemented in Us'em. Yet, they are set by the therapist instead of by the user, ensuring that is proper to the patient. In addition, this mobile app sorts users' goals by specific categories. In this research project, the designed mobile app also divides goals, but according with user's activities.

Graphically, WebMD Pain Coach's UI design presents comprises more colors than the mobile app previously analyzed. Its buttons have a significant size, but overall text size is smaller. In addition, there are more and longer text elements which require a longer period and a greater focus to perceive information. Sometimes, text is not legible because of its size and font style (both sans-serif and serif are used in different parts). On the bottom of the screen there is a menu with five clickable buttons that enables users to access to certain information. It is always available on the screen, so users can any time change to other screen without having to return to the main screen. From these characteristics, the design of Us'em mobile app considered the need to display readable text elements, the use of (only) a sans-serif font style, the presence of some elements in every screen to enable users to access them any time – "help" and "settings" buttons.

CatchMyPain mobile app

This mobile app[58], by Sanovation[59], aims to help patients with pain. It focuses on the visualization and the tracking of the user's pain. It works as a pain diary through which user can express the intensity and location of his pain, through detailed drawings (Figure 18) as well as pain occurrence time, a description and more. User can, thus, explain better his pain problems to other like his care provide. He/she can also share his diary with his therapist and print mobile app's information out on paper. By scanning its barcodes, user's drugs can be tracked (Figure 19) (currently only Swiss and US drugs).

Figure 18: CatchMyPain iPhone mobile app (screen with pain localization feature)[60]

Figure 19: CatchMyPain iPhone mobile app (screen of drugs tracker)[61]

[58] Retrieved June 06, 2014, from http://www.catchmypain.com/
[59] Retrieved June 06, 2014, from http://www.sanovation.com/
[60] source: Retrieved June 06, 2014, from https://itunes.apple.com/app/id666029416?mt=8
[61] source: Retrieved June 06, 2014, from https://itunes.apple.com/app/id666029416?mt=8

Information inserted by users is being used by the Swiss government, researchers and care providers to gain new insights about chronic pain. This mobile app is available for iPad[62], iPhone[63], *Android* tablets[64] and smartphones[65] and computer.

After reviewing this mobile app, the most relevant feature considered to this research was the possibility to report and share patient's condition with their therapists. Us'em enables sharing information with them too.

The design of this mobile app's UI is simple and clear. Like the previous mobile app, it uses mainly blue, grey and white colors, and vivid and warm colors to emphasize relevant information. Buttons are simple, without details and only have one color. Clickable areas are sizable and noticeable. Some of its screens present more and more detailed information, which requires a long period to be analyzed. Overall, these buttons, text size and font style (sans-serif) seemed appropriate and designed in Us'em mobile app.

7.3 Sports and Fitness mobile app

More and more sporting and fitness mobile apps are being designed, due to the increasing desire for controlling health and maintaining good shape. Such mobile apps feature, among others, biometrics control and exercising motivation. For these reasons, and bearing in mind the mobile app aimed to develop in this thesis, it is relevant to know and analyze examples of those mobile apps. Other reason why these mobile apps were considered has to do the potential that fitness training has in physical improvements (Langhorne et al., 2009). As Us'em relates directly with that, it is intended to outline mobile apps' characteristics with respect to motivation and enhancement of physical activity. In this section, some sports and fitness mobile apps are therefore presented.

Nike+ Running mobile app

Nike+ Running mobile app, by sportive brand Nike[66], available for iOS[67] and A*ndroid*[68] devices, aims to help its users tracking and reaching their running goals (NIKE INC., 2014). It uses mobile devices' software, such as GPS (global positioning system) module and accelerometer, to gather various data. Distance, pace, time of users' run and their burned calories are collected. These metrics are, then, provided to users visually (Figure 20) or through audio during the exercise.

---

[62] Retrieved June 06, 2014, from https://itunes.apple.com/en/app/catchmypain.com-das-schmerztagebuch/id578988873?ls=1&mt=8#

[63] Retrieved June 06, 2014, from https://itunes.apple.com/app/id666029416?mt=8

[64] Retrieved June 06, 2014, from https://play.google.com/store/apps/details?id=com.sanovation.catchmypain

[65] Retrieved June 06, 2014, from https://play.google.com/store/apps/details?id=com.sanovation.catchmypain.phone

[66] Retrieved June 06, 2014, from http://www.nike.com/us/en_us/

[67] Retrieved June 06, 2014, from https://itunes.apple.com/us/app/nike-gps/id387771637?mt=8

[68] Retrieved June 06, 2014, from https://play.google.com/store/apps/details?id=com.nike.plusgps

Figure 20: Nike+ Running iPhone mobile app[69]

This mobile app has also a social component, so its user is able to share information about his run with his friends, who may cheer him during the exercise. Furthermore, as an incentive system, user can 1) listen to music while running, 2) compare his results and compete with his friends,3) invite them to join his run, and 4) get positive feedback from Nike's top athletes.
Bearing in mind Us'em mobile app purposes, this mobile app showed 3 relevant aspects to its design. First, Nike+ running mobile app users are tracked and informed about their metrics in real time. Us'em users have also a constant deliver of their personal data, becoming aware of the frequency of their moves and their progress. The social component of the mobile app was also considered similarly. Us'em users can also share their data with others, though they cannot receive feedback or information from them thought the mobile app. That is might be provided then through personal interactions. As they know other will see their data, maybe they will be more likely to train more, to show better results. In the same way Nike's mobile app is a motivational support for work out, Us'em mobile app may turn the recovery process into a better experience.

Fitbit mobile app

Fitbit mobile app, by Fitbit[70], available to iOS[71] and *Android*[72] devices, is used to provide information gathered through Fitbit tracking devices. Fitbit wireless wristband[73] or smart

[69] source: Retrieved June 06, 2014, from https://itunes.apple.com/us/app/nikegps/id387771637?mt=8
[70] Retrieved June 06, 2014, from http://www.fitbit.com/home
[71] Retrieved June 06, 2014, from https://itunes.apple.com/us/app/fitbit-activity-calorie-tracker/id462638897?mt=8&ign-mpt=uo%3D4
[72] Retrieved June 06, 2014, from https://play.google.com/store/apps/details?id=com.fitbit.FitbitMobile
[73] Retrieved June 06, 2014, from http://www.fitbit.com/force

scale[74] track and collect users' data that is synced wirelessly (Bluetooth) and in real time to the mobile app. Users of Fitbit tracking mobile devices can access and see their data through this mobile app (Figure 21). Furthermore, they can check their previous exercises (Figure 22) set their own goals, receive notifications when they are close to or achieve them and also rewards when goals are achieved (Figure 23).

Figure 22: Fitbit *Android* mobile app

Figure 21: Fitbit *Android* mobile app[75]

Figure 23: Fitbit badges[76]

Like Nike's mobile app, Us'em comprises a rewarding system as a mean towards increased users' motivation and engagement. Instead of badges, with are provided by a message with a smiley image.

This mobile app is seen as a good example of what is aimed to implement is Us'em mobile app. In fact, both mobile apps intend to receive and display data gathered through wearable mobile devices. Doing this in real time makes this feature even more relevant, as users can know their metrics at any time. With respect to Us'em mobile app, as mentioned before, users can know which arm-hand they are moving more in real time.

Although this project refers to the mobile app and not to Us'em devices, it is important to mention Fitbit's capability in syncing with other devices wirelessly. In the future, it might be positive to make Us'em wearable devices capable to transmit data via wireless.

Concerning UI design of Nike's mobile app, it has positive characteristics that were considered to Us'em mobile app design. Its less positive aspects were also analyzed to avoid their use in Us'em mobile app. The positive aspects are: 1) backgrounds with light

---

[74] Retrieved June 06, 2014, from http://www.fitbit.com/aria

[75] source: retrieved June 06, 2014, from https://play.google.com/store/apps/details?id=com.fitbit.FitbitMobile

[76] source: retrieved June 06, 2014, from http://techcraver.com/wp-content/uploads/2012/04/badges.jpg

colors; 2) screen's title; 3) the use of a sans-serif text font; and 4) vertical bar charts. The less positive were: 1) the low contrast and the small text size of some interface elements and 2) the design of some charts (Figure 24) that can be not understandable for some users.

Figure 24: Fitbit iOS mobile app[77]

PEAR Training-Intelligence mobile app

The PEAR Training-Intelligence mobile app (for iPhone[78] and *Android* smartphones[79]) is part of a real-time training system, by PEAR sports[80]. This system has a wearable Bluetooth monitor (Figure 25) and earphones.

Figure 25: Pear Bluetooth Wireless Heart Rate Monitor[81]

It provides training plans, training results reviews, a sharing system and a real-time audio coaching. Users can, hence, access to specific workouts adapted to his fitness level.

[77] source: retrieved June 06, 2014, from https://itunes.apple.com/us/app/fitbit-activity-calorie-tracker/id462638897?mt=8&ign-mpt=uo%3D4
[78] Retrieved June 06, 2014, from https://itunes.apple.com/us/app/pear-training-intelligence/id563723189?mt=8
[79] Retrieved June 06, 2014, from https://play.google.com/store/apps/details?id=com.pearsports.android.pear
[80] Retrieved June 06, 2014, from http://pearsports.com/
[81] source: Retrieved June 06, 2014, from http://pearsports.com/shop/training-intelligence-for-iphone-and-android.html

During the exercise, they use the monitor to visualize their tracked and measured heart rate data. Then, through the earphones, they can listen to the feedback and the real-time coaching.

The mobile app considers users' biometrics and advises them all exercise long about the right intensity to get the maximum benefit. They can also view their training plans (Figure 26), goals, workout history, statistics, exercises progress and mapped routes. In addition, the mobile app enables them to listen to music during sporting and share their plans and results via email and social media.

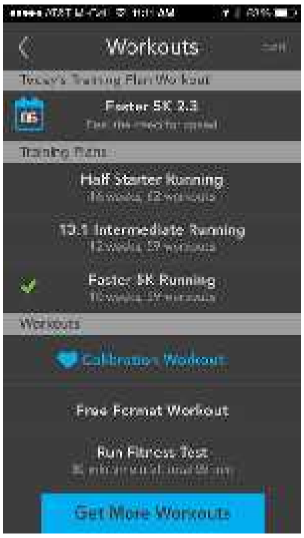


Figure 26: PEAR Training iPhone (portrait) mobile app[82]

PEAR's system and mobile app presents similarities with Us'em system and mobile app. Both systems comprise a wearable device that tracks and gathers users' data and a mobile app to show that information. In relation to technical matters, while the first uses Bluetooth as communication protocol, the second one uses the ANT protocol[83].

Overall, the features considered for this research project were the following: 1) monitoring users tracked data while exercising/moving; 2) workout history; 3) goals visualization; 4) data sharing, and 5) feedback.

At a graphic level, by contrast with Nike's mobile app, this one has a dark colored background. Its other mains colors are blue, grey and white. Very few interface elements have vivid colors. When used in portrait/vertical orientation, UI is mainly organized in one column with list-based menus, descriptions or other information. The landscape/horizontal view is better to visualize charts. Buttons are recognizable by their bigger text size or different color. This mobile app uses a legible text font (sans-serif) and size, fewer icons that other previously analyzed, and a big area for each item of menus. Descriptions of, for instance, workout plans or goals may be too long for some users. Hence, interface design

[82] source: Retrieved June 06, 2014, from https://itunes.apple.com/us/app/peartrainingintelligence/id563723189?mt=8

[83] ANT is an ultra-low power wireless protocol that is responsible for sending information wirelessly from one device to another device. Retrieved September 16, 2014, from www.thisisant.com

features considered to this project are 1) text size, 2) sans-serif text font, 3) the big area of each menu's item and 4) the use of different colors to emphasize certain information.

Edomondo mobile app

Edomondo mobile app[84] is another mobile app which provides workout tracking and analysis, and challenging system between friends. However, it is mentioned because it has other relevant features regarding Us'em mobile app.
It has an audio feedback system. Users can obtain feedback not only from the audio coach (information related to the exercise) but also from user's friends. They can write short messages on Edomondo's website and, a few seconds later, users can listen to these messages, being encouraged during his activity (Figure 27). Other aspect is the social component, enabling users to post their exercises on Facebook and visualize their friends' exercises and activities (Figure 28). Later on, it is possible to access to user's exercises personal diary at Edomondo's web page.

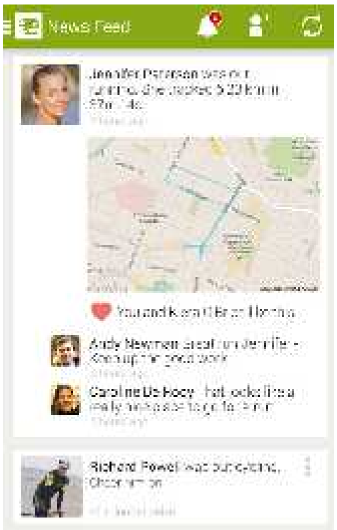


Figure 27: Edomondo *Android* mobile app[85]

Figure 28: Edomondo *Android* mobile app[86]

Edomondo's mobile app features allow getting feedback from both the virtual coach and user's friends in real time. In order to design Us'em mobile app as an engaging rehabilitation support, real-time auditory coaching from a physiotherapist would enable patient performing exercises correctly and incentives from other patients may motivate the user. Although this feature was not implemented, it is mentioned as a potential future development.

---

[84] https://play.google.com/store/apps/details?id=com.endomondo.android&hl=pt_PT
[85] source: Retrieved June 06, 2014, from https://play.google.com/store/apps/details?id=com.endomondo.android&hl=en
[86] source: Retrieved June 06, 2014, from https://play.google.com/store/apps/details?id=com.endomondo.android&hl=en

In terms of UI design, Edomondo's mobile app uses, in general, white background, green buttons and black and gray text. Thus, there is contrast between background and text making it readable. In some screens, however, when text is light gray it is more difficult to read it. Font style is sans-serif, icons are simple and most of them have only one or two colors. Items of some menus have a description that describes the functionality of it.
Regarding this project, the interface design characteristics considered were the contrast between text and background colors that makes text more readable and the simplicity of the icons, and the user of sans-serif font style.

EveryMove mobile app

EveryMove's mobile app, by EveryMode[87], is available to iPhone[88] and *Android*[89] devices. It works as an integrator of users' health and other fitness mobile app they use. According to training results, EveryMove mobile app generates points. These are a means of recognition users who are, then, rewarded by services, brands, merchants, partners and those who are part of EveryMove network (Figures 29 and 30).

Figure 29: EveryMove iPhone mobile app[90]

Figure 30: EveryMove iPhone mobile app[91]

Its rewarding approach was considered to Us'em context. Although more literature review and data gathering is needed to understand the best method to reward post stroke patients, the system used in EveryMode mobile app was taken into account. Us'em

[87] EveryMode's team works on rewarding systems in health field. They aim integrating devices and apps, such as Edomondo, Nike+ and FitBit, and turning users' workout into rewards. Retrieved June 06, 2014, from https://everymove.org
[88] Retrieved June 08, 2014, from https://itunes.apple.com/app/id563721483
[89] Retrieved June 08, 2014, from https://everymove.org https://play.google.com/store/apps/details?id=org.everymove.everymove
[90] source: Retrieved June 06, 2014, from https://itunes.apple.com/app/id563721483
[91] source: Retrieved June 06, 2014, from https://itunes.apple.com/app/id563721483

mobile app users are, hence, provided by feedback rewarding messages. However, this approached could be extended and Us'em users could be provided by offers or discounts in specific rehabilitation services or products according with the effectiveness of their training at home or with their progress, just as EveryMove mobile app. Despite not implementing, it can be approached in the future.
With respect to its UI design the more relevant features were some buttons visible in every screen, and the navigation by time frames (week, month and year).

Race by Hearts mobile app

The basic concept of Race by Hearts[92] iPhone mobile app is working out, being social and having fun simultaneously. It provides, in real time, information about user's heart rate data and burned calories which can be visualized by both users and their team members. In this way, while working out, it is possible to check team's ranking based on the comparison of member's workout intensities (Figure 31). Furthermore, a team leader can control a team's workout (Figure 32) and ask its members to join and train together. Users' data is stored, so they can review their activities later on.

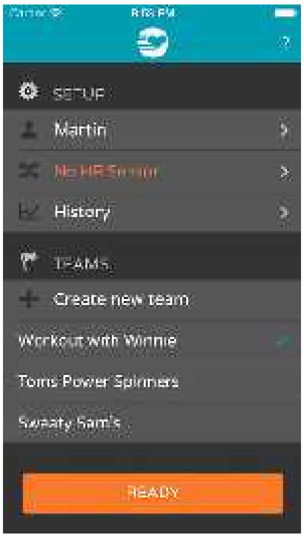


Figure 31: Race by Hearts mobile app[93]

Figure 32: Race by Hearts mobile app (team's workout)[94]

Considering this dissertation, the relevant features of this mobile app were data sharing and review. Both were already justified in previous mobile apps' descriptions in this section: Us'em users can share their data with others and access the history of their moves.

[92] Retrieved June 09, 2014, from https://everymove.org http://www.racebyhearts.com/
[93] source: Retrieved June 06, 2014, from https://itunes.apple.com/us/app/race-by-hearts/id521471371?ls=1&mt=8
[94] source: Retrieved June 06, 2014, from https://itunes.apple.com/us/app/race-by-hearts/id521471371?ls=1&mt=8

With respect to its UI, the aspects considered positive were the contrast between background and text, which makes it clearer, the simple and clear icons and the big and colorful buttons. Contrary, the negative aspects of this mobile app considered to be avoided in Us'em mobile app were the size of some elements and the large quantity of information displayed on some screens.

7.4 Rehabilitation Systems and Products

In healthcare field, technology has been improving not just the way individuals interact with each other, but also the tools can be used in care. The rehabilitation is also affected, so a wide range of interventions has been made and there are different products and tools which make this process easier and more efficient.
Since this project's scope is the upper limb's affection, it may be important to get to know some of those systems and products working on those problems. There will not be a detailed analysis of products' technical aspects, as they are not relevant to this dissertation. A review is present below.

There are various products for supporting upper limbs rehabilitation. Some of them can be used at both home and clinical settings and are specific to weakened wrist, hand and/or fingers (SaeboFlex[95] (Figure 33), SaeboStretch[96] (Figure 34)), hand and elbow (SaeboReach[97] (Figure 35)), shoulder and elbow (SaeboMas[98] (Figure 36)), or may be used in different other parts of patient's body, like the Saebo MyoTrac Infiniti (Figure 37).
In addition, there are products, such as SaeboStretch, that enable customization according to patients' requirements.

Figure 33: SaeboFlex[99]

Figure 34: SaeboStretch[100]

Figure 35: Saebo Reach[101]

95 Retrieved June 17, 2014, from https://everymove.org http://www.saebo.com/products/saeboflex/
96 Retrieved June 17, 2014, from http://www.saebo.com/products/saebostretch/
97 Retrieved June 17, 2014, from http://www.saebo.com/products/saeboreach/
98 Retrieved June 17, 2014, from http://www.saebo.com/products/saebomas/
99 source: Retrieved June 17, 2014, from http://www.saebo.com/products/saeboflex/
100 source: Retrieved June 17, 2014, from http://www.saebo.com/products/saebostretch/
101 source: Retrieved June 17, 2014, from http://www.saebo.com/products/saeboreach/

Figure 36: SaeboMas[102]

Figure 37: Saebo MyoTrac Infiniti's use[103]

Rehabilitation Exercise

Rehabilitation Exercise by Philips Research[104], aims is to support both patient (when executing functional exercises) and therapist (to assess the patient) (Willmann et al., 2007). It has a patient unit (figure 38) a motion sensor system, linked to a UI in therapist's station (Figure 39).

Figure 38: Rehabilitation Exercise patient UI: screen with instructions of how to wear sensors[105]

Figure 39: Rehabilitation Exercise therapist interface[106]

Together, therapist and patient set rehabilitation goals. Then, the former define exercises and the training plan that patient will execute at home. While performing the exercises, his posture and movements are measured by wearable motion sensors he uses. This data is, then, compared to motion targets defined by therapist who will gain a better understanding about patient's rehabilitation progress. Both patient and therapist can access this information (via an internet connection), through a visual interface: the former is given "*timely information*", the latter can do it remotely. At a later face-to-face meeting, they can review and analyze this information and, according with their findings and patient's

[102] source: Retrieved June 17, 2014, from http://www.saebo.com/products/saebomas/
[103] source: Retrieved June 17, 2014, from http://www.saebo.com/products/saebomyotrac-infiniti/
[104] Retrieved June 06, 2014, from http://www.research.philips.com/
[105] source: Willmann et al., 2007
[106] source: Willmann et al., 2007

requirements, adapt the training plan. This system is an example of a passive[107] rehabilitation system.
Regarding therapists' role in this system, they can: 1) set patients' goals, 2) receive data of each patient's performance, which is previously transferred and stored in a database, 3) select and define exercises' settings which will be added to the system and, then, presented to patients, and 4) through an interface, they can review the results of training sessions which allow them to adapt the training plan, track and monitor their progress and give encouraging feedback. Moreover, they are provided by quantitative information of joint angles of patients' movements, exercise's duration, peak velocity and jerk as well as charts which show an historic of patient's performance.
According to the authors, designing patient's UI was a crucial step due to their characteristics. They did design an interface with a "*simple state-based dialog model*"[108] which made patient's unit having a pre-determined and linear flow. Consequently, the interface got simple and usable by patients even those with no or less computer skills or cognitively limited. The interface layout, in turn, is also simple with few large size elements and, sometimes, a video. With regard to feedback the users, the system can present information on the screen or through speech output. While performing the exercise, they are provided by a 3D animated figure on the screen mimicking their movement in real time and verbal hints written on the screen and displayed auditory (speech). At the end of their performance, patients are provided with a graphic presentation of their performance feedback. After that, they can visualize charts and plots which show exercises parameters such as duration, speed and range of movement. In addition, they can see their progress, and thus enhance their motivation, through a comparison of previous, current and expect session's performances. Additionally, to enable patients interacting with the system a game-pad with only two large colored buttons and a touch-screen was developed. These devices were designed to solve the barrier in interacting with a key-board faced by some stroke patients.
This system presents significant issues were addressed in the brainstorm of Us'em mobile app design. Because, just as Us'em system, it targets home-based rehabilitation patients with upper limbs impairments and it comprises wearable sensors. Although its UI is in a computer rather than in a smartphone, there are various aspects that can be considered in the light of the scope of this dissertation.
Us'em system defined in this research project also features goal setting by therapists who can receive information about patients' moves. These aspects were only defined theoretically and were not implemented given the scope of this work. However, Us'em app UI was designed taking into account these potential implementations.

---

[107] Passive rehabilitation system means that it "*does not have any means to actively move the* patients' limbs or stimulate the muscles", so it targets sub-acute and chronic stroke patients who are already able to move their affected limb by their own, without external support (Willmann et al., 2007).
[108] "*Generally systems with state*-based dialogue control restrict the user's input to single words or *phrases that provide responses to carefully designed system prompts*." (Mctear, 2002)

H200 Wireless Hand Rehabilitation System

The H200 System's advanced technology[109] (Figure 40), by Bioness Inc.[110], provides a solution in regaining hand function and the possibility to perform essential daily activities for individuals with injuries as stroke.

Figure 40: H200 Wireless Hand Rehabilitation System[111]

The H200 patient can reach, grasp and pinch more efficiently due to the system's wrist support in a functioning position and the possibility to move the fingers and thumb. The system, due to the low-level electrical stimulation, stimulates the appropriate nerves and muscles of the patient's hand and forearm. It has two main components: the orthosis[112] (fits the forearm and wrist and deliver mild stimulation which helps the patient moving his hand) and one control unit, a microprocessor, both connected via wireless. The level of that stimulation can be adjusted by the handheld control unit, which can also turn the system on and off. Hence, the health specialist can set up the system according to the specific patient's therapy program. The wireless control unit is an easy to use handheld device and it can be carried in a pocket or bag. This system's aims, among others, to increase hand function, to reeducate muscles, to increase or maintain hand range of motion and to increase blood circulation.
The main aspect of this system considered to this dissertation was the personalization: it is designed to be set according to the specific user's needs.

---

[109] Retrieved June 06, 2014, from http://www.bioness.com/H200_for_Hand_Paralysis.php

[110] The Bioness Inc. company develops products to help people to improve quality of life and productivity, regaining mobility and independence. They design for people with different neurological impairments such as stroke. Even though they have products to benefit people with both upper and lower limb impairments, the one which mentioned below is to be used by patients with upper impairments. Retrieved June 06, 2014, from http://www.bioness.com/Home.php

[111] source: Retrieved June 06, 2014, from http://www.bioness.com/H200_for_Hand_Paralysis.php

[112] Orthosis is an orthopedic appliance or apparatus used to support, align, prevent, or correct deformities or to improve function of movable parts of the body. Retrieved June 06, 2014, from http://medical-dictionary.thefreedictionary.com/orthosis

Intelligent haptic robotic system for upper limb rehabilitation after stroke

The Intelligent Haptic Robotic System purposes increasing the treatment of upper limb rehabilitation after stroke (IATSL, 2014). Its developers aim building a low cost and portable system so it can be used at the hospital or at home.
The system has 3 main components: the robotic arm (controller component), an artificial intelligence controller and a graphical interface (Figure 41).

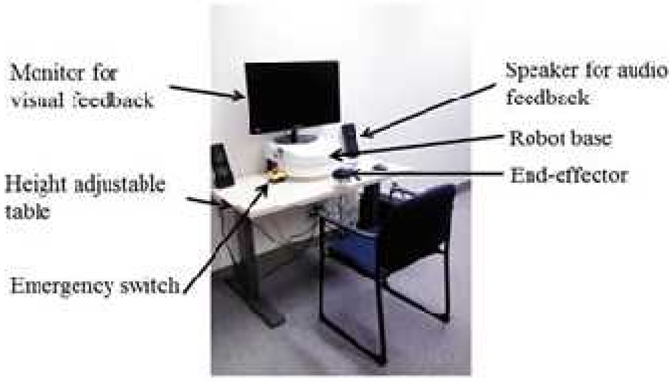


Figure 41: Intelligent haptic robotic system for upper limb rehabilitation after stroke[113]

The controller component adapts exercise parameters according to the settings defined through the computer interface. The latter, in turn, also provides users performance feedback and interactive activities and games to motivate them.
The implementation of this game-based approach is justified by the authors' findings about positive aspects of games in exercising. While playing a game, patients do not reflect on the system, having a better experience. This concept is, hence, a relevant aspect of this project and it was considered to be integrated in Us'em app to enhance its users' motivation in training more.

Biomove 5000

The Biomove 5000, a Biomove's[114] product, is a device suited to stroke recovery as well as to muscle rehabilitation. It can be used at home by stroke victims and by specialists in a clinical setting (Curatronic Ltd., 2014). It has a control knob to execute all possible functions and it is fully automatic. First, the muscle stimulation level is set and then a relaxation mode is turned on and music is played. When it stops, a blue light starts blinking to inform the user that he must start his voluntary move efforts. Then, a blue light bar expresses the electrical muscle activity and moves up (Figure 42).

[113] source: Retrieved June 06, 2014, from http://www.ot.utoronto.ca/iatsl/projects/haptic_stroke.htm
[114] Biomove company dedicates its work to the development of rehabilitation and therapy devices for patients and professional therapists use. Retrieved June 06, 2014, from http://www.biomove.com/

Figure 42: Biomove 5000[115]

Once it reaches a green light, the user knows he achieved his goal. This level to be reached is monitored and memorized and it depends of the voluntary muscle movement that the patient is able to do. In this way, if the user's move is minimal, the target level is automatically set up in a low level so the user can reach it. After that, the patient receives stimulation impulses to enable his muscle to move.
This product is here presented because its feedback aspects were relevant to this research project. It uses different methods to abstract patients from technology that supports their exercising to make them use it properly. It was also intended to make Us'em app ubiquitous, providing users a good experience so that they would not be so aware of using Us'em devices and app.

SaeboReJoyce

SaeboReJoyce[116] is a workstation for orthopedic and neurological patients with arm and hand impaired function designed to improve upper extremity rehabilitation. The system includes a physical tool with which patients can perform a range of specific training tasks to practice upper limbs moves. Those tasks represent daily activities such as opening a door (Figure 43), enabling dexterity training. This system includes activity-based computer games (Figure 44) that makes training funnier and more motivating.

[115] source: Retrieved June 06, 2014, from http://www.biomove.com/stroke-rehabilitation-device.html
[116] retrieved June 06, 2014, from http://www.saebo.com/products/saeborejoyce/

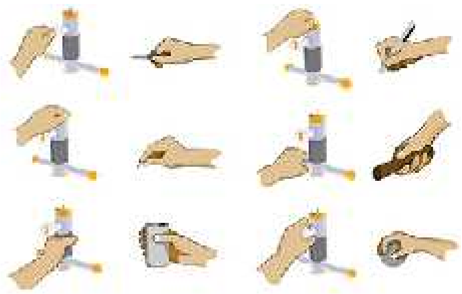


Figure 43: SaeboReJoyce activities[117]

Figure 44: SaeboReJoyce computer games[118]

Although, users need to use a physical component to move their limbs, they do it according to the game they are playing. Hence, they forget they are using that tool and focus more on the game. Consequently, they are more likely to train more and for longer. Through these games user' speed, endurance, range of motion, coordination, among others, can be tested. The system can be customized to match patient's therapy needs and it can be used at healthcare centers or at home.

This system is here described due to its gamification component seen as important element in rehabilitation. As referred earlier in this section, Us'em also makes use of this concept.

A system for remote orthopedics rehabilitation

This system can be used at the hospital and at home as an orthopedics rehabilitation process support (Tacconi, Tomasi, Costa, & Mayora, 2013). The architecture of this system (Figure 45) requires an internet connection and comprises a patient and a physiotherapist host and a backend server. It is based on motion capture technologies, game interfaces and remote motoring. By using a gaming interface (Figure 46), users execute exercises and their data is collected by the system. Thus, patients can obtain feedback immediately and be remotely monitored by their physiotherapists. These, in turn, can adapt patients' therapy plan according to their data.

[117] source: Retrieved June 06, 2014, from http://www.saebo.com/products/saeborejoyce/
[118] source: Retrieved June 06, 2014, from http://www.saebo.com/products/saeborejoyce/

Figure 45: System architecture[119]

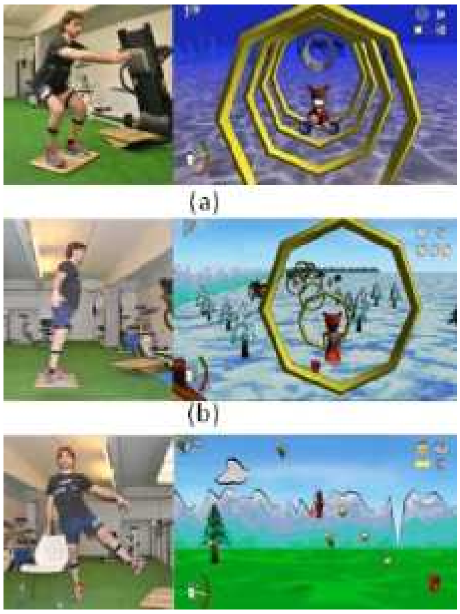


Figure 46: System's exercises and game interfaces[120]

To track the patient's moves, minimal intrusive wearable high precision sensors positioned on his body are used. They have embedded pressure sensors, 3D accelerometers, gyroscopes and magnetometers connected with Bluetooth. Its function is monitoring the correctness of the performed exercise taking in account specific and relevant parameters such as balance, joint and limbs angles. System's sensors and board enable users controlling games visualized through the gaming interface.
Games are chosen and its parameters are defined in advance, through a web interface, by therapists according to rehabilitation's goals. They provide feedback, keep players' attention and are prepared to detect inappropriate moves. When players' performance is good, game rewards them. Therapists can monitor patient's performance, access to session's data previously recorded and adjust the program if needed.
As the previous system, it also uses the power of gaming platforms for improving physical rehabilitation of individuals with neurological damages such as stroke. According to its authors, practicing intensively with this type of systems can be beneficial also to motor recovering, improving patients' balance, strength and coordination.
Given the scope of this research work, the aspects of the system here described were taken into account were: the gamification concept, the relevant role of therapists in setting different aspects of the system, enabled, in part, by their remote monitoring, the feedback to users, and the personalization according to each user. Although not implemented, for Us'em system definition it was also considered this system's architecture. Communication and data exchanging between therapist and patient is possible due to the internet and a backend data storage. Us'em system architecture and features defined in this work are described in detail in chapter *Prototyping*.

---

119 source: Retrieved June 06, 2014, from http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6563954
120 source: Retrieved June 06, 2014, from http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6563954

SWORD

SWORD is still a research project of a tele-rehabilitation system. It is a motion capture system designed to automatically evaluate upper limb motor function after neurological injury (Ferro & Bento, 2012). It is "*portable and low-cost, being easily assembled in a wearable garment*", thus it can be integrated is an ambulatory framework and in an ordinary clinical environment with a range of patients. Patient's recovery process can be continuously documented and his therapists can remotely and dynamically adjust his rehabilitation plan. Consequently, there will be a more efficient management of patient's rehabilitation plan.
Globally, the SWORD system's architecture (Figure 47) comprises 3 components: 1) a central server, 2) the patient's host (SWORD wearable devices (Figure 48) and a graphic UI) and 3) the clinician's host (web-based application).

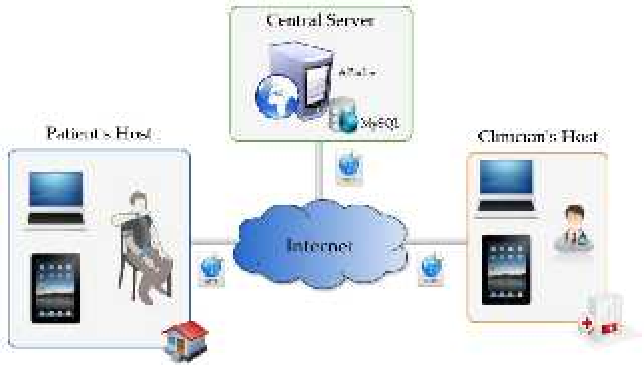


Figure 47: Global architecture of the SWORD system[121]

Figure 48: SWORD wearable devices[121]

The SWORD stimulation wearable devices have a light-weight, ergonomic and low-cost easily configured structure. It features are: 1) "*the stimulation device that delivers target vibrotactile stimulus in an intelligent form*" and 2) "*the motion quantification system that evaluates the motor task performed in terms of its kinematics*". With the SWORD devices it is possible to set the rhythm of the training and making patient perform correctly along all the session, which leads to a more efficient treatment. In addition, it acquires the three-dimensional kinematics of the upper-limb, analyzes the motor task performed in a qualitatively and stores this data as well as the number and the timing of both correct and incorrect executions, and feedbacks the patient with vibration.
For patient's adherence to therapy and to motivate them performing motor tasks - one of the most important elements of the recovery process -, SWORD system provides a set of simple games through a graphic UI. While playing, patient's movements are represented by the motion of an object on the screen. Increasing the difficulty of the task is done through the increase of level of difficulty of the games patient is playing. For instance, in a game designed for simple motor executions, the difficulty of the game is set by the speed of an object. Patient has, thus, to adapt his moves according to that object. A fast motion

[121] source: Retrieved July 07, 2014, from Ferro & Bento, 2012

of the object requires patient a quicker control of his arm. User's haptic interface is used also to provide him feedback.
Patient's kinematic data and game' scores are sent to the central server. The former refers to 1) number of correct and incorrect executions, 2) performance timing and 3) current level of difficulty, which provides precisely documentation patient's recovery. This data can be, then, be accessed by clinical staff and turned into a relevant insight for them in managing more efficiently patient's rehabilitation plan.
Data transfer model is lightweight and scalable as it uses a Web Service. This, in turn, stores the received information in a MySQL database. Clinicians can then, access this data. For that, they use a web-based application (with an internet-connected computer, tablet or smartphone) through which they can view data of all their patients. In this way, they are able to analyze and document patient's performance and manage their rehabilitation plan. They can schedule new motor tasks, define levels of difficulty and the duration of training sessions.
The quality of patient's moves relates, in this project, to the maximum range of motion user achieves. It is defined in terms of "*range-of-movement for simple movements or by the tunnel of motion in more complex ones*."
The SWORD system is here detailed due to its similarities with the previous Us'em system (explored in greater depth in the chapter Us'em *system*). Both comprise wearable devices to track upper limbs motion and a patient's UI. Nevertheless, while SWORD's purpose of using the devices is, among other, a qualitative evaluation of patient's moves, Us'em devices were designed to gather quantitative information. In addition, SWORD's users can interact with the system and view their own data through a graphic interface on a computer, tablet or smartphone. Us'em users, however, are able to only view their data and only using a smartphone. This project was, thus, important to characterize the new of Us'em system, defined in this dissertation, as well as Us'em app designed.
As aforesaid, despite the core of this research project is the redesign of Us'em mobile app UI, it is crucial to understand the whole system that comprises not only the devices and the app, but also the parties concerned. All of these elements and the interactions between them may influence potential features of Us'em app. It is here regarded again gamification as a major in enhancing motivation and engagement of physical therapy patients.
Bearing in mind the likeness of SWORD's system, its approach of communication between therapists and patients might be a valuable solution for Us'em system. That means that Us'em devices data (patient's moves data) would be transferred to a server through a web service, and requested by therapists' host. And, in turn, Us'em system would require an internet connection.

7.5 Mobile apps for rehabilitation

Hoogstraat Revalidatie mobile app

This mobile app's goal is to encourage post stroke victims to exercise independently. For that, the mobile app provides patients the same exercises as the exercise guide book[122] they can obtain. They can select them and define an exercise plan according with the severity of their condition and possible physical limitations (Figure 49). Exercises are, then, displayed in video (Figure 50).

Figure 49: Oogstraat Revalidatie mobile app: select impairments[123]

Figure 50: Oogstraat Revalidatie mobile app: video of an exercise[124]

Figures 49 and 50 show that the UI of this mobile app is very simple. It has only a bottom menu with 3 buttons, a top bar where is the title of the screen and one button. The content is presented more graphically rather than textually, which can make easier for some patients to perceive information.

It is important to refer this mobile app first because it is designed by a Dutch rehabilitation clinic, showing how rehabilitation therapy is interpreted and provided in this country. As perceiving information and rehabilitation and healthcare systems approaches may vary from culture to culture, it is important how and with which information Dutch patients should be provided. Secondly, because it was mentioned by Dutch therapists in an interview conducted in this research project. They mentioned it is becoming more and more used by patients and it a useful tool to provide them exercises when they are not at the clinic.

[122] Retrieved June 06, 2014, from http://www.dehoogstraat.nl/onderzoek-innovatie/beroerte-cva/diensten-en-producten/oefengids-beroerte

[123] source: Retrieved June 06, 2014, from http://www.dehoogstraat.nl/onderzoek-innovatie/beroerte-cva/diensten-en-producten/oefen-app-beroerte

Constant Therapy mobile app

Constant Therapy[124] mobile app is designed to individuals with cognitive, language, communication and learning disorders, such as stroke victims. It is a tool of continuous and customized therapy tool that can be used independently or together with a therapist. Users are provided by: 1) a personalized therapy map according to their strengths and deficits, 2) instant feedback on their task performance, and 3) therapy exercises library.
Therapists, in turn, can use this mobile app for various purposes, that make them providing better services, such as 1) setup their homework, 2) monitor and manage each patient's progress, and 3) search therapy tasks.
Unlike most of the mobile apps formerly described, this one has a more detailed dashboard. There is more information which requires more time to analyze it. In patients' interface (Figure 51), the gray color is the most used for background, some icons and some text elements. Graphic elements representing alerts or more relevant information have vivid colors, which attract users' attention. The dashboard of therapists' mobile app (Figure 52) is more detailed and with more information.

Figure 51: Constant Therapy mobile app patient dashboard[125]

Figure 52: Constant Therapy mobile app therapist dashboa1rd[126]

Rehabminder mobile app

Rehabminder mobile app[127] is a mobile tool to assist physical therapy patients. Creating an injury profile, users are provided by a list of specific and appropriate exercises (Figure 53) that they can view and add to their program (therapy plan customization). They are alerted by the frequency with which they should perform the exercises that are described with text and photos (Figure 54). In addition, their therapist can add instructions. Furthermore, this mobile app shows a graph that presents the number of exercises that

[124] Retrieved June 02, 2014, from http://constanttherapy.com/
[125] source: Retrieved June 06, 2014, from https://itunes.apple.com/us/app/itherapy/id575764424?mt=8&ign-mpt=uo%3D4
[126] source: Retrieved June 06, 2014, from http://constanttherapy.com/key-benefits-patients
[127] Retrieved June 02, 2014, from Retrieved from http://www.rehabminder.com/

the user has viewed, a glossary of hand and upper limb terminology and information resources important to people with hand impairments. In turn, therapist can revise patient’s program and help him to adapt it according to his condition.
Graphically, this mobile app has a simple and legible menu whose icons have a gradient background and a white image (Figure 55). Other screens present list menus with legible items and big photos with short descriptions. Overall, the UI elements seem to be clear, readable and understandable.
The most important aspect of this mobile app that was considered to this dissertation was its personalization.

Figure 53: Rehabminder mobile app: exercises selection[128]

Figure 54: Rehabminder mobile app: exercise explanation[129]

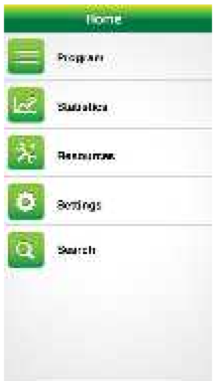


Figure 55: Rehabminder mobile app: home[130]

My Rehab Pro mobile app

My Rehab Pro mobile app[131] (Figures 56, 57 and 58) is designed to provide a better communication between patients, physicians and therapists and give to the latter an instant control over patients’ rehabilitation.

[128] source: Retrieved June 06, 2014, from http://www.rehabminder.com/
[129] source: Retrieved June 06, 2014, from http://www.rehabminder.com/
[130] source: Retrieved June 06, 2014, from http://www.rehabminder.com/
[131] Retrieved June 02, 2014, from Retrieved from http://www.myrehabpro.com/

Figure 56: MyRehabpro mobile app[132]

Figure 57: MyRehabPro mobile app (menu)[133]

Figure 58: Myrehabpro mobile app (content)[134]

In this way, it will be easier for all of them to follow and understand rehabilitation plans and patients will, thus, receive better and more efficient services. It also provides exercise reminders and enables inserting text notes. Lastly, and as the most relevant feature to address in this research project, this mobile app requires customization. It is fully functional only when a patient connects his mobile app to a clinician. He, in turn, will define the rehabilitation plan according with that patient. Hence, patient will be provided by personalized information. As seen before, post stroke patients are unique, so they greatly benefit from customized services like MyRehabPro mobile app offers. In the same matter, ensuring personalization in Us'em mobile app was aimed in its design process to positively affect users' experience. Regarding Us'em system as whole, the possibility MyRehab pro mobile app offers in providing provide therapists patient's analytics, as well as the need to connect the mobile app to a clinician to make it work, were also considered for its definition.

Regarding the UI design, this mobile app is clear and simple. Menus and its items (with a gradient background) are considerably big, filling almost the entire screen. It is used a sans-serif font style and text is, almost always, clear and readable. Subjectively, although information is clear, this mobile app does not have an attractive graphic interface.

StrokeLink mobile app

StrokeLink iPad app[135], by StrokeLink[136], is a tool to support stroke survivors regaining their independence, offering daily therapy exercises and monitoring. It has four main

[132] Source: retrieved June 03, 2014, from http://www.hatfieldmedia.com/wp-content/uploads/myrehav.jpg

[133] Source: retrieved June 03, 2014, from https://itunes.apple.com/us/app/my-rehab-pro/id663296117?mt=8

[134] Source: retrieved June 03, 2014, from https://itunes.apple.com/us/app/my-rehab-pro/id663296117?mt=8

[135] Retrieved June 06, 2014, from https://itunes.apple.com/ca/app/strokelink/id556672225?mt=8

sections: 1) My goals, 2) My Programs, 3) My Progress and 4) My Library. The first one is used to set goals of user's therapy program. In "*My Programs*", different exercises and therapy programs are presented through photos, videos, text or audio descriptions (Figures 59 and 60).

Figure 59: StrokeLink iPad mobile app (exercise demonstration)[137]

Figure 60: StrokeLink iPad mobile app (program builder)[138]

In "*My Progress*", there are reports that show daily StrokeLink's usage and therapy activities, enabling users to watch his progression. To learn more about stroke prevention and strategies to live after a stroke accident, a library of resources is provided. This mobile app offers to therapists the possibility to build, edit and delete therapy exercises and programs using StrokeLink Capture and the iPad's camera. They can use captured photos and videos of patient performing the required activities. Hence, patients can remind how to practice and then, as well as the therapists, track and check their evolution. The aspects of this mobile app that were considered for Us'em mobile app were the possibility to see and monitor their own rehabilitation progress.

7.6 Games for rehabilitation

The potential of interactive video games to improve physical rehabilitation is already known. They empower and engage patients in their recovery, making it a faster and better process, decreasing associated costs. Gamification concept is, thus, a relevant aspect for rehabilitation systems, applications, services and products. Below are presented some examples of games that were introduced or tested in rehabilitation field.

[136] StrokeLink's mission is "*to improve access to rehabilitation and improve the quality of resources patients are given to self-manage the rehabilitation process*". They aim to deliver to their patients and their community members a better management of the physical rehabilitation process. Retrieved June 06, 2014, from http://strokelink.ca/

[137] Retrieved June 06, 2014, from https://itunes.apple.com/ca/app/strokelink/id556672225?mt=8

[138] Retrieved June 06, 2014, from https://itunes.apple.com/ca/app/strokelink/id556672225?mt=8

Nintendo games

The application of Nintendo Wii[139] interactive video games in post stroke rehabilitation therapy is beneficial in improving upper limbs control (Deutsch et al., 2011).
As gaming interfaces, the system comprises haptic sensor-based controllers and a Kinect force plate. In playing it, users are represented in the game by its avatars and their real movements are translated in those avatars' moves. In Deutsch et al.'s study, participants played Wii Sports and Wii Fit games[140], so act like doing sportive activities such as pitching and batting in a baseball game (Figure 61). In this way, they needed to move their arm in multiple ways, improving their skills and ability in moving their arm.
Nonetheless, Wii controllers' (Figure 62) design and games' levels difficulty represent some obstacles to using these games.

Figure 61: People playing baseball Wii games[141]

Figure 62: Wii controllers[142]

Goji Play mobile app

Goji Play system, by Blue Goji[143], is a tool to transform cardio exercises into an entertaining fitness experience. It requires an iOS mobile device and exercise equipment. Before the training, user attaches controllers to the exercise equipment, e.g. an exercise bike or a treadmill, and connects them wirelessly to his mobile device. Then, while working out, he can play a game on his device which can be positioned in the equipment (Figure 63). Through Goji Play mobile app, users can set goals, choose a game and track the game. Exercise's statistics like calories, distance and time that are tracked (Figure 64).

[139] Retrieved June 06, 2014, from http://www.nintendo.com/wii
[140] Retrieved June 06, 2014, from http://wiifit.com/
[141] Source: Retrieved June 06, 2014, from http://www.gameguru.in/sports/2006/22/wii-sport-to-be-launched-in-december-2006-by-nintendo
[142] source: Retrieved June 06, 2014, from http://www.nintendo.co.uk/Wii-U/Hardware-Features/Hardware-Features-660145.html
[143] Retrieved June 06, 2014, from http://www.bluegoji.com/

Figure 63: Goji Play mobile app and controllers[144]

Figure 64: Goji Play mobile app UI [144]

Users can share their status and fitness tasks with friends and, as MyFitnessPal's members, earn prizes (MyFitnessPal Inc., 2014).

Finger Robot-Assisted Guitar Hero for Finger Rehabilitation after Stroke

FINGER is a robot that assists stroke victims regaining their finger functions. It intends to make stroke patients playing a game similar to Guitar Hero[145] to make them moving their fingers in naturalistic and grasping exercises in a large range of motion (Taheri et al, 2012). Music is played and its notes are graphically presented on a screen. The goal is to make players moving their fingers to specific positions and in specific moments, representing the play of a guitar. Also here, with a gamification concept on its basis, systems makes users practice physical moves and training parts of their body (in this case, their fingers), while having fun with the game.

Vera

Vera™, by Reflexion Health[146], is a physical therapy program based on Microsoft Kinect[147]. It aims to make physical rehabilitation an engaging, effective and affordable process and motivate patients to train on at home. The system explains patients how to perform exercises, captures patient's moves, compares them to the prescribed exercises and provides real-time feedback. This information is shared with their physical therapists, enabling them to coach, guide and support patients and adjust their exercising plan remotely.

144 source: Retrieved June 06, 2014, from https://www.myfitnesspal.com/apps/show/125
145 Retrieved June 06, 2014, from http://guitarhero.com/
146 Retrieved June 06, 2014, from http://reflexionhealth.com/
147 Retrieved June 06, 2014, from http://www.microsoft.com/en-us/kinectforwindows/

7.7 Final Considerations/Conclusions

This chapter dealt with the interface design, features and characteristics of mobile apps, systems and products in the scope of rehabilitation.
After the analysis of the rehabilitation mobile apps, systems and products aforementioned, it was possible to bring to conclusion several relevant aspects to this research project. This analysis fostered new ideas and inputs that were taken in account to develop the final Us'em mobile app prototype. In general, the aspects of the tools and mobile apps analyzed that were relevant for this research project were the following:

- connection and communication between a patient and a therapist host;
- information collected by mobile devices is transferred to a server through a web service;
- important role of therapists in settings various aspects of the system (including the mobile application);
- the need to connect the mobile app to a clinician to make it work;
- real time delivery of users' personal data , coaching and feedback;
- real time remote patients/users monitoring by their therapists/coaches;
- help and support system (that supports user interaction);
- goals system (including goals approval by therapists and goals setting according to user's activities and rehabilitation or exercises plan);
- mobile app customization;
- review of user history (metrics, workout);
- user's metrics tracked by a mobile device and provided to the user through a graphic interface;
- gamification.

Regarding UI design, the main aspects of these tools considered to this dissertation were:

- the use of sans-serif font style;
- short text elements;
- simple and flat UI;
- simple and two-colors icons;
- one-color buttons;
- use of vivid colors to highlight relevant information;
- main colors are light;
- use of a title to identify screens;
- menu always present;
- use of vertical bar charts;
- big interface elements;
- low number of buttons and interface elements;
- present more graphic than text content;
- contrast between background and text;
- navigation by time frames (week, month and year).

Table 3 presents an overview of the aspects of the tools and mobile apps analyzed.

Table 3: Summary of the aspects considered of the rehabilitation mobile apps, systems and products analyzed

Mobile app	**Aspects considered**	
	Features	**UI design**
Healthcare management tools		
Microsoft HealthVault	Connection to monitoring and tracking devices; Data sharing between medical professionals and users (user's progress monitoring, goals setting)	Simple, flat and clear; Arrangement of UI elements and information based on a grid; Sans-serif font style; Short text; Vivid colors to highlight relevant information; Simple and two-color icons; Screen identification
Healthcare management tools		
Welframe	Communication between patient and therapists through the mobile app; Real time analysis of patients' care plans.	Sans-serif font style; Short text; Simple and one-color icons; Small menu (3 buttons); Feedback and alert pop-ups design.
Healthcare mobile apps		
WebMD mobile app	Tips about user interaction and functions.	Two-color buttons, icons and text elements; Use of vivid colors to highlight relevant information; Short text.
WebMD Pain Coach mobile app	Review personal patterns (user's history); Individual user experience according to the specific patients' conditions (customization); Goals setting (goals approved by therapists); Goals divided according with user's activities.	Menu always presented.
CatchMyPain mobile app	Report and share patient's condition with therapists;	Main colors: blue, grey and white colors; Vivid colors and warm colors to emphasize relevant information; Simple and one-color buttons; Sans-serif font style.

Mobile app	Aspects considered	
	Features	**UI design**
Sports and Fitness mobile app		
Nike+ Running mobile app	Constant delivery of users' personal data (awareness of the frequency of their moves and their progress); Metrics (tracked by mobile devices software) provided visually; Users can share information with friends.	Not considered.
Fitbit mobile app	Users' data tracking (through wearable mobile devices) and collection; Real time data syncing with the mobile app; Rewarding system.	Backgrounds with light colors; Screen's title; Sans-serif text font; Vertical bar charts.
PEAR Training-Intelligence mobile app	Monitoring users tracked data while exercising/moving; Workout history; Goals visualization; Data sharing; Feedback system.	Text size; Sans-serif font style; menu's items big area; Use of different colors to emphasize certain information.
Edomondo mobile app	Real-time auditory coaching.	Contrast between background and content; Sans-serif font style; Simple and one- or two-color buttons.
EveryMove mobile app	Rewarding system.	Buttons visible in every screen; Navigation by time frames (week, month and year).
Race by Hearts mobile app	Data sharing and review.	Contrast between background and text; Simple and clear icons; Big and colorful buttons.
Rehabilitation Systems and Products		
Rehabilitation Exercise	Goals setting; Sharing information with users' therapists.	Not considered.
H200 Wireless Hand Rehabilitation System	Personalization.	Not applicable.
Intelligent haptic robotic system for upper limb rehabilitation after stroke	Gamification.	Not applicable.

Mobile app	Aspects considered	
	Features	**UI design**
Rehabilitation Systems and Products		
Biomove 5000	Feedback system; Ubiquitous characteristic.	Not applicable.
SaeboReJoyce	Gamification	Not applicable.
A system for remote orthopedics rehabilitation	Gamification; The relevant role of therapists in setting various system aspects. Remote patients monitoring. Feedback and system personalization according to each user (communication and data exchanging between therapist).	Not applicable.
SWORD	Communication approach: transferring data collected by mobile devices to a server through a web service. This data is then requested by therapists' host.	Not applicable.
Mobile apps for rehabilitation		
Oogstraat Revalidatie mobile app	Personalization.	Simple; Low number of buttons and interface elements; More graphic than text content.
Constant Therapy mobile app	Personalization.	Vivid colors to show more relevant information.
Rehabminder mobile app	Personalization.	Big interface elements.
My Rehab Pro mobile app	Customization; Patient's analytics provided to therapists; The need to connect the mobile app to a clinician to make it work.	Simple and clear; Big menus; Sans-serif font style.
StrokeLink mobile app	Patients see and monitor their own rehabilitation progress.	Not considered.
Games for rehabilitation		
Nintendo games	Gamification; Real time feedback.	Not applicable.
Goji Play mobile app	Gamification; Real time feedback; Goals setting; Data sharing with friends.	Not applicable.

Mobile app	Aspects considered	
	Features	**UI design**
Games for rehabilitation		
Finger Robot-Assisted Guitar Hero for Finger Rehabilitation after Stroke	Gamification; Real time feedback.	Not applicable.
Vera	Gamification; Real time feedback; Data sharing with therapists.	Not applicable.

8. Us’em system

This research was conducted within the framework of Us’em project, which is described in this chapter. It is divided into two parts: one respects to the technical issues of Us’em, the other respects to its UI.

Us’em is a motivating arm-hand wearable technology for post stroke patients and it is part of the research conducted by the department of Industrial Design of the Eindhoven University of Technology[148], in the Netherlands. It has been improved since 2009, along various research projects. This dissertation is, thus, the most recent research of Us’em project. Its main aim is increasing motivation of post stroke rehabilitation patients for using their arm-hand through the day, promoting their self-rehabilitation and improving the outcomes of their recovery.
The project was initiated by Freek Boesten in 2009 (Boesten & Markopoulos, 2009). The purpose of this first research was to design a motivational tool for stroke patients for using their impaired arm-hand in specific daily activities, to improve their rehabilitation. In addition, it was aimed to make this tool capable of providing therapists information about the “Actual Amount of Use for specific daily activities” of their patients. In general terms, the requirements for Us’em project were defined as follows: 1) to focus on daily activities performed in both rehabilitation center and home, 2) to be not intrusive in monitoring patients and fit their daily tasks, 3) to feedback patients on their use of the impaired arm-hand in daily life and when training predetermined arm-hand skills, and 4) to enable patient to use it independently of others.
The prototype of Us’em comprised 2 interconnected watches (Figure 65).

Figure 65: Us’em project by F.Boesten

One of them could measure and compare the activity of the other one, giving feedback about their use relates to each other. That is to say they could compare movements of both arms of the user, allowing him to obtain feedback about his recovery process. The control of the system was performed by an external pc.

After that, in 2010, L. Beurgens redefined the first prototype at a technical level, without changing its function and form (Figure 66). This one was already working with a control of an Arduino Micro Controller.

[148] http://www.tue.nl/

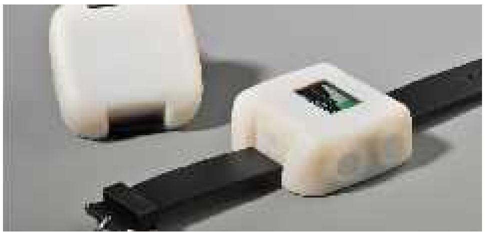


Figure 66: Us'em project by L. Beurgens

In 2011, R. van Donselaar, continued the Us’em project, focusing on the technical and aesthetic aspects of Us’em devices. These became smaller, more convenient to use and with a better and life-increased battery (Figure 67).

Figure 67: Us'em project by R. van Donselaar[149]

Then, in 2012, Robert van Vliet’s work considered the electronics and form design of Us’em devices (Figure 68) and added a new component to Us’em system: a mobile app, redesigning Us’em towards a closed system (Vliet, 2013).

Figure 68: Us'em project by R. van Vliet

The main improvement on Us’em devices was its design without a display. Each of Us’em devices had a 3D printing casing with different colors - one with blue color (left arm) and another with orange (right arm), and a mobile app. The devices were designed to be the easiest to wear by the patient. Each of these comprised 4 components: 1) an accelerometer that measured the user’s movements, 2) a micro-controller to process data and control the wireless protocol, 3) a wireless transmitter which sent data from the devices to the smartphone, and 4) a battery to power all the components.
The information gathered by Us’em devices was, then, sent to the mobile app and displayed to user through a graphic interface. Hence, instead of being provided through the display attached to one of Us’em bracelets, as in the previous projects, the information

[149] Source: retrieved from Wingen, 2013

was provided through a smartphone. The patient could, hence, see the usage of his left arm compared to the right one over the total movement – movement's ratio.
A prototype of Us'em mobile app was designed. It had only 2 screens where the information from Us'em devices was displayed. One of them provided data about moves in the last 5 minutes, and the other one a representation of his moves' history.
From a technical point of view, Vliet's project is the more recent, so it had contributed to this research project at the technical level. The aspects considered to this project are described below in *Technical issues*. In addition, although the most recent Us'em mobile app prototype is the one designed by Wingen (described next), reason why it was considered to this research project, the mobile app designed by Vliet is also analyzed. It has relevant aspects there were relevant for this dissertation. These issues are also detailed below in *Technical Issues* as they concern more on the communication between Us'em devices and mobile app rather than on the UI design.

The most recent project, by Wingen (2013), has the latest improvements and updates on Us'em project (Wingen, 2013). Its main focus was on the design of the mobile app user interface. Given that, Wingen's work gave a great contribute to this research project. That project is described in detail below, in Us'em *UI*.

8.1 Technical Issues

As mentioned before, Us'em most recent technical modifications were made by Vliet.
The Us'em mobile app was developed in Java with an implementation of the *Android* SDK (Vliet, 2013). It was designed to run in *Android* (version 2.1) devices that support Ant+[150], a wireless technology. In Vliet's project, as well as in this research, the smartphone used was the Sony Xperia X8, model e15i (Figure 69). Some of its features[151] are described in Table 4.

Figure 69: Sony Xperia X8 e15i[152]

[150] Retrieved July 15, 2014, from http://www.thisisant.com/
[151] Retrieved July 15, 2014, from http://www.gsmarena.com/sony_ericsson_xperia_x8-3403.php
[152] Source: retrieved June 26, 2014 from http://www.gsmarena.com/sony_ericsson_xperia_x8-pictures-3403.php

Table 4: Features of Sony Xperia X8 e15i

OS	*Android* v2.1[153]
Dimensions	99 x 54 x 15 mm
Weight	104 g
Display type	TFT capacitive touchscreen, 16M colors
Display size	320 x 480 pixels, 3.0 inches (~192 ppi pixel density)
Wlan	Wi-Fi 802.11 b/g
Bluetooth	v2.1 with A2DP
USB	microUSB v2.0
others	ANT+ support

The monitoring application, executes three main steps before display Us'em devices' data:

1) Writing of data receiver and storage application,
2) Creation of the connection between the bracelets and the smartphone,
3) Compression and storage the data sent by the accelerometers.

Data is collected through a process that runs in a background, so it does not require running the mobile app constantly. Then, this monitoring application (*Android* can have different applications) uses data from the database and displays it through the UI. This method of setting up the application enables using the same database for input of other applications.

At a hardware level, one of the components of Us'em devices is a (ANT+) wireless transmitter module – ANT+ AT3 chipset[154]. It is connected to a coin cell battery and to the accelerometer that measures the moves of patient's upper limbs. Using a built-in micro microcontroller, it sends data to the smartphone, specifically to a (ANT+) receiver controlled by an application on the smartphone. It is required, thus, to define a reference of each device that is, then, written within the code of Us'em mobile app. Hence, Us'em mobile app will run without errors if there will be 2 devices (2 references) that are referenced in its code. The full system and the connection between its components are showed in Figure 70.

[153] http://developer.android.com/about/versions/android-2.1.html

[154] Retrieved July 15, 2014, from http://www.thisisant.com/developer/components/at3-modules#12_tab

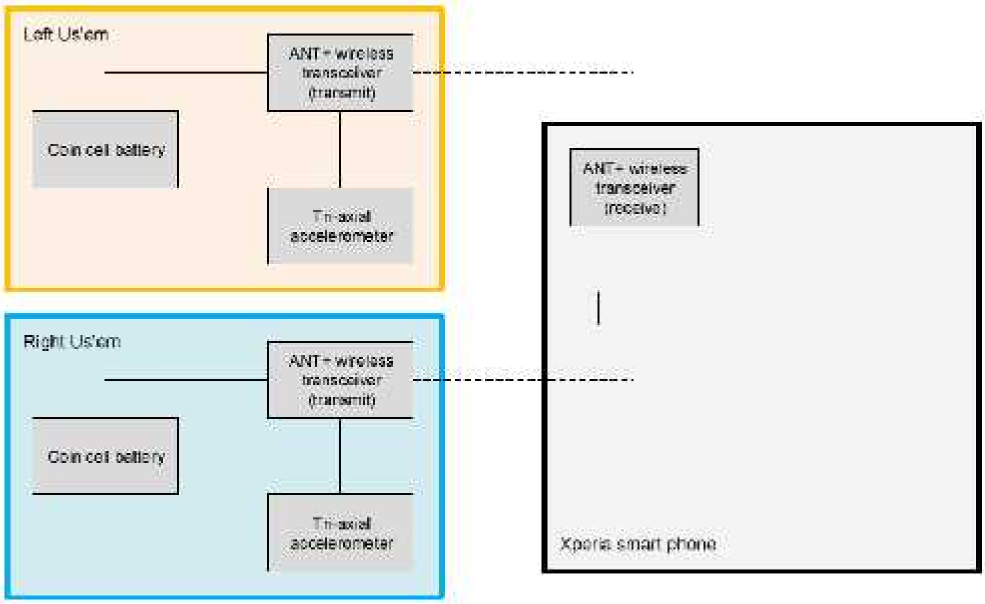


Figure 70: Us'em system by Vliet (2013)[155]

In detail, the Us'em devices functionality depends on the conversion of the accelerometer analog data into understandable data. The steps taken by Us'em software are listed below:

1) ANT+ chip has an analog to digital sampling rate of 32Hz per axis;
2) a basic filter is applied to the chip resulting in 1 measurement that represents the average of the 4 last AD samples taken;
3) thus, for every axis there are 8 (32/4) values generated per second;
4) as the ANT+ chip can only send one value per message, the values are transmitted by a message ratio of 24Hz (3*8);
5) consequently, there will 24 messages coming in every second (8 per axis per second) on the phone;
6) each message is decoded to extract the actual measurements coming from the accelerometer;
7) thus, there will be a 16 bit integer value (0 – 65535) representing the measured acceleration.

After that, the signal is calibrated: the 16 bit value is divided by 2 and multiplied with a number smaller than 1 which can be unique for every axis (this factor is 0.05, resulting in values in the range of 0 – 200). Then a delta is subtracted from these values, which may be unique for every axis.

Only when there are x, y and z values, the code continues running, calculating a length vector based on the formula: √(x2 + y2 + z2). Then, another calibration is made. Every time a new vector is created, the system compares the last 7 vectors. If they are all the same, it means that the sensor did not moved, to the patient is not moving as well.

In the end, during a certain period of time, the application stores 8 values per each arm, per second. Then, every minute, the average of those values is calculated, stored in the persistent database of the mobile app and, then, reset to 0. Data is, thus, the ratio

[155] Source: Vliet (2013)

between the moves (frequency) of both arm-hands – quantitative information. It is, then, presented to patients through Us'em mobile app graphic UI.
Given these issues, it was necessary, in this research project, to learn the basis of Java programming and dealing with Ant+ communication protocol issues.
It was necessary to certificate that Us'em mobile app, developed by Robert, was correctly connected to Us'em devices and was receiving their information. This process included checking batteries, checking and defining the references of Us'em devices and those written in the code of the mobile app (using the software ANTware II v.3.200) and checking if the mobile app was receiving values form both devices. This last procedure was done with Eclipse, an integrated development environment for Java, integrated with the plugin *Android* Development Tools for *Android*. Tackling with these issues was a time-consuming process, as they were not known by the researcher. In addition, as dealing with Us'em devices and smartphone was only possible at TU/e, it could not be done earlier.
Understanding these technical issues in detail was of great relevance to this research project. It was important to understand how Us'em mobile app works and, thus, design its UI according to its functions. For instance, to design this mobile app UI, it was necessary to know which information was transferred from Us'em devices to the mobile app.

8.2 UI

The mobile app designed in Wingen's project is the most recent Us'em mobile app UI designed. It has 3 main features: 1) choose an activity, 2) see the progress of a day and a week, and 3) chose an emoticon that reflects the state of the patient's feelings (Wingen, 2013). It has an initial screen, with Us'em logo (Figure 71), that is shown while launching the mobile app for the first time.

Figure 71: Logo of Us'em mobile app (Wingen's project)[156]

On the first screen there are two options: one provides an explanation about how to connect the mobile app with the bracelets and the other gives more insights about the mobile app. This first screen is shown until the user pairs the mobile app to the bracelets.
Once this connection is made, the user choose an activity to start with. Once he starts that activity, he is provided by the ratio of movements of his both arms. There is also a screen were user can see an overview of the ratio of his movements in a day, week, month or year (Figure 72).

[156] source: Wingen (2013)

Figure 72: Us’em mobile app: (2) screens of overview of the ratio of movements (Wingen’s project)[157]

The user can select an emotion to represent his feelings of a day and add comments abot it. The mobile app has also a screen with user’s personal data, including his averages, successes, feedback, and impaired arm. Finally, there is a settings screen with mobile app’s version, contact of its authors, its statues and a ‘help’ page.

On this mobile app, it is required to indicate which arm is the impaired one in order to represent graphically which exercises contribute to the increase of the impaired arm moves.

The interface has gray colors for text, backgrounds and icons. In addition, the blue color is used to represent the bracelet of the left arm and the orange to represent the bracelet used on the right one. This choice was made based on the previous iteration of Us’em, by Robbert van Vliet. His definition was based on a simple trick: the letter L is in the words ‘left’ and ‘blue’, and the R is in the words ‘right’ and ‘orange’.

As futures developments, Wingen’s project required 1) the connection between Us’em bracelets and mobile app, so users could see real data; 2) the development of real and programmed screens, because the mobile app was made only of interactive images rather than real programmed screens; and 3) new prototype iterations to adjust graphics that represent the information as well as the whole mobile app, to further design the mobile app. In addition, 4) the icons to represent users’ emotions and feelings should be reviewed to be more realistic in representing certain emotional states. Furthermore, 5) the activities available to set without the help of the therapists should be reviewed; 6) the time to perform an activity should be set and reminded to the patient. 7) It should also be certificated that the use of Us’em will not make patient execute a movement with compensation of his body. However, this can only be assured observing several situations and use of Us’em. 8) Regarding Us’em bracelets, they should be decreasing in size and be waterproof. This UI was not accessible during this research project. The only information available was the report of that work which included some images of the interface.

As mentioned in *Technical Issues*, Vliet’s work focused on the technical issues of Us’em mobile app. Yet, it also comprises the design of Us’em mobile app. Hence, although

[157] source: Wingen (2013)

Wingen’s work is the most recent, reason why it was considered to this dissertation, Vliet’s work on the UI of Us’em mobile app was also considered to this research project. Its aspects that were addressed to this research project are described below.
The UI designed by Vliet has only two screens: monitor (Figure 73) and progression (Figure 74).

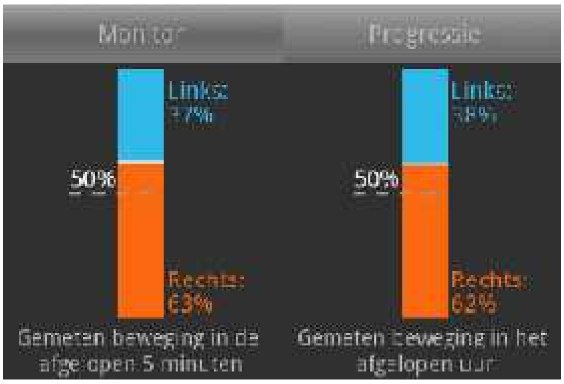


Figure 73: Us’em mobile app interface (by Vliet (2013)): monitor screen[158]

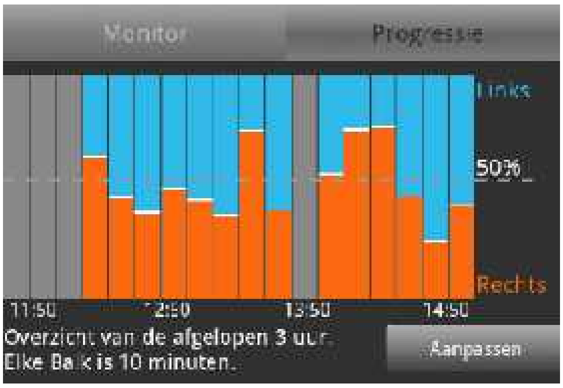


Figure 74: Us’em mobile app interface (by Vliet (2013)): Progression screen[159]

The first one displays data about patients moves in the last 5 minutes and last hour.
The monitor, in turn, provides a representation of the history of user’s moves, with the possibility to adjust the time scale.
In both screens there are ratio bars divided into 2 parts representing the percentage of the average of the total use of each arm over a certain period (the top part respects to the left arm and the bottom one to the right arm). The colors of the two parts of the bar, orange and blue, correspond to the Us’em wearable devices used by the patient. There is also a horizontal line in the center of the bars that indicates the ratio of 50% (moving both arm-hands with the same frequency).
Regarding the Us’em mobile app and the smartphone, the future developments were defined as:

- Using a smartphone with a larger interface and with a longer battery life; and
- Bearing in mind the difficult some patients face in holding the smartphone, it should be designed a stand for it. This object could also support Us’em bracelets to help patients wearing them correctly.

To conclude, the two most recent Us’em projects are Robert’s and Wingen’s work and both are on the basis of this dissertation. The first researcher focused mainly on the technical component (Us’em devices and information transfer to Us’em mobile app). Robert’s work contributed of Us’em mobile app UI. Wingen’s focus was the UI of this app reason why her work was relevant to this dissertation. The research project presented in this document has the purpose to improve Robert’s and Wingen’s work with regard to the UI of Us’em mobile app. The specific goals of this research are described in section “Prototyping”.

---

158 Source: (Vliet, 2013)
159 Source: (Vliet, 2013)

9. Research Methodology

This chapter presents a description of the research methodology and the preparation and application of the instruments that were used to guide this research. The latter allowed us to answer the research questions and provided guidelines for the redesign of the Us'em mobile app. This research methodology involves the prototype of Us'em mobile app. Its development, which includes prototype design, implementation and evaluation, is described in chapter *Prototyping*.

9.1 Research Nature

This research project was based on the action research[160] and development research[161] methodologies. On the one hand, it is considered an action research because it is aimed a theoretical construction, but also because it is problem-focused (it aims solving practical problems), context-specific, future-oriented and it involves a change intervention (M. M. Ferreira & Carmo, 2008; Blaxter, Hughes, & Tight, 2010). Indeed, it is considered that the mobile app that is intended to prototype may be a potential tool to support self-rehabilitation of post stroke patients with upper limbs impairments, in the context of Us'em system. In addition, it is considered an action research because it intends to be a "*way of producing tangible and desired results for the people involved, and it is a knowledge-generation process that produces insights both for researchers and the participants*" (Greenwood and Levin (1998) cited in Blaxter, Hughes, & Tight, 2010). Another reason that justifies this classification is because there is a set of iterative cycles of planning, acting, observing and reflecting that are interlinked (Blaxter et al., 2010). On the other hand, this study is based on a development research as it involves the design of a prototype that narrows the concept into reality (M. M. Ferreira & Carmo, 2008).
Quantity[162] and quality[163] research approaches were used in this study, which means that it was used a mixed method[164] (Gray, 2009). The reason of this mix has to do with the benefits that both methods have to expose different aspect of the empirical reality, such as the increased validity and meaningfulness of the results (M. M. Ferreira & Carmo, 2008; Gray, 2009).
At the beginning of this project, an analysis model was designed to guide and support the research. It includes relevant research topics, detailed in categories such as concepts,

[160] Action research's purpose is solving practical problems that do not have a solution based on pre-defined theories, with scientific methods (M. M. Ferreira & Carmo, 2008).
[161] Development research aims designing products for a particular purpose and with detailed specifications (Ferreira & Carmo, 2008).
[162] "Quantitative research is empirical research where the data are in the form of numbers" (Puch (2005) cited in Blaxter et al., 2010)
[163] "Qualitative research is empirical research where the data are not in the form of numbers" (Puch (2005) cited in Blaxter et al., 2010)
[164] "Mixed methods have been defined as 'the collection or analysis of *both quantitative and qualitative data in a single study in which the data are collected concurrently or sequentially, are* given priority, and involve the integration of data at one or more stages in the process of research'" (Creswell et al., 2003 cited in Gray, 2009, page 204)

dimensions, sub-dimensions and indicators, and the necessary collecting data instruments.

To identify Us'em users' requirements and needs, as well as Us'em mobile app features, User Stories[165] were used. They were written from the point of view of the system and mobile app end-users and written in a language they would use rather than system language. To that, normal paper was used, rather than on paper note cards, the traditional method. User stories were built up according to the format Mike Cohn has canonized in 2004: "As a [actor], I want [feature], so that [value, benefit]" (Cohn, 2004). Here "stroke patient" refers to a stroke patient with upper limb impairments, the focus of this project. For the sake of documentation, the user stories can be found in document *User Stories* annexed to the CD of this dissertation. Two examples of User Stories are below.

Example 1: User Story (patient)

As a: Stroke patient (with upper limb impairments)
I want: To see the frequency of my each upper limb movement in real time
So that: I can see which one I am moving more

Example 2: User Story (therapy team)

As a: Rehabilitation team member
I want: To see the progress of a patient across a specified time period in a certain activity
So that: I can get a more in-depth insight in possible processes

In addition, to detail User Stories data, Use Cases[166] were also created. Comparing to User Stories, Use Cases were more detailed and focused on functionalities and were not designed from the point of view of the users. A Use Case represented the steps that a user needs to perform to achieve certain goals. In other words, it represented the system functionality and requirements from a user's perspective.

The use of Use Cases was relevant by explaining how system's behavior should be in order to support users achieving their goals, supporting the system's design process. They included information about who was the user, what he wanted to do, his goal and the steps he needed to take to achieve it and the system's behavior responding his actions. On contrary, Use Cases do not detail and describe system's elements (such as interfaces or screens) and its implementations.

Bearing in mind the scope of the prototyping phase of Us'em mobile app, the Use Cases had the following elements: 1) *Actor* (who performs a behavior and uses the system), that is to say a post stroke patient, his physical therapist, rehabilitation team and carer; 2) *Stakeholders* that are individuals who are interested in the system's behavior, that are the

---

[165] A user story is a description of the valuable system or software's functionalities to its users. It includes a written story's description, "conversations about the story" to detail it and "tests that *convey and document details and that can be used to determine when a story is complete*" (Cohn, 2004, page 4).

[166] A use case is also description of a set of interactions between users (a person, another system or a process) and the system, which is, in this case, the Us'Em app (Usability.org, 2014; Franks, 2014; Cohn, 2004).

rehabilitation team and, in some cases, patients' carers; 3) *Primary actor*, that is the patient, who starts an interaction with the system to achieve a goal; 4) *Preconditions* that represent "*what must be true or happen before and after the use case runs*"; 5) "Triggers", the event that triggers the use case; 6) *Main success scenarios*, which represent a successful use case; and 7) *Alternative paths*, which represents potential flows of the system when anything occurs wrongly. On the basis of Franks (2014) and Cockburn's (2001) work, the development of Use Cases had taken 5 main steps: 1) Identification of stakeholders and goals; 2) Identification of successful scenarios; 3) Creation of narratives; 4) Identification of failure conditions; and 5) Identification of failure handling.

Identification of stakeholders[167] and goals

The stakeholders that were identified were: 1) the patient, 2) the physical therapist, 3) the rehabilitation team and 4) the patient' carer. Then, they were labeled as primary[168] – patient – and as secondary actors - physical therapist, rehabilitation team and patient' carer.

Each stakeholder's goals were identified, detailed and organized in different levels, containing main and sub-goals. The higher number of the level, the less desirable are mobile app/system functionalities. Bearing in mind the scope of this project, its focus on the primary actor and his interaction with Us'em mobile app, more attention was given to patients' goals organization with regard to the mobile app. However, goals of the other stakeholders concerning Us'em system were also approached as they influence Us'em system and mobile app.

Identification of successful scenarios[169]

Scenarios were designed as a mean of achieve the final concept of Us'em mobile app. They included a rich description of users and their goals, enabling a link between the initial design idea and the solution. Furthermore, they include a brainstorm of potential paths of failure in successful scenarios and states of how the system or product should react. For a better understanding, a Use Case is a major task and a User Scenario represents the various ways it may occur. Hence, each Use Case has one or more Scenarios. Possible Scenarios were identified: first, the starting states/contexts and secondly, the main success scenarios.

Creation of narratives

The narratives designed during the third phase described how users can achieve their goals using the system, that is to say, the basic course of event of user interactions. In addition, they also inform how the system responds to those interactions. These descriptions are primary Use Cases. Hence, there is one story for each goal of each different stakeholder.

---

[167] Stakeholders are people with a "vested interest in the behavior of the use case", although they may never interact directly with it (Cockburn, 2001). An actor is a stakeholder that has a behavior.

[168] A primary actor is a stakeholder who uses system's services aiming a certain goal with respect to it and getting satisfied by its operation. Usually, it is the person who triggers the use case.

[169] Scenarios are a story and step-based explanation of how and in which context the (Us'Em) system or a product (Us'Em app) will be used to allow its user to achieve a goal.

Identification of failure conditions
As a fourth step of this process, potential failures that may occur during interaction with the system were brainstormed. They correspond to the different courses that may be taken alternatively and may break an otherwise good experience. These uses cases are called secondary or “edge” use cases.

Identification of failure handling
As a last step, it was identified and described how the system will supposedly react to each failure. In this way, different Use Cases were built in order to describe stakeholder’s needs and behaviors when interacting with the system. Each Use Case represents, thus, all possible interactions they may execute.

Use cases can be exemplified by the two presented below (see more examples in document *Use Cases* annexed to the CD of this dissertation).

Example 1: Use case – see real time measurements

Use Case ID	1
Context of use/Description	View ratio of real time measurements of patient’s upper limb moves tracked by Us’Em devices
Scope	Us’Em mobile app
Primary Actor	Stroke patient
Stakeholder (s)	-
Pre-conditions	Patient is using Us’Em devices; Us’Em devices are measuring upper limb movements;
Triggers	Patient want to know the frequency of his upper limb movements;
Main success scenario	
User input	**System Response**
1. Patient select “My moves” icon in mobile app’s menu	
	2. mobile app changes to “My moves” screen

Example 2: Use case – setting sharing data

Use Case ID	6a
Context of use/Description	(stop to) Share data with patient’s carer
Scope	Us’Em mobile app
Primary Actor	Stroke patient
Stakeholder (s)	Patient’s carer
Pre-conditions	-

Triggers	Patient (so not) want to share his information with his carer(s)
Main success scenario	
User input	**System Response**
1. Patient select “Settings” icon	
	2. mobile app changes to “Settings” screen 3. It shows a list of settings can be changed
3. It shows a list of settings can be changed	
	5. mobile app shows (off) on button to (not) share information with patient’s carer
6. Patient select (OFF) ON to (not) share information with his carer(s)	
	7. mobile app shows feedback message to confirm user’s option
8.1 Patient confirm the change of sharing status 8.2 Patient cancel the change of sharing status	
	9.1 (response to 8.1) mobile app changes sharing data status 9.2 (response to 8.2) mobile app cancel changing sharing data status
	10. mobile app return to “privacy settings” screen

UML diagrams

Next to the Use Cases’ creation, Use Case diagrams were designed. They are based on UML (Unified Modeling Language[170]) and work as a visualization of a top-down perspective of Us’em system and mobile app’s functionalities (see part of the Use Case diagram in Figure 75. It respects to the therapist role in Us’em system. This diagram is present in document *UML Use Case* annexed to the CD o this dissertation).

[170] Retrieved April 24, 2014, from http://www.uml.org

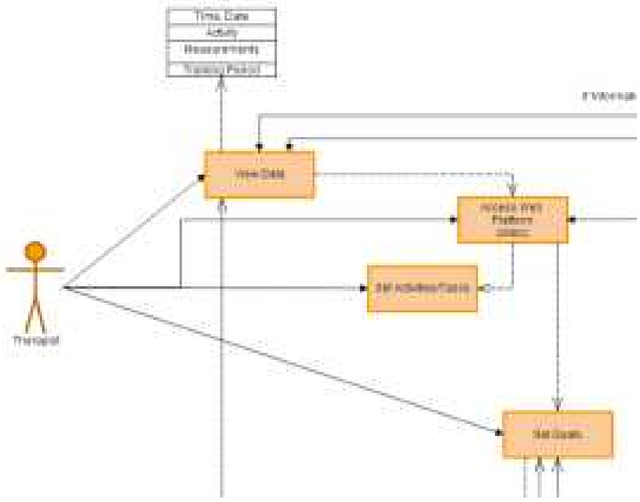


Figure 75: Part of the Use Case diagram

The diagram related to the system includes 1) the 4 actors who can interact with the Us'em system, 2) the system, 3) the use cases it can support and 4) the relationships between these 3 elements. The other diagram has the same components but with reference to Us'em mobile app rather than Us'em system. In the same way, it refers to the patient rather than the 4 system's actors.

The design of UML diagrams was an iterative process: they have changed as more information became available and the Use Cases were refined along the project. UML diagrams were used as an object of discussion with patients and therapists. These diagrams design is explained in chapter *Prototype Design*.

9.1 User Centered Design

"*User interface design focuses on designing flexible environments that have a positive* impact a user's ability to experience and interact with a product whether that product is a *mobile communication device, website, information kiosk, or applicance*" (Sears & Jacko, 2007, page 331).

The usability of mobile interfaces is a relevant aspect that affects the user experience. So, it must be approached and measured during the redesign process. In turn, in order to design a usable interface, it is necessary an understanding about the context of use and the users' needs and requirements.

The design process of interactive applications for mobile devices is facing new challenges due to the growing diversity of mobile technology. In fact, there are no specific methodologies for mobile, handheld and ubiquitous devices. Nevertheless, even if it is still necessary to define new approaches, user-centered design (UCD) methodologies (product design methodologies) may be applied for mobile apps design. This methodology considers end-users as important factor to shape the design and gives a great attention to initial stage of design (van der Weegen et al., 2013; Sá, Carriço, & Duarte, 2014).

In this project, a UCD process was used and it had four main stages, based on Sá e Carriço (2006), in (Sá et al., 2014): 1) End-users and Context identification, 2) Concept Development, 3) Product Design and 4) Evaluation.

9.1.1 End-users and Context identification

The first stage of the Us'em mobile app design was data gathering, an essential starting point to design interactive applications (Sá et al., 2014). The main purpose of this stage was to answer two questions with respect to Us'em mobile app: 1) "Who are the users?" and 2) "What do they want to do with the system?". Hence, it did comprise identification of: 1) Us'em mobile app and system users, 2) user's requirements and needs and 3) context of use of Us'em mobile app. To gather this information, literature readings and analysis, interviews, questionnaires and observations were done. Collecting this data required, thus, the participation of potential end-users of Us'em mobile app and other individuals involved in its context of use. The target group of Us'em mobile app is post stroke rehabilitation patients with upper limbs impairments. The context, in general, comprises post stroke physical rehabilitation, in particular rehabilitation of upper limbs. In that context, rehabilitation patients interact with other participants such as physical therapists and patients' carers. Indeed, with the collecting data methodologies aforementioned, it was concluded that there is a direct link between rehabilitation context's participants. Both patients and therapists play an important role in the rehabilitation process and act reciprocally towards patient's recovery. Therapists set, manage and evaluate patients' recovery, supporting them along that process. Patients' carers are also relevant. They support patient and, sometimes, they might be a bridge between patient and therapist. Given that, this phase also included an investigation on therapists and carers, including their functions during rehabilitation process and how they affect and interact with the patient. It was concluded that patients' needs and requirements are influenced by their relation with rehabilitation context and its participants. Likewise, these aspects might influence Us'em mobile app users. It is important, hence, to determinate users' needs and requirements considering, at the same time, their relation with therapists and carers.

Even though this research project focuses on Us'em mobile app and its end-users, it also approaches Us'em system and other relevant individuals involved in rehabilitation process. Us'em system is regarded as a whole system constituted by Us'em devices and Us'em mobile app in which patients, therapists and carers participate. While they are the target of that system, patients are the end-users of Us'em mobile app. This approach was determined based on the reasons presented above.

One important aspect considered in this phase (context and end-users identification) was the context changing. Pervasive and ubiquitous characteristics of mobile technology lead to a constant change on context, settings and scenarios of use and, consequently, different requirements and needs are implied. Hence, it was required to understand what changes between settings and scenarios. In fact, contexts are important not only to get to know users but also to define certain aspects in following stages such as design and evaluation (Sá et al., 2014). Because Us'em mobile app is designed to be used by stroke patients in personal settings, it could be assumed that usage contexts of each user would not vary much. However, this was not concluded since it is not mandatory to use Us'em mobile app always in the same context. Even though, it is considered that the main context of Us'em mobile app is patient's home. Even if all Us'em mobile app users would always use it in the same settings, it will vary, as each user has his personal and specific context. This, in addition to personal needs and conditions of the users of Us'em mobile app, influence their requirements. Despite being a factor of great relevance, it was not possible to study in detail the context of use as it is personal.

9.1.2 Concept Development

The next step was to analyze and to compare the findings from literature review, questionnaires, interviews and observations of the user and context descriptions. It was possible to define and detail Us'em users' requirements, considering its end-users. Then, the mobile application core concepts were defined as well as the ideas of realization. These were put into practice in the next stage (*Product Design*). These issues are presented in Figure 80 in section *User Centered Design* in *Research Methodology* chapter.

9.1.3 Product Design

"*Good design does not needlessly draw attention to itself. It just works. This is the role of good design.*" (Sears & Jacko, 2007, page 331).
The design solutions were created based on disciplines and principles. Some of them are present and described below (Sears & Jacko, 2007).
In addition, based on Shen et al. (2005), the best methods of information visualization, including the understanding of semiotics, iconic design, and aesthetics, including color, spatial layout and composition, typography, navigation and user interaction (user experience) were considered.
In this phase, several prototypes were created. The first ones were low-fidelity prototypes, made of paper sketches and wireframes. Then, they were translated into digital and interactive prototypes – medium-fidelity prototypes. Finally, high-fidelity prototypes were designed using *HTML*, *CSS* and *Javascript*. The prototypes were designed and then shown and tested with this project's coordinators, therapists, and stroke victims during the whole design process to ensure they meet end users' requirements. Each prototype was, thus, designed according to the feedback and tests results of the previous one. All prototypes are described in section *Prototype Design* in chapter *Prototyping* and present in the following appendix: *Summary low- and medium high-fidelity prototypes* and *Summary high fidelity prototypes*. The last designed prototype was tested with more detail during the next phase of the project, *Evaluation*, described next.

9.1.4 Evaluation

The last prototype designed during the *Product Design* phase is the result and final product of this research project (for a better understanding, watch the video demonstration of the final prototype annexed in the CD of this dissertation - *Us-em_mobile_app_demonstration.avi*). This prototype was assessed in the final stage – *Evaluation*. In this process, the group of participants included more potential end-user (8 stroke victims) and 2 Dutch physical therapists This number is very low to generalize the results of the tests. However, it was very important to test with real potential end-users of Us'em mobile app to get the most reliable feedback. The number of participants was justified by the lack of availability of clinical patients. The fact that they have participated only in the final stage had to do with the time needed to contact them and, in the case of the Portuguese participants, because the research was conducted in the Netherlands. In the defined contingency plan, the strategy to face the low number of post stroke victims with upper limb impairments available was test the mobile app with people without these characteristics. However, it was not applicable because the results could lead to wrong conclusions.

Although field and usability tests are a relevant tool to detect usability problems, providing less erroneous results than laboratory test, they were not possible to do (Sá et al., 2014). Us'em mobile app is intended to be used at patients' privet environments. Thus, and also because it was only possible to contact with end-users at 2 rehabilitation centers (Libra Revalidatie & Audiologie (Libra)[171] and at the Professional Rehabilitation Center of Gaia, originally "Centro de Reabilitação Profissional de Gaia" (CRPG)[172] in Portuguese), they were not conducted in this research. Yet, tests took place in a calm and privet room of the these rehabilitation centers with the researcher, the patient and, sometimes, with one or two therapists.

9.2 Usability tests

To test Us'em mobile app final prototype, a cognitive walkthrough methodology[173] was used. This procedure was a mean of reviewing the interface design of Us'em prototype, its usability, and users' experience. In addition, they were relevant to determine the adequacy and effectiveness of the concept and of the design. There was, yet, one of the tests in which the patient started to talk about the options he was doing as well as his thoughts. This was, thus, a thinking aloud test.

The usability tests were designed based on the Usability Software Defect Log by Constantine (document *Usability Software Defect Log (Constantine)* annexed to the CD of this dissertation).

The tests were conducted with post stroke rehabilitation patients, four from the Netherlands (Libra) and three from Portugal (CRPG), and two therapists, from the Netherlands (Libra). It was done by walking through the most typical user tasks and goals, and it did occur in the context of several specific user tasks.

The Us'em mobile app prototype tested in the Netherlands, in Libra clinic, was conducted in English (Figure 76).

---

[171] Libra Revalidatie & Audiologie is a center for specialist rehabilitation care in Eindhoven (the Netherlands) Retrieved September 16, 2014, from http://www.blixembosch.nl/blixembosch

[172] CRPG - Centro de Reabilitação Profissional de Gaia, in Portugal. Retrieved September 16, 2014, from http://www.crpg.pt/sobreNos/Paginas/default.aspx.

[173] a "*usability inspection method that focuses on evaluating a design for ease of learning*" (Wharton et al., 1993, page 1).

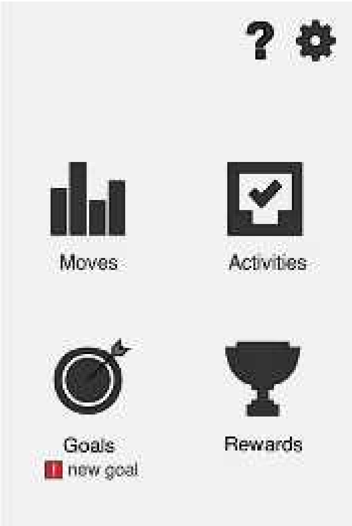


Figure 76: Us’em mobile app prototype in English

50% of the usability tests conducted in the Netherlands comprised the researcher and the patient, while the other 50% included three participants: the researcher, the patient and his/her therapist. The later assumed a relevant role in translating the communication (from English to Dutch) and supporting and guiding the patient. The report of this usability test can be found in the document *Usability Test Libra (results)* annexed to the CD of this dissertation.
In turn, the tests at CRPG, with its clients - Portuguese patients – were conducted in Portuguese (Figure 77).

Figure 77: Us’em app prototype in Portuguese

Hence, and given the conditions of patients, the communication between them and the researcher - tests’ participants – did not require any support from a therapist. Conducting these tests required the consent of the participant (post stroke victim) to ensure legal issues. Hence, before the test, participants were asked to read and sign a document, as

an agreement of their participation in this study. These tests are reported in the document *Usability Test CRPG (results)* annexed to the CD of this dissertation.
The participants' group of all usability tests comprised acute, subacute and chronic post stroke patients[174]. There was no specification concerning the time after the accident given the low number of patients available to participate in the tests.
More information about the evaluation of the various stages of prototyping as well as tests' contributes for design Us'em mobile app are described along the *Prototype Design* chapter.

The evaluation process comprised five main stages: 1) definition of walkthrough inputs; 2) a walking through the action sequence of each task, 3) recording of critical information and 4) analysis of the evaluation findings and 5) the redesign of the interface to fix problems.

As a prerequisite, defining the walkthrough inputs involved the definition of: 1) mobile app users, 2) a detailed description of interface design "in the form of a paper mockup or a working prototype", 3) a task scenario (a description of one or more representative tasks that may be performed with the system and "explicit assumptions about the user population and the context of use) that would be analyzed (see the example of a task scenario in Table 5; for further information see document *Usability Test Tasks* annexed to the CD of this dissertation), and 3) the correct action sequence that is required to successfully perform each task, and its description.

Table 5: example of a task description (walking through method)

2.1 - change time frame in history	Menu Moves History Click time frame button

Defining the users included a description of their characteristics such as technological literacy and impairments. These characteristics have, in fact, the potential to influence their attempts in interacting with the prototype. Being aware and consider these issues enabled a more revealing walkthrough.

The second phase respected to the test itself in which user actions were individually and sequentially considered. After an explanation, test's participants were asked to act in order to perform a certain action and accomplish a goal. It was intended to verify 1) if users can execute the right action, 2) if they notice that the correct action is available and where, 3) and if they will be aware of their progress toward the completion of the task they are trying to execute. It is important to mention that the walkthrough tests were different due to its participants. Tests with therapists were conducted with no special consideration. But those conducted with patients addressed a particular attention due to their cognitive

[174] There are three different categories of stroke patients according to the time after the accident (A. Timmermans, 2010): 1) Acute: patients who had experience a stroke accident until thirty days ago; 2) Subacute: those who did experience the accident between thirty days to six months; and 3) Chronic: those who did suffer a stroke more than six months ago.

problems and/or lack or low level of technological literacy. These facts were relevant to define which tasks were evaluated, in which order and how they should be described. For instance, in tests with participants with more cognitive impairments or lower technology literacy the tasks that require a combination with others were not evaluated. In general, tests with patients comprised the core (basic) functionalities of the mobile app. While evaluating, participants' actions and intentions were recorded using paper-based forms.

The next stage included analytical work of information gathered previously. A detailed analysis of each action of every task did occur, including positive and negative aspects. Data describing negative aspects could mean the need of redesign the interface in order to fix problems. An example a walkthrough of one action performed in this prototype test can be seen in document *Usability Test CRPG (results)* annexed to the CD of this dissertation.

9.3 Interviews

Interviews with post stroke rehabilitation therapists, physical rehabilitation researcher and patients from the Netherlands

This section presents and describes the interviews conducted with post stroke rehabilitation therapists from the Netherlands, with a physical rehabilitation researcher and post stroke rehabilitation patients. Interviews' goals, procedures, participants, script and analysis are here detailed.

9.3.1 Interviews' goals

The interviews conducted were based on an exploratory in nature approach. The reasons for that was because the researcher had no deep and detailed knowledge about the research topic (Quivy & Campenhoudt, 2005). Exploratory interviews aimed to gather relevant information that was not provided through the literature review. It was possible, thus, to complement the information already collected. In addition, interviews were used to contact with the reality of the study participants. Interviews with post stroke rehabilitation therapists, in particular physical therapists, with a physical rehabilitation researcher and with a post stroke victim, Jamel van Dam, were conducted.

Interviews with post stroke rehabilitation therapists (physical therapists)

With regard to the interviews carried out with physical therapists, it was purposed to:

- know the Dutch reality in post stroke rehabilitation;
- know the relationship between therapists and patients during clinical therapy sessions and after it;
- get therapists' perspectives about Us'em system, its mobile app and potential patients' requirements in using it;
- obtain feedback on graphic elements designed to Us'em mobile app prototype.

Interviews physical rehabilitation researcher

The purpose to interview the physical rehabilitation researcher was to have another point of view and to collect scientific data. Its goals were to:

- understand therapy and rehabilitation process methodologies in clinical settings;
- get more information about post stroke rehabilitation patients in order to complement the literature research made previously and, thus, characterize these patients with more detail;
- gain knowledge about post stroke rehabilitation patients' needs and requirements during their rehabilitation and when using technology in their recovery process;
- verify the adequacy of Us'em mobile app features (to know if they would meet patients' needs, bearing in mind a therapy session in privet settings)
- verify the adequacy of UI design elements of the Us'em mobile app prototype designed.

Interviews with a post stroke victim, Jamel van Dam

The interview with Jamel aimed at collecting data related to his condition as a post stroke victim and, given his cooperation in previous Us'em projects, his experience and feelings about Us'em system, including Us'em mobile app. In particular, these interview's goals were defined as:

- understand the consequences of his stroke, including physical and cognitive impairments;
- know the changes in his life due to the stroke event;
- know his rehabilitation process procedures and his needs after discharge from clinical settings, in particular at home;
- understand his feelings about the system as well as his requirements in using it;
- understand his experience with Us'em mobile app;
- understand which aspects of Us'em mobile app should be changed and which should be maintained from this participant point of view.

Apart from Jamel, it was possible to gather more data through other patients. This data collection had occurred during therapy sessions: patients were asked some questions, with the help of the present physical therapist. This was only possible in some sessions because of context settings such as noise and number of people present, patient's characteristics and therapy session characteristics. However, the collection of this data cannot be considered interviews. To be an interview, it should, among other aspects, take place in a proper context and the interviewed should be informed about interview duration. It was not possible to interview post stroke patients from Libra neither from CRPG due to patients unavailability and with ethical matters.

9.3.2 The interviewees (post stroke physical rehabilitation therapists)

Interviewing the entire universe of post stroke rehabilitation therapists was impossible as it involves a high number of individuals. Hence, only some individuals of the universe were selected and interviewed (M. M. Ferreira & Carmo, 2008; Blaxter et al., 2010). Given the lack of a sampling frame for the population of this study, and so the impossibility to use a probabilistic[175] method to select the interviewees, a non-probabilistic approach was used. With this method, the individuals have different chances to be selected (Blaxter et al., 2010). For that reason, the sample may not represent adequately the universe of therapists, reason why a careful analysis during this research was required (M. M. Ferreira & Carmo, 2008). In particular, the non-probabilistic approach that was used was a convenience sample method: sampling the most convenient (available) participants (Blaxter et al., 2010). Interviewees were invited to collaborate in this study via email. In the end of this process there was, thus, a sample of post stroke rehabilitation therapists that was, then, interviewed.

To select the interviewees, two rehabilitation clinics in Eindhoven were contacted: Libra and Adelante. Both did agree to cooperate in this research project. Regarding to Libra clinic, there were two physical therapists available to be interviewed - Marielle Timmermans and Roy van der Meer -, while from Adelante it was only possible to interview a physical rehabilitation researcher. These individuals were, thus, the sample of the interviews.

As mentioned before, other interview was conducted with Jamel van Dam. He experienced a stroke accident in September 2012. Consequently, he gained physical and cognitive impairments, including speech and left arm-hand impairments. As Jamel is right-handed, he could still perform several daily activities. He started his rehabilitation process with physical therapy but, at the time of the interview, he was just attending to psychological therapy sessions. Jamel has participated in the previous Us'em project (Robert's[176] work), thus he was already aware of Us'em system and he had tested the mobile app of the previous project.

9.3.3 Interviews' *procedures*

Interviews are a powerful tool to gather rich data on participants' "*views, attitudes and the meanings that underpin their lives and behaviours*" (Gray, 2009).

In this research, exploratory interviews were conducted. They did not aim to verify pre-specified hypothesis, but to find new issues, ideas and hypothesis for consideration (Quivy & Campenhoudt, 2005). Its purpose was to find out new ways to tackle the research problem instead of test the research ideas validity. As they were little directed, the researcher (interviewer) had a high level of freedom. The interviewer's role was to pose non-specific questions, listen to interviewees' responses, pose new questions and take notes. In addition, during the interview with Jamel it was also necessary to consider his characteristics and pay attention to his behaviors as well as to keep the conversation informal. Thus, it was a complex process.

In order to safeguard the quality of the collected data, interviews were prepared taking in consideration and defining 1) with who is relevant to do the interview, 2) what does the interview consist of and 3) how to explore the interviews to make them enable to breakout preconceptions and preconceived notions. In addition, based on Quivy & Campenhoudt's principles, there was a particular preparation of the researcher as an interviewer. It was

[175] Probabilistic methods are based on random sampling. Hence, the individuals of the group of interest have an equal chance to be selected (Blaxter et al., 2010).

[176] Robert is the author of one of Us'em research projects. This project is described in Vliet (2013).

considered that 1) he should make the fewer number of questions as possible, 2) his interventions should be as open as possible, enabling the interviewee responding in his own language and with his personal concepts and ideas, and 3) he should not discuss ideas with the interviewee. Moreover, it was defined that the interview should occur in a proper context.

Furthermore, before the interviews, issues and questions that were intent to be covered were listed and arranged to pre-define a potential flow of the interview - semi-structured[177] interviews. As a result, it was designed an interview guide (see document *Interviews-Libra Therapists (guide)* annexed to the CD of this dissertation). Even though, it was known that, certainly, the interview direction and the order of its questions would change and additional questions would be made as new issues would arise along the interview. For instance, interviewees did expand their answers and added new relevant topics that, in some cases, made the interview diverse in a new pathway that, before the interview, was not considered. Yet, interviews took other direction only when the researcher considered that the new issues would add value to the research towards meeting its objectives. This method of interviewing was used given the uncertainty of the interview's conditions, such as therapists' availability, and the possibility of new information arise during the interview.

After the interviews, its notes were summarized and transcribed to a new document, organized in accordance with interview's topics and questions and, then, carefully analyzed.

Although interviews are considered more as qualitative research technique, in this research they were conduct as a means of qualitative and quantitative data collection (Blaxter et al., 2010). The information gathered through this method was both quantitative – patients' age, number of session's exercises, number of times that patients give up to perform the exercises, etc. - and qualitative – patients' stroke consequences, therapy exercises, interaction between therapists and patients.

From a technical perspective, interviews should also be recorded or documented by note-taking or tape-recording (Quivy & Campenhoudt, 2005; Gray, 2009). However, due to ethical and privacy issues it was only possible to document them using a note-taking method.

Interviews with therapists

The guide of the interviews conducted with therapists (see document *Interviews-Libra Therapists (guide)* annexed to the CD of this dissertation) was designed based on the intended goals. Its questions were divided in two groups: one related to rehabilitation at a Dutch clinic and another one with regard to Us'em system. The first set of questions had the purpose to understand how clinical rehabilitation in the Netherlands, in particular at Libra, occurs, including: 1) its goals, 2) what is done at each stage, 3) how and who is involved in this process, 4) how do post stroke rehabilitation patients physical therapy and its session occur, in particular that of post stroke rehabilitation patients with upper limbs impairments, 5) what does motivate patients and 6) if patients are encouraged to train on recovery exercises at home. The second group of questions intended to understand

[177] These method that enables having detailed responses as the interviewees are asked to clarify what they say (Gray, 2009).

therapists' feelings and opinions about Us'em system, in particular its mobile app, and to gather information about potential needs of patients while using Us'em system.
Overall, these interviews aimed to identify and characterize the potential contexts and ways of use and interaction of Us'em mobile app by patients, and the broad of their requirements bearing in mind the diversity of post stroke rehabilitation patients' characteristics.
The interviews were conducted in three phases. In the first one, interviewees were informed about the project and its research goals, including the previous and the intended Us'em mobile app. Then, they were informed about interview's purpose, type, steps and estimated time. In addition, considering Gray (2009), the interviewer explained who the formation would be for, why it was being collected and how it would be used. In addition, the interviewees were asked to give permission to use and transcript interview's information in this research project. It was a mean of their informed consent, a "*key ethical consideration*" (Gray, 2009, page 393).
In the second phase, the data collection, therapists were asked the questions pre-defined in the interview guide. During this stage, it was sought to make interviewees comfortable and have a natural speaking, without being interrupted.
Lastly, the therapists were provided by graphic elements designed to Us'em mobile app prototype and asked to give their opinion. These graphics respected to the information related with goals, real time moves and patient's moves history in the mobile app. Thus, it was possible to find out which were the best approaches to represent this data bearing in mind potential patient's cognitive problems.
To close the interview, it was checked if all the intended questions were done and if all the respondents, the therapists, had any question or comment to make. In addition, a thanks was given to the interviewees for participating in the study.
With respect to this interviews conducted with Libra therapists, the contacting process was time-consuming and interviews were conducted later than it was expected at the research planning.
The outcomes of these interviews are described in the appendix *Interviews-Libra Therapists (results)*.

Interviews with Jamel

Jamel's interview had occurred informally in public space on 27th of March 2014. As an interview, it was modeled on a face-to-face and open-ended conversation between Jamel and the researcher, who aimed to collect data and to "*facilitate the subject talking at length*" (Blaxter et al., 2010). The intention of this informality was to make Jamel feel comfortable, without putting any pressure on him, considering that, for some stroke victims, talking about stroke events and its consequences may be difficult. Particular attention in carrying out the interview was given to potential sensitive questions such as those related to Jamel's impairments and life changes after the stroke. In addition, this interview comprised questioning and discussion, which was, in some parts of the interview, prompted by the use of images and graphics of some UI design elements designed to the Us'em mobile app prototype.
As Jamel did already experience an Us'em mobile app prototype from a previous project, it was not necessary to provide him a detailed explanation about it or about Us'em system. Yet, a brief review of the project was given to him, so he could remember better

the project and its purposes. Because the interviewer did not know Jamel and how we could react in certain circumstances and to keep the meeting informal, Jamel was not provided with an explanation about interview's details as it was done with the therapists. Instead, he has received a short explanation about how the meeting would occur, including its purpose and estimated time. In addition, he was also informed about why the information was being collected and asked about his permission to use it in this dissertation.

It was a normal conversation about five main topics: 1) Life changes after stroke, 2) Rehabilitation services, 3) Self-Rehabilitation, 4) Family support and 5) Us'em system.

In addition, graphic charts were presented and discussed with Jamel to find out the best approaches to represent the information bearing in mind potential patient's cognitive problems. These charts represented data related with goals, real time moves and patient's moves history in the mobile app. At the end of the interview, it was ensured that all the intended questions were made and that Jamel had no questions or comments to give. He expressed interest in cooperating and participating more in this research project. To close the interview, thanks was given to Jamel for participating in the interview.

This interview and its outcomes are reported in the document *Interview with Jamel (results)* annexed to the CD of this dissertation, but a short summary of the findings gathered through it is presented below.

In this interview, Jamel did mention that when testing Us'em system under the procedure of the previous project he had forgotten he was using Us'em devices. Because of that, he was using Us'em mobile app only at the end of the day to check his moves data. Regarding to the previous mobile app, he stated that the graphic bars representing his moves ratio were not clear, so he required an explanation before his first interaction with the mobile app.

When asked about potential Us'em mobile app improvements, Jamel pointed out simplicity and clarity: "*Keep it as simple as possible*! (…) It does not need to be fancy".

He also said it would be relevant to set goals and make the mobile app remember users about them. For him, it would be beneficial to use Us'em mobile app through other devices, such as a computer or a tablet. His opinion was justified by the bigger screens these devices have that, in turn, enables better data visualization and interaction.

In also added that a connection to social media networks (such as Facebook or Twitter) and the provision of information about stroke or rehabilitation should be avoided or configurable. "*If I will need that information, I will just use the internet or I will wait for the next appointment with my therapist*".

9.4 Questionnaires

This section presents and describes the questionnaires conducted with post stroke rehabilitation therapists from Portugal, its goals, procedures, participants, script and analysis.

9.4.1 Questionnaires' *goals*

One of this research study's goals was to compare some facts between the Netherlands and Portugal. Thus, it was necessary to collect data from both countries. Because that stage occurred during the stay at TU/e, in the Netherlands, interviews or direct observation were unachievable. The solution was to use a questionnaire in order to gather information about Portugal. Hence, it was directed to Portuguese clinical therapists with the purpose to get to know the reality of post stroke rehabilitation in Portugal from its therapists' point of view. Because of the same reason, the most appropriate way to conduct this questionnaire was via internet. The use of a questionnaire is also justified by its low costs in terms of time and money, its quick and from many individuals inflow, its questions can be coded quickly and is relatively simple to analyze the collected data (M. M. Ferreira & Carmo, 2008; Gray, 2009). From the point of view of the respondents, questionnaires may be done at a convenient place and time and its anonymity can be assured. However, bearing in mind potential drawbacks of a questionnaire such as low return rates, referred by Gray (2009), and possibly poorer answers as there is no one to help the respondents, referred by M. M. Ferreira & Carmo (2008), they were designed as shorter as possible with proper terms related to rehabilitation field. To ensure that, before the administration of the questionnaires, they were validated, as is described later in this section. At the end, three Portuguese therapists answered the questionnaire, as it is presented later in this section.
Although questionnaires might be seen as a strategy of quantitative research method on first consideration, in this study they did intend collecting qualitative data (Blaxter et al., 2010). The questionnaire included a set of questions aiming to gauge the more frequent Portuguese stroke victims' characteristics, such as age and gender, their impairments and consequent needs and requirements during the recovery process. It was also intended to use this questionnaire to gather information about the clinical rehabilitation therapy methodologies and the relationship between therapists and patients in Portugal. In addition, although therapists were provided with an explanation of Us'em system, they were asked to provide their opinion about it and its potential benefits for post stroke arm-hand self-rehabilitation.

9.4.2 Questionnaires sample

Just like the interviews, the questionnaire respondents were sampled through convenience, a non-probabilistic sampling method. It is known that this method do not enable generalizing the results and representing the population (M. M. Ferreira & Carmo, 2008). But, despite being the only method to reach Portuguese therapists, it was used to define the main characteristics of the group of the study and to gather relevant information. This method was justified by the restricted access to only a few therapists. Indeed, CRPG was the only Portuguese rehabilitation clinic that was contacted to collaborate in this study. In addition, because not all the therapists were available to participate in this study, only a few of that population were selected, by convenience. In fact, the sample comprised three physical therapists.

9.4.3 Questionnaires design procedures

The design of the questionnaires used in this research project was based on its purposes and it is detailed in this section.

Questionnaires construction

Questionnaires were constructed with a web tool by Google: Google Forms.

As web-based questionnaires, they had the advantage of offering facilities for its design "*that are not available in traditional, paper-based formats*" (Gray, 2009). They had drop-down menus, a status bar to inform the respondent how much the questionnaire was completed and a simple design.

The questionnaire comprised three main parts: 1) the introduction, 2) a set of numbering questions and 3) the acknowledgments.

The introduction comprised a presentation of: 1) the researcher, the research project for which the questionnaires were intended as well as its research goals, 2) the questionnaires' purpose, 3) the estimated time for completion of the questionnaire, and 4) who the formation would be for, why it was being collected and how it would be used. Still in this part, the questionnaires participants were informed the questionnaires could be anonymous, that they have no deadline to fill them and, finally, they were invited to fill the questionnaire. As this introductory text on the first screen could be long for some respondents, there was a skip button in that screen.

The second part of the questionnaire included 19 questions: 16 closed and three open questions. Closed questions offered a predefined set of responses, restricting the respondent's response, requiring less time to be answered and leading to a future easier response's analysis (Gray, 2009). In this research's questionnaires, the options available on each question were based on previous data collections. Based on Gray (2009) and Blaxter et al. (2010), these predefined option were of different structure:

- List questions – respondent can select any response from a list;
- Ranking questions – respondent has to rank his replies in order and
- Category - respondent can select a category.

In addition to the predefined set of responses, and bearing in mind this restrict approach, it was added the option of "Other (please specify)", in Portuguese "Outro (indique qual):" in some questions. That enabled the respondent to provide information either to supplement his response using the predefined options, if he was not sure about which option(s) he wanted to choose, or to add an option that was not exposed. These aspects are the reason why closed questions were in the majority.

In contrast to closed questions, open questions do not offer a range of possible answers (Gray, 2009). Respondents may answer without a definite reply and, so, to answer in their own words. Given that, questionnaires were designed in order to provide its respondents enough space to answer: the space appropriate to write them could increase according to the text, ensuring they have the space they need. In addition, and because respondents could write want they want, these questions enabled collecting rich responses that the researcher did not have thought before. Due to the same fact, these responses required a more detailed analysis.

Furthermore, the respondents were informed when the questionnaire did end and asked to submit it. This could be important if, for instance, the respondent wanted to review his responses. Once submitted, there was no chance to edit them.

Validation and submission of the Questionnaires

Piloting the questionnaires is a very important process in different stages of its construction before to carry them out (Gray, 2009). In doing that, the researcher may receive feedback and, in the light of it, it might be need to modify it (Blaxter et al., 2010). Hence, it was aimed to sample potential respondents and ask them to fill the questionnaire. However, due to lack of access to therapists and time constraints, it was not done.

To face this situation, a primary version of the questionnaire was internally validated, by this dissertation supervisors that reviewed the questionnaire, identifying few flaws and suggesting modifications. The first validation provided feedback mainly about the understanding of the questions and general aspects such as the length of the questionnaire. In turn, the second test was relevant to improve the questionnaire with regard to the use of proper and context-based terms. From these iterations, a final version of the questionnaire was constructed in a digital text document (see this document, in Portuguese, in document *Questionnaires Portuguese Therapists (model-PT)* annexed to the CD of this dissertation). Then, it was translated to a digital version, put online (using Google forms) and disseminated to the audience.

After that, CRPG was contacted to spread the questionnaires among its therapists. To that, an email with the link of the online questionnaire was sent to this clinic. Given these circumstances, respondents' identity is not known. This contact generated few responses: three. Hence, in an attempt to get more responses, the period during which questionnaires were available for filling was extended: from 08-04-2014 to 14-07-2014.

As the questionnaires were sending only to rehabilitation physical therapists of post stroke patients and there was any more specification to select them, it was no necessary to characterize the participants. Thus, questionnaires did not have any question with respect to that information.

Questionnaires analysis

The results of these questionnaires can be found in the document *Questionnaires Portuguese Therapists (results)*, annexed to the CD of this dissertation. For a better understanding, they were reported in English.

The most relevant issues gathered through them were as follows:

- In average, Portuguese patients are aged between 25 and 45 years old and most of them are man;
- Mostly, in the beginning, patients want to recover a specific arm-hand function and during their rehabilitation they want to train after the clinical meeting;
- Portuguese patients become more motivated when they know the evolution of their recovery process, and when they practice exercises related to daily activities;
- Some therapists do interact with their patients online in consultation;
- Patients' recovery is evaluated through their rehabilitation progress in terms of autonomy when executing specific tasks;

- The inability to perform an exercise discourages patients. They are encouraged when therapists know they are able to do it;
- Therapists assure patients train out of the clinic through communication and confidence. To support them in doing that, patients are visited at their home by their therapists, are provided with information by phone calls and by paper format;
- The autonomy of patients in their rehabilitation process varies;
- Using technology to support self-rehabilitation of these patients is valuable but it requires support and monitor the patients; and
- It is important to consider stroke consequences that do not enable patients to use technology.

9.5 Observation

This section presents and describes the observations that occurred in this research project - Observation of post stroke rehabilitation sessions and patients in the Netherlands. Its goals, participants, procedures and analysis are detailed next.

9.5.1 Observation goals

The field observations were conducted in rehabilitation clinics (Libra and Adelante), a relevant setting to this study. They had occurred during individual and in group therapy sessions of post stroke rehabilitation with arm-hand and other impairments, by the presence of a physical therapist. The specificity of post stroke rehabilitation patients has to do with research goals which consider, in particular, patients with that sort of impairments.

These observations had the purpose to understand clinical rehabilitation context in a most deeply and detail way, including:

- Post stroke rehabilitation practices and methodologies,
- Environmental facts and events,
- Patient-therapist relationship during therapy sessions at the clinic,
- Patients' performance on therapy exercises,
- Patients' feelings about their therapy and training sessions and exercises,
- Patients' point of view on Us'em system.

Overall, it was aimed to study post stroke rehabilitation patients and therapists in the natural rehabilitation field, which is associated with ethnographic methodologies[178] (Gray, 2009).

Observations enabled qualitative data gathering which, in turn, provided an understanding of the meanings and interpretations of those who were observed. In doing that, the researcher was present during the observations, becoming part of the observed group. In that way, the researcher could experience and better understand the situation she was observing, learning that symbolic world. In addition, she could report her experience in the

[178] Ethnographic methodologies study people in their natural settings or 'fields' (Gray, 2009).

field, including her feelings and fears. This research immersion in the research setting means that it was a participant observation. Because of that, the observed individuals were aware of his presence and of the observation, which makes it an overt observation[179].

9.5.2 Observation participants and context

The observations participants included post stroke rehabilitation patients, physical therapists from both Libra and Adelante clinics and the researcher.
All participants were, again, sampling with a non-probabilistic method – sampling by convenience. Although this method does not enable generalizing the results, as mentioned before in the sections of the other data collection methods, it was the only way to select the participants and to understand the main characteristics of this group. Jus as the access to the participants of the questionnaires, the access to observation's participants was restricted. The reason of this fact are that only two clinics – Libra and Adelante – were contacted and only two therapists and their respective patients were available to participate.

Observations at Libra
Each observation at Libra comprised one patient, one therapist and the researcher.
The researcher was part of the observation – participant observation. This method enables an interpretation of a meaning and a collection of more detailed data. For instance, it is possible to assess people's action, as it enables "*to get beyond their opinion and self-interpretation* of their attitude and behaviors" (Gray, 2009). However, it also addresses drawbacks. On the one hand, the researcher may affect the observations' results in the way that his mental constructs may influence his interpretation of the facts he observes. It means that the researcher will interpret in her own way, seeing what he wants to see, disregarding relevant information. On the other hand, as she is part of the observation and is among or close to the individuals who are being observed, she may influence the observed facts and events. As Blaxter et al. (2010) mentioned "*How people see and understand their surroundings will no doubt play a part in the ways in which they behave, they act and interact with others, and in the ways their actions are perceived by others*" (page 177). In this case, both therapist and patient were aware of the researcher presence, so their actions can have been modified.
Individual therapy sessions were observed, with the permission of both therapists and patients, in calm and privet contexts. In this way, the observer could focus and observe in detail the participants and events. Some participants of these observations were aged 25-45, but most of them were older than 45 years old. Besides, in some observations, with a help of the present therapist and without affecting the session, it was possible to ask some questions to patients. In these cases, it was used the group of questions, predefined before the observations.
In Libra, it was also possible to observe a group therapy session (4 people) of patients with arm-hand impairments who were under the supervision of a therapist. As the patients

[179] "Overt observation is where those being observed are aware that the observation is taking place" (Gray, 2009)

were used to do the therapy, the therapist did not need to provide any information or explanation. Because it did occur in a privet room, there was a very calm environment. In this case, the participants were aged 65 to 75.
Regarding the sample, a selection of patients with arm-hand problems was not done because it was aimed to have an overview of rehabilitation therapy process and there were not enough patients with those impairments available.

Observations at Adelante
The observations at Adelante occurred differently. The research did not take part of the observation due to privacy (of patients) issues and not to disturb the rehabilitation sessions. Only patients and therapists were part of the observation. Thus, they were not aware that they were being observed. The researcher was accompanied by a clinical researcher who gave him the permission to observe and take notes of physical therapy sessions.
These sessions were taking place in the same room. It was a shared area where individual therapy sessions were being conducted. Patients were mainly aged over 50-years-old. The context of these observations was a room where several privet therapy sessions were taking place. From the same point, sometimes a bit far, each therapy was observed during a couple of minutes. Hence, it was not possible to observe neither all the process nor its details. Thus, because the researcher was not a participant, she could not observe with the same detail as it was done at Libra, so the data collected was poorer.
The information gathered through the observations was both quantitative – patients' age, number of session's exercises, number of times that patients give up to perform the exercises, etc. - and qualitative – patients' stroke consequences, therapy exercises, interaction between therapists and patients. Just as interviews and questionnaires, observations were relevant to add more information to the analysis model.

9.5.3 Observation procedures

At both Libra and Adelante clinics, as procedures in observations matters, there were three main stages: 1) before the observation, 2) the observation itself and 3) after the observation.

Before the observation
Observations may be very time consuming either during the observation itself or after that, when data is interpreted and analyzed (Blaxter et al., 2010). As Gray mentioned, "*Observation is not simply a question of looking at something and then notin*g down 'the facts'. Observation is a complex combination of sensation (sight, sound, touch, smell and *even taste) and perception*." (Gray, 2009, page 396). Given that, preparing the observation was important to obtain good results. It included preparation of the observer (the researcher), observations permissions and recording data tools.
Observation involves watching and listening attentively, feeling and perceive what is happening, which poses a challenge to the observer. Hence, it is important to prepare him. That included:

- understanding clearly observation's purposes;
- defining what was important to record;

- reading and knowing observation guide;
- knowing the main characteristics of observation's participants.

In addition, as the observer was the researcher of this study, she already had the knowledge of the main and relevant topics that were on the basis of the observations.

The use of observation research method may raise ethical concerns (Blaxter et al., 2010). This is because the researcher is much closer to the subjects and for longer periods than in other approaches. Thus, gaining informed consent is considered a good practice in the use of this collect data method. These facts were considered at the beginning of the observation in both clinics and permission to do the observations was asked. It was not necessary to do it formally. At Libra, patients were asked about their consent by their therapist who was present during the observation. At Adelante, the clinic researcher who did accompany this project's researcher gave the permission to observe the therapy sessions and to take notes. In doing that, in both cases, a brief explanation about research purpose, observation goals and procedures, and information about how data collected through the observation would be used was provided.

As a mean of recording observations, a guide and field notes were prepared and used, both with an open-ended format aiming at recording both expected and unexpected information. Any devices such as a camera or a video recorder were not used, mainly, due to ethical reasons. Other reason of that was to not disturb or influence the context, enabling capture the natural environment and process of therapy sessions and patients-therapists interactions.

The observation guide is a document designed and used as a collecting data tool (see document *Observations Guide* annexed to the CD of this dissertation). Even though a more structured guide helps to register observations, it will be more difficult to "*record variations or unexpected occurrences*" (Taylor-Powell & Steele, 1996). Hence, and because the observer was aware that unplanned events could occur, the guide was not structured in detail. It did comprise a list of important actions and events that should be observed and collected and a form to record the observations. In addition, a set of questions to therapists and patients was prepared, considering the chance to inquire them during the observation. That was done based on literature review of stroke rehabilitation topics. The goal of these questions was collecting information about patients' feelings about their therapy and training as well their point of view on the use of Us'em system. This was important to gather more information from the point of view of post stroke victims, as there was only one patient available to be interviewed. Interviews to patients at the clinics were not possible due to ethical issues and patients' availability.

Field notes were used to record relevant information in a narrative and descriptive style (Taylor-Powell & Steele, 1996). These do not require any predefined recording form because they are used to recording events that might not be considered in advance. Most of the times, due to time constraints, they were brief notes. Later, together with mental notes, more descriptive notes were written.

The observation itself

This phase comprised two steps that occurred at the same time: 1) observation and viewing people's actions and events of interest, and 2) data recording.

Data recording is an ongoing process since the beginning of the observation. Because of that, the researcher may "*interact with data, to expose gaps in knowledge and identify* *where further investigation is required*" (Gray, 2009, page 418). Several facts were observed and its results were written up as field notes. These notes constitute the beliefs of the researcher as a fieldworker and observer and are essential to have a successful work. They are "*the backbones of collecting and analyzing field data*", according to Bailey (1996) (as cited in Gray, 2009, page 402).

In this study's observations, field notes were related to the following topics:

- Context of the study;
- Participants' characteristics;
- The activities took place;
- Significant events that occurred,
- Participants' perspectives and meanings.

The negative aspect of field notes has to do with the probability of the researcher does not write down a certain event, believing that it will occur later (Gray, 2009). If it will not happen, that information may be not collected which may affect the study. In fact, during an observation it should be noted down as much data as possible. Hence, before the observations of this study it was decided that during its occurrence every event and observer's feelings should be written, even if, at that time, the researcher would not take it as relevant data. In addition, the researcher captured notes mentally with which it was possible to complement and to make more comprehensive the field notes.

After the observation

The last stage of the observations consisted in data analysis and interpretation of people's behavior. Gathered field notes were rewritten and organized to make data collected clear and summed to data recorded through the observation guide. In addition, researcher's mental notes were added to it to complement the information. Next, a report was elaborated summarizing the observations' procedures and findings. This document was elaborated with respect to observations at Libra and at Adelante *(*documents *Observations Libra (results)* and *Observations Adelante (results)*, respectively, annexed to the CD of this dissertation*).*

At the end, observations' findings enabled to complement data that was gathered up to that time. They were a very relevant contribution to a better understanding about stroke rehabilitation process, its participants and, in particular, about their needs with respect to Us'em mobile app.

Analyzing data gathered from observations requires special attention with respect to data validity. That data may be insufficiently "*objective to represent a true reflection of events*" (Gray, 2009, page 416). The analysis of the information collected through observation took in consideration that that information might be not a true reflection of the reality. Other reason why observation's findings cannot be generalized is because the researcher did not stay "*in the field long enough to observe or experience the full range of routines that typify the case*" (Gray, 2009).

The observations enabled collecting relevant information such as follows:

- physical therapist plays an important role in therapy sessions;
- they know patients' needs, exercises they must do and how to do them;

- they give exercises instructions, real time feedback regarding to exercise performance, encouraging them and they may adapt the training at any time during the session;
- patients did show that performing some exercises can be a tough task. These were less motivated and they did require more support and incentives from the therapist;
- using technology in rehabilitation requires consideration of both patients and therapists;
- features of Us'em mobile app should be organized in terms of level of difficulty to enable a proper customization to each patient;
- rewarding and make patients know they improved is important;
- technological systems and devices should be used to set and use;
- the adequacy of the graphic elements of Us'em UI depends on each patient.

After the observation and its analysis, a reflection (documents *Observations Libra (results)* and *Observations Adelante (results)*, annexed to the CD of this dissertation) about the directions defined during the brainstorm was done: it was concluded that therapists and their relevant role during patients' rehabilitation should be more considered. For instance, patients' goals need to be set by therapists because patients, sometimes, are not aware about what are the feasible goals or achievements.

9.6 Synthesis

This chapter presented and detailed the design, implementation and evaluation processes of the data collection methods used in this research project. Interviews, questionnaires and observations were used. Interviews and observations had occurred in the Libra and Adelante rehabilitation clinics, in the Netherlands. Questionnaires, in turn, were conducted via the internet as a means of collecting information about the Portuguese rehabilitation system.

10. Prototyping

Us'em system comprises different components, but this research's purpose is improving Us'em mobile app UI (Figure 78). Still, it was necessary to work on the other system's components.

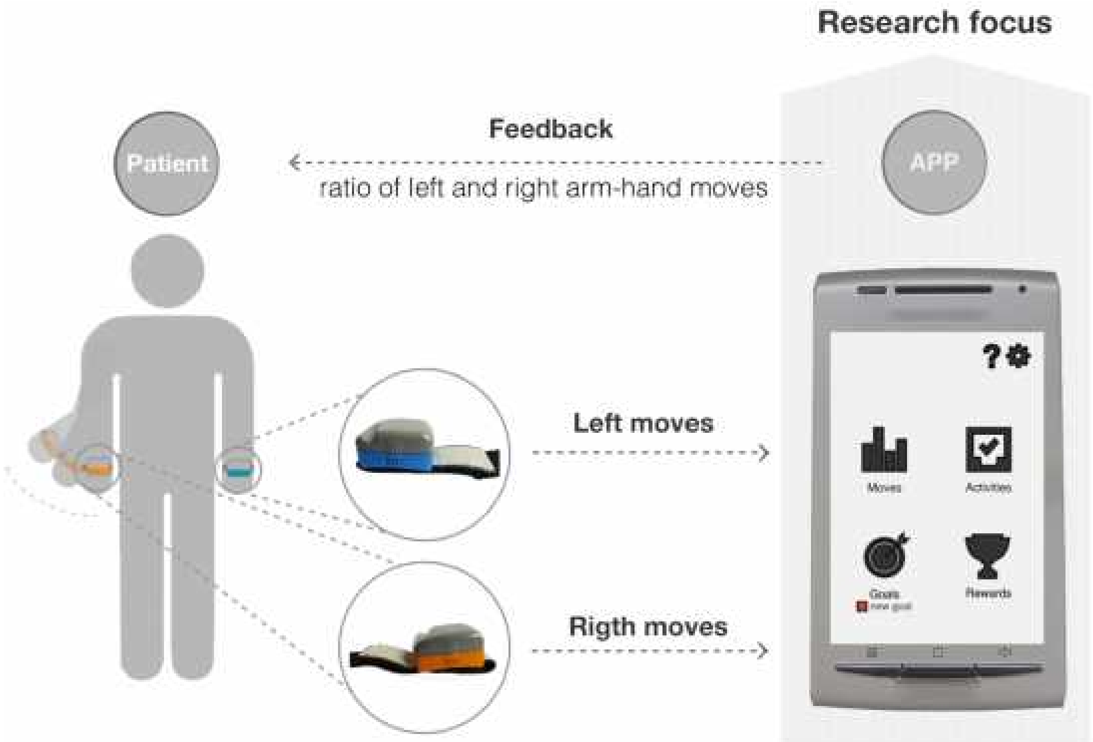


Figure 78: Us'em system and the research focus[180]

This section presents the prototyping stage of this project.
First, *Technical issues* as well as *Requirements and features* of Us'em mobile app are presented for a detailed understanding of the prototype designed. Next, the prototyping process is described in detail. It presents each stage of low-, medium- and high-fidelity prototypes, including developments, tests and evaluation. Finally, there is a subsection for a final discussion and conclusions.

Us'em is a passive system, as it does not have any means to actively move patient's limbs or stimulate his muscles (Willmann et al., 2007). Hence, it is assumed that only stroke patients who are already able to move their affected limb without extra support can use this system.
Moreover, it is of great relevance to mention that Us'em system is designed to support upper limbs rehabilitation after stroke but it cannot replace rehabilitation professional treatment.

[180] Figure 78 was designed by the researcher of this project.

10.1 Technical issues

Although this research project focus on Us'em mobile app and aims its improvement, it requires an understanding about Us'em system and its functionalities, described in detail in Us'em *system* in chapter *State of Art*.

It was necessary to study how Us'em wearable devices work as well as the connection between them and the mobile app. This was a time-consuming process as it required a detailed study of Robert's project in order to learn the technical issues of Us'em, learning about *Android* mobile apps and a new programming language – Java.

Furthermore, before starting the redesign process, it was necessary to assure Us'em devices were working properly, sending real values to Us'em mobile app. At the beginning, both devices were working correctly. However, after some experiments, there were some problems. Sometimes devices' batteries were exhausted, other times the problem was about chips' references in Java code of the mobile app. In fact, to work correctly, he devices are required to be connected to the Us'em mobile app through a reference code. Thus, Us'em mobile app's code only makes possible to connect it with a specific set of two devices.

Given the lack of knowledge in developing *Android* mobile apps, the solution found was to develop a mobile web app based on Java's *webview* - an *Android* component that displays web pages. This enables transferring data between both *Java* and *Web page* parts. Us'em devices data can, thus, be displayed in the UI, although the final prototype does not use that information. Implementing this strategy required a detailed study about this *Android* feature and how it could be implemented. It is important to mention the help given by Robert, the author of the previous Us'em project, and Nikos Batalas, a PhD student with strong programming skills, that made this process easier.

The *Android* software development kit, in combination with the eclipse IDE (to program in Java), were used. The platform used for the application app was *Android* 2.1, the same run by the smartphone used in this project, the Sony Xperia X8.

The restrictions of the *Android* version (2.1) imposed a challenge in implementing certain features. After 2.1 version there were more 6 A*ndroid* updates, being the most recent version the 5.0 (Lollipop)[181]. So, simple functionalities implemented in current *Android* smartphones are not supported by version 2.1. It was required, thus, to search and confirm which features could be implemented. However, sometimes, because the mobile app was developed in a web browser on a computer, it was only possible to verify it after implementing that feature and checking it when running the mobile app on the smartphone. Some functions were working correctly on the web browser but not in the smartphone. Thus, it was required using a different method to develop the same feature, which was a time-consuming process.

10.2 Requirements and features

This subsection presents the requirements and features, as well as the details of Us'em mobile app UI designed in this research project.

[181] Source: http://www.android.com/versions/lollipop-5-0/

10.2.1 Requirements

Us'em *system*

Us'em mobile app is the focus of this dissertation, but it was also required to definite Us'em system as a whole. Its components and stakeholders influence and are relevant to determine Us'em mobile app features and UI design.

Thus, theoretically, Us'em system was defined with five main components (Figure 79): 1) Us'em devices (bracelets), 2) Us'em mobile app (patient's host), 3) Therapist's host, 4) Carer's host, and 5) a central server.

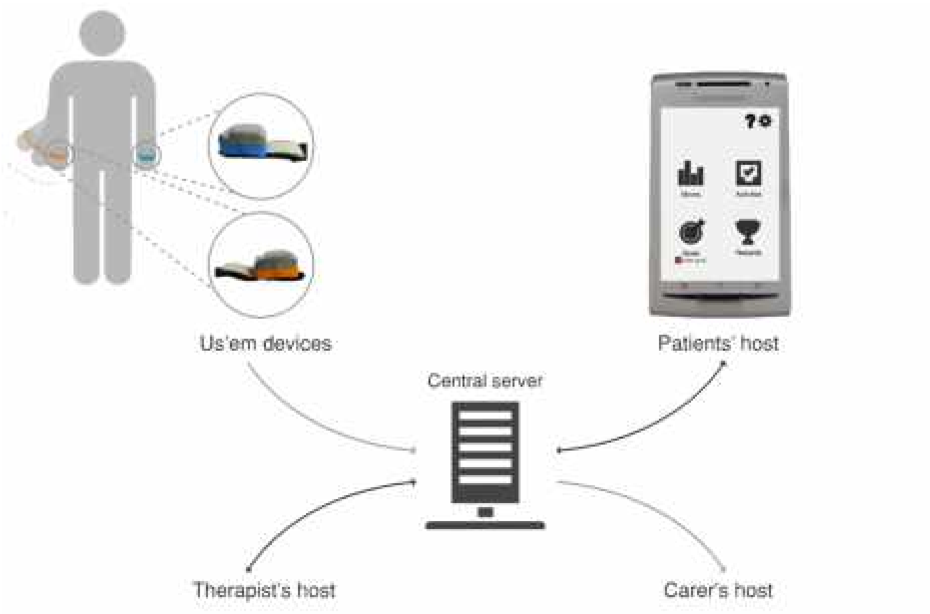


Figure 79: Us'em system components[182]

Us'em devices (bracelets: one orange and other blue) measure the movements of the arm-hand of the user (the patient). This information is, then, sent to a central server where it is stored and processed. Then, it can be sent to Us'em mobile app, to a therapist's host (for instance, an online management platform to use in the clinic) and, according to mobile app's settings, to a carer's host (that may be a computer or mobile app). The system requires, thus, an internet connection for data transfer. This connectivity will enable a more detailed reviewing of patient's progress, accessing and monitor patient's data.

On this definition of Us'em system, an example of a scenario could be as described next. A post stroke patient with upper limbs disorders is discharged to home. His/her rehabilitation plan involves training his/her impaired arm-hand when eating. So, at home, she/he uses Us'em devices and track, through the mobile app, the ratio of his/her moves. This data is, then, provided to his/her rehabilitation therapist through another interface, who analyses this information. He/she becomes more aware of patient's activity and progress and may adjust rehabilitation plan or activities. In the next clinical meeting or therapy session, they can discuss about it and the patient may be provided by feedback on his/her performance tracked by Us'em.

[182] Figure 79 was designed by the researcher of this project.

In this regard, therapists must know how to use information provided by Us'em. As mentioned before, it provides only quantitative information - the ratio of the moves of both arms - which does not enable an accurate patient's assessment. It is needed, thus, to make sure therapists understand the meaning of Us'em system and its information and, therefore, understand how it can be used to assess their patients. Moreover, the concept of Us'em mobile app defined in this research project refers that therapists have another responsibility with respect to Us'em system. As mentioned before, therapists are the ones who understand both physical and cognitive patients' needs, and define patients' rehabilitation plan. In the same way, they can realize how and which functionalities of Us'em mobile app the patient is likely to understand and use. Therefore, it is defined that the use of this app by a patient requires a therapist to set some aspects of the mobile app and to define which functionalities are available to the patient. In this way, Us'em mobile app has a set of basic functionalities that is common to all users, and, according to patient's ability, their therapist can add extra functionalities from which the patient will benefit. In this way, it is possible to set Us'em mobile app in a simple or more complex mode, enabling a more tailored user experience.

In addition, given their relevant role of caring and support patients, it is also important that patient's carers comprehend information provided by Us'em mobile app, so they can understand correctly patient's condition and progress.

For further information about Us'em stakeholders' goals see the appendix Us'em *stakeholders goals*.

Us'em *mobile app*

"*Keep everything simple as much as possible; simpler is more useable for elderly users.*" (Phiriyapokanon, 2011, page 22).

In practice, the Us'em system's component designed in this project was the mobile app. Its core requirement is simplicity. The end-users of this mobile app are post stroke rehabilitation patients with upper limb impairments. They, as stroke victims, are likely to have cognitive inabilities. Moreover, stroke accidents affect more elderly people, who are more likely to have also fewer cognitive abilities and technological literacy comparing to younger individuals. Because of these facts, Us'em mobile app users require requiring the simplest ways of communication and interaction. In this way, it was intended to design UI elements, the mobile app content and functionalities and interactions methods as simple as possible. All these components are described below.

Additionally, it is purposed to engage patients in rehabilitation and in using Us'em system. To that, it is required to implement certain features that have the potential to involve, motivate, engage users and support them in learning how to proceed with their self-rehabilitation.

"*Tell me and I forget, teach me and I may remember, involve me and I learn.*" (Benjamin Franklin, n.d.)

These requirements were translated into concepts and, then, into Us'em mobile app design, as showed in Figure 80.

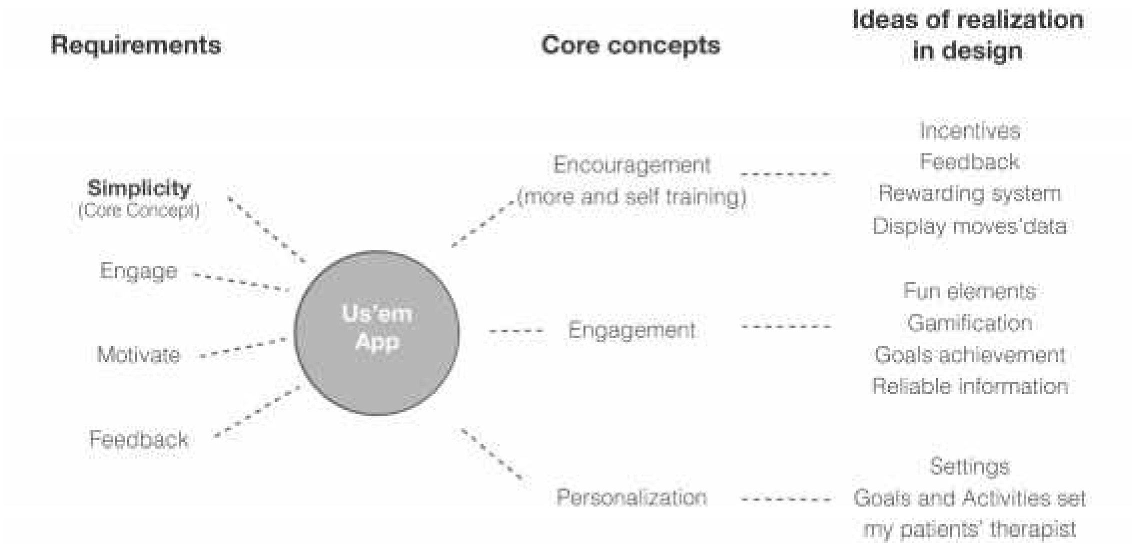


Figure 80: Us'em mobile app requirements, core concepts, Design Ideas[183]

10.2.2 Features

Us'em mobile app has various features that can be organized in: 1) Real time moves; 2) Moves history; 3) Goals; 4) Activities; 5) Rewards, and 6) Settings (Share, Language, Text Size and Sound).

Real time moves

Us'em mobile app works as a feedback tool. It informs its users about the quantity of their upper limbs movements, in the form of the ratio between the usage of the impaired and the non-impaired arms. This information is calculated with the outcome of Us'em devices (bilateral arm accelerometry data).

While using Us'em devices (main menu > moves), this information can be provided in real time, giving to users a clear idea about the frequency of the moves of their affected and unaffected arms. In the moves screen, there is a dynamic semi-circle chart that communicates the percentage of use of both left and right arms.

Furthermore, in the same screen (moves), there is a vertical bars chart that presents the information about the ratios of both arm-hands usage and how that percentage has changed in the last hours. The chart has a black line in the middle that represents the 50 percentage value. This reference value means that the user moves his/her both arms with the same frequency – the assumed desired level. According to Boesten's findings (2009), this level seems to be the more representative for real-world arm use than only the scores of the impaired arm. Boesten used percentages to better represent the ratio of patients' moves and concluded that the score of 50% represents the desired level of Us'em users/post stroke patients. The same author noted that it is important to make clear for patients that this level is a reference value used to indicate the healthiest status of upper

[183] Figure 80 was designed by the researcher of this project

limbs function. Indeed, for healthy people, the percentage of the moves of both arms is equal, without considering which of them is the dominant.
Determining this information (arm-hand use ratio) is relevant for the improvement and optimization of the rehabilitation process. In addition, it is important in goals achievement and upper limbs functioning assessment. Us'em users (patients) should aim reaching that level, moving both arms with the same frequency.
Both semi-circle and vertical bars graphs have two colors that represent the information gathered by Us'em devices. Thus, the blue color represents the moves of user left arm-hand, and the orange the moves of the right one.
Moves screen provides, thus, information about user's real time moves and his/her daily (last hours) activity at a glance.

Moves history

Apart from the ratio score, it is beneficial and more objective to measure patient's actual functioning within daily life (Boesten & Markopoulos, 2009). Hence, monitoring continuously the use of both arms during a long period is valuable. In addition, post stroke patients become more motivated when they know how they are progressing. They want to know, among other facts, if they are moving their impaired limb gradually over time. Hence, it is worth providing them an overview of the frequency of their moves since they started using Us'em. However, in this context, user's progress may be very slow and the differences are only noticeable in the long-term. Viewing a small difference may be negative and demotivating for the patient. Because of that, Us'em mobile app enables its users to see an overview of (a mean of) their moves' frequency by days, weeks and months (main menu > moves > moves' history). In this way, for instance, for patients who have little progress between weeks, it will be more positive to the chart that compares months. Thus, he/she can see significant differences and understand his/her progress.
As mentioned before, a history of patients moves comparing hours can be seen in *Real time moves* screen.

Activities

Literature research, observations, questionnaires and interviews conducted in this research project showed that each rehabilitation patient has his/her own therapy plan which includes specific activities. These activities are tailored and set according to patient's needs, requirements and/or desires to recover certain functions and become able to perform certain activities they could perform before the stroke. Improving a skill in a specific and patient-tailored daily activity is likely to lead to an increase of the amount of time and movement performed by a patient in an activity (Boesten & Markopoulos, 2009) Rehabilitation exercises are, hence, task-oriented and based on meaningful and engaging moves (Van Peppen et al., 2004; Timmermans, 2010). For instance, an observed patient who wanted to regain the ability to gardening was performing an exercise that required him to execute similar moves to those he would perform during that activity.
This personalization is also approached in Us'em mobile app (main menu > activities). Though Jamel have mentioned that defining activities and providing this specific information might be complex for some users, it is concluded that Us'em mobile app should consider these aspects, given their relevance in assessing upper limb recovery. In order to know the ratio of the frequency of their moves in a particular task, Us'em mobile

app can show the measurements of the moves executed while performing that specific task. To that, and to make this information more valid, users need track the activity. In other words, users inform the mobile app to record the information of their moves during a specific period that corresponds to the time they are performing that activity. To that, users select an activity from a list of predefined activities and click on the tracking button. These listed tasks are related to patient's rehabilitation plan and are defined by his/her therapist. Once again, the therapist is the one capable to evaluate patient's condition and decide which activities they should perform in order to obtain better results in their rehabilitation.

To represent these aspects in the prototype, in *Activities* there are four activities (eat, drink, dress up and wash) that were chosen according to this research's findings. For further information about it see *Training preferences* in section *Rehabilitation therapy*.

It is necessary motivating and encouraging post stroke patients during all their rehabilitation process. Achieving that is possible through challenging patients and providing them game-based experiences.

To ensure Us'em mobile users are motivated and encouraged to use Us'em system and to continue their rehabilitation, Us'em mobile app was designed with a goals and a rewarding systems, described next.

Goals

Us'em goals system enables settings specific goals to the user. Just like in *Activities*, goals are directly related to patient's rehabilitation plan and are defined by his/her therapist to ensure the goals are feasible. An example of a goal is “Move more your right arm this week while you are eating”, where right arm means patient's impaired arm. With this goal to accomplish, the patient is challenged to move more his/her impaired arm in a specific activity. Once the user achieves his/her goal, he/she receives a congratulatory message as a recompense for his/her achievement (as described in *Rewards* and in *Feedback*).

It is important to patient's therapist to see this information to be aware of the patient's achievements and to monitor and assess better his/her recovery.

Rewards

As showed previously in this document, gamification is a relevant element used to engage and motivate post stroke victims. For instance, home rehabilitation might be less frequent and efficient because exercises can be boring and not stimulating (Lövquist & Dreifaldt, 2006).

To cope with the potential Us'em users' demotivation, Us'em mobile app comprises a rewarding system: users are rewarded when they complete an objective. Patient's aim of achieving a goal is, thus, triggered by the desire in collecting more rewards and acting towards his/her recovery.

Then, users can access a list of their rewards, see the date they receive them as well as the ratio of their movements to achieve that goal (main menu > rewards). The implementation of these aspects (information about the goal user has achieved) is justified the Jamel's feedback during the test of a high-fidelity prototype (stage 1) – see appendix *Test high-fidelity prototype (Jamel)-results.*

Settings (Share, Language, Text Size and Sound)

The defined Us'em system enables data transfer through the internet from the devices to the central server. From there, it can be sent to patient's, therapists' and carer's host. It is not possible to disable the access to his data by patient's therapists because it is important they are aware of patient's moves. However, Us'em mobile app enables its user defining some aspects regarding to information sharing.

In *settings* (settings > share) the user can define who, apart his/her therapist(s), is allowed to view his/her information (Figure 81), and specify which information is shared with each of those individuals (Figure 82).

Figure 81: Settings - share screen (Us'em mobile app prototype)

Figure 82: Settings - sharing details screen (Us'em mobile app prototype)

To do that, he/she needs to access the *settings* screen (list of the aspect that can be set) and click in *share* button. The next screen shows a list of people with who the user is sharing or already shared some information. In this scree, there is also a button to add other person with who the user wants to share information. When selecting one item of that list, the screen shows which information (moves, activities, goals, rewards) is being shared with that specific individual.

The connection between Us'em mobile app and the device of the one who receives Us'em user's data was not implemented. In the future, before implementing this feature, it is required to concern about several aspects such as data privacy and ethics. In addition, it is important to find out what is the best solution for the method that enables different hosts (carers, family, friends) receive that information.

To expand the target group of the mobile app, it is possible to set its language (feature not implemented; only designed). In the prototype tested with Dutch patients the available languages were Dutch and English, while in the one tested with Portuguese patients there were Portuguese and English.

Bearing in mind potential difficulty to read small text, users can define the size of the mobile app's text between three different sizes. Despite this feature was not implemented, a screen as designed with the purpose to represent it.

Although the mobile app has no sounds, they must be implemented in the future as a method of feedback. But, as this preference may vary between users, it was designed a screen where the user can turn on and off the sounds of the mobile app (settings > sound).

Defining settings in Us'em mobile app is a means of customization. This possibility takes into account users' uniqueness and gives them the opportunity to customize the mobile app according to their preferences and/or requirements/needs and, thus, to have a more tailored and valuable user experience. This is of great relevance considering the specificity and variety of post stroke rehabilitation patients, each one with specific impairments, different requirements and needs. In this way, customization enables covering a bigger range of needs and extending the group of end-users of Us'em mobile app.

In addition, each patient has a personal rehabilitation plan, with tailored exercises to perform and goals to achieve. That must also be reflected in Us'em mobile app, considering that Us'em mobile app support their recovery. Therefore, the customization of this mobile app involves patients' therapists, who are responsible for patients treatment. Therapists define patients' goals and activities presented in Us'em mobile app. Moreover, according to therapists interviewed in his research, some users might be not able to define these settings through the mobile app. Thus, in some cases it might be necessary to transfer this responsibility also to therapists.

Feedback

As mentioned in *Feedback*, in section *Rehabilitation therapy*, providing feedback to patients while training help them to improve their motor skills and motivating them (Timmermans, 2010; Willems, 2013; Kemna & Culmer, 2009). Regarding UI interactions, it is also beneficial to provide feedback the user in order to make him more aware about what is happening. Us'em mobile app prototype has a feedback screen (Figure 83) that pops up when the user achieves a goal.

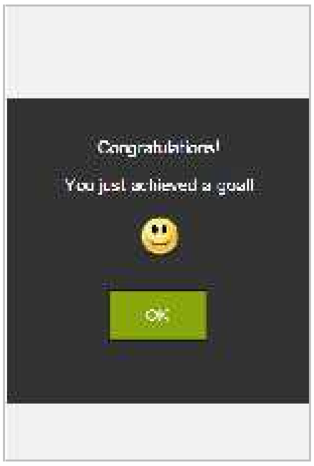


Figure 83: Feedback screen (Us'em mobile app prototype)

This pop-up message reports user's achievement and congratulates him for that. The message has text component, a smiley image with a positive meaning and a button that enables the user to close the screen and continue using the mobile app. It uses message vocabulary is usual for users in order to be meaningful and understandable (Wharton et al., 1993). As this feedback message is provided by an external source, it is extrinsic feedback (Timmermans, 2010).

Tour

Common users may forget what they did in previous interactions with a mobile app. In addition, they may forget which features are available in certain screen or the meaning of some UI elements. Us'em mobile app end-users, given their potential cognitive disorders, are more likely to face these problems. To tackle these aspects, and to enhance Us'em mobile users' interaction and experience, the mobile app has a help system: a guide tour.

On the top menu of every screen there is a help button (a question mark) that when clicked informs the user about the main features that are available there. It is a canvas that overlaps the screen which, in turn, becomes darker, giving relevance to the tour content. Users do not need to visualize all the steps of the tour. They can skip the information and close the tour.

Connection between patients' and therapists' *hosts*

The possibility to connect patient's and therapist's hosts, through the internet, is justified by the relevance of the therapist in the rehabilitation process. As it has been mentioned along this document, rehabilitation therapists play a crucial role in monitoring, supporting, guiding and assessing a post stroke patient during his/her recovery and treatment. The fact is that, nowadays, they interact with each other at a clinical environment most of the times. Face to face interaction is possible and, thus, communication and providing rehabilitation services to patients is easy.

Us'em devices and mobile app are designed to be used out of clinical contexts where therapists are not present. Taking in consideration that information produced by Us'em system relates to patients' moves and, thus, to their upper limbs recovery, it is important to make it available to their therapists. To ensure that, Us'em system was defined with an internet connection, enabling a remote connection between these two stakeholders and contexts. In this way, therapists will get more information about their patients and, thus, assess, monitor and provide better services regardless geographical barriers.

In what concerns to patients assessment by their therapist based on Us'em devices there are some aspects to consider.

The evaluation of the recovery progress of upper limbs impairments requires the analysis of both quality and frequency of patients' movements. Thus, because Us'em system can only measure the frequency of the moves, it cannot represent, by itself, the condition and progress of the patient. For instance, one may increase the frequency but not the quality of his/her movements, which can be a meaning of no rehabilitation or negative results of patient's recover.

Yet, providing therapists information about the frequency of patients' movements help them to have a clear and better knowledge about their patients, and consequently to assess, feedback and support them more regularly and efficiently. Us'em tracked data is, thus, of great relevance to these stakeholders. In particularly, physiotherapists are informed about 1) Us'em users' movements; 2) their goals and 3) rewards.

In addition, therapists are responsible by defining patient's rehabilitation plan, which includes therapy exercises and patients' goals. In this sense, to provide a tailored user experience, Us'em user's goals should be also defined by his/her therapist. To that, it is defined in this research that, from their host, the therapist must be able to set the goals that are displayed in Us'em UI, in *Goals*. In the same way, the therapist must be informed about user's achievements, that is to say, also to access the information about the *Rewards*.

Transferring Us'em information from the server to therapist's host is always possible: Us'em mobile app users are not able to define this aspect.

Yet, therapists' role in Us'em system covers other responsibilities.

They are evolved since the beginning, before the patient start using Us'em system. It is necessary to ensure the patient understands it and makes a proper use of it, without compromising his/her health condition and recovery. To that, therapists 1) give an explanation to the patient about Us'em system and mobile app features and the meaning of the information provided through the Us'em mobile app, 2) teach them how to use both Us'em devices and mobile app and 3) certificate that the patients are able and responsible to properly use both Us'em devices and mobile app. Whether because Us'em mobile app users have cognitive disorders and/or low technology literacy or just they do not have experience in using Us'em mobile app, they require a learning and adaptation period, which can be shortened by this therapist support.

Connection between patients' and carer's hosts

Patients' carers, such as family members, friends, among others who support the patient along all their rehabilitation process also play an important role. After discharged from a clinical setting, patients are mostly or only supported by their family. They help patients to integrate in their new life, encouraging them in training more for better rehabilitation results. In this sense, receiving patient's data regarding his/her use of Us'em and so his/her moves' frequency is beneficial as they become more aware of patient's progress. Although relevant, sharing personal information gives rise to concern on data privacy and quality. Hence, Us'em mobile app users are able to define with who they share information. In addition, they are also able to select which information is provided to each person: moves, activities, goals and/or rewards.

The final prototype of Us'em mobile designed in this research does not enable connecting it to a carer's host. However, the *Share* (Figure 81) and sharing details (Figure 82) screens (in *Settings*) were designed to simulate these functionalities.

10.2.3 UI design

Us'em mobile app UI design includes a set of several elements such as color, font texts and other graphic elements (icons, buttons, diagrams, graphs and images/photos), that are described below. UI elements were designed and defined with a terminology that would be understandable for Us'em mobile app users in order to make users act correctly – "*label-following strategy*" (Wharton et al., 1993).

The interface is divided into two main parts: the top menu and the content. The first one has, in maximum, three buttons. The second one comprises all the rest of the information, including main menus, charts, text, buttons, etc.

Colors

The interface uses seven colors: black, dark gray, gray, light gray, orange, blue, red and green. Its usage is presented in Table 6.

Table 6: Us’em mobile app UI colors

Color	Color reference	Usage
	Black #000000	Icons’ outline
	Dark grey #333333	Icons’ fill
	Grey #666666	Icons’ fill
	Light grey #FFFFFF	Background
	Orange* #FF9933	Charts Text
	Blue* #009999	Charts Text
	Red #CC3333	Buttons Text
	Green #999900	Buttons

In general, Us’em mobile UI have grey scale and black colors. Vivid colors are used in buttons, charts and text and to represent relevant information. In particular, orange and blue colors (in text, charts) always respect to Us’em devices (Orange: right device; Blue: left device). Red and green are used to present relevant information such as alerts and buttons which function is executing an action. For instance, a red button is used to stop tracking an activity and a green is used to start it.

The use of the aforementioned colors is justified by the necessity of contrast between UI elements and UI background.

Post stroke victims and senior people are likely to have cognitive disorders including poor vision. Given these circumstances, they benefit from contrast between UI components (Talbot et al., 2004). Furthermore, these individuals can be color blindness. In this sense, the colors which work the best for them are contrasting colors or those on the opposite ends of the color spectrum[184].

As mentioned before in this document, the meaning of a UI element should not be conveyed only through colors. It may address comprehension barriers, as colors are perceived in different ways, due to aspects such as culture, background, vision impairments. Considering these aspects, Us'em mobile app UI elements do not rely only on its color to transmit its meaning and function but also in its shape and associated text. For instance, the green tracking button has a text element that informs which function will be activated once clicked. In this way, this button is more likely to be perceived correctly.

Typography

The font used in Us'em mobile app prototype is Helvetica, a sans serif font. It is used a 16 point font size for almost all text elements and a 14 point font size for diagrams' subtitles. According to Phiriyapokanon (2011), a sans serif font and a text size between 12 and 14 point are the most appropriate to display information on an interface used by people with low vision.

Buttons

There are different types of buttons in Us'em mobile app UI: 1) main menus (Figure 84), 2) top menu (Figure 85**Error! Reference source not found.**), 3) check (Figure 86), and 4) navigation arrows (Figure 87), and 5) page buttons (Figure 88).

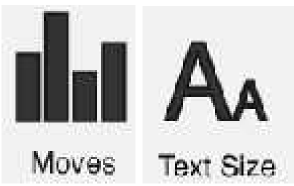


Figure 84: main menu buttons (Us'em UI)

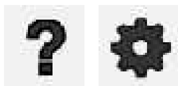


Figure 85: Top menu buttons (Us'em UI)

[184] http://www.usability.gov/get-involved/blog/2010/02/color-blindness.html

Figure 86: Check buttons (Us'em UI)

Figure 87: Navigation buttons (Us'em UI)

Figure 88: Page buttons (Us'em UI)

Main menu buttons are present in the first screen (main menu), giving access to the four main areas of this mobile app (moves, activities, goals and rewards). They are also in *activities*, *goals* and *rewards* screens, to represent the access to the screen of 1) each activity, 2) goals and 3) rewards, respectively. The *Settings* screen has also main menu buttons to provide the access to *share*, *language*, *text size* and *sound* areas.
On the top menu, in every screen, there are, in maximum, three buttons: two top menu buttons and a navigation arrow. The help button (a question mark) represents the access to the guide tour through the mobile app that explains its users how to use it. The other button (sprocket) represents the *settings* screen. The navigation arrow is used to return to the previous screen, reason why it is not part of this menu only in the first screen of the Us'em mobile app.
Navigation arrows are the buttons that enable users to navigate through moves' history.
Finally, page buttons are those that are in the content part of each screen and in the guide tour of the mobile app. They include the buttons 1) to select the time frame on history diagrams, 2) to start and stop sharing information, and 3) to access to moves' histo*ry*, *language* (in *settings*) screens, among others.
Buttons are flat and have gray colors. Most of them comprise a text element and an icon to make them clearer and were design with a language that users understand. For instance, the text of the button that enables the access to *Text size* screen was changed during this project from "Font size" to "Text size". This decision is justified by the fact that "Font size" is less likely to be understood by users without a design or a technical background.

Icons[185]

Although a good graphic design does not require text, as mentioned by Suzanne Watzman and Margaret Re in Sears & Jacko (2007), that does not mean that Us'em mobile app's UI is poorly designed and that graphics have an unclear meaning. In this case, the use of both image and text is justified by potential users' needs (Figure 89 and Figure 90).

[185] "*Icons and other visual cues are a form of visual shorthand, which helps users locate and remember in*formation." (Sears & Jacko, 2007, page 344).

Figure 89: Tracking icon (Us'em UI)

Figure 90: New goal icon (Us'em UI)

Us’em mobile app users are likely to have cognitively impairments which, in turn, may affect their ability to perceive graphics and text. Using both graphics and text together enhances Us’em mobile app’s usability, as they reinforce the UI element meaning, increasing the number of users that will understand it.

However, some icons may be not understandable by some users considering cultural aspects. Indeed, it is difficult to find a solution of an icon that communicates the same information across different cultures (Sears & Jacko, 2007).

From the technical point of view, the icons where designed using Illustrator. All of are flat and have, in maximum, two colors.

Charts

Us’em mobile app uses vertical bar charts to compare and represent the ratio between the moves of user’s both arm-hands (Figure 91).

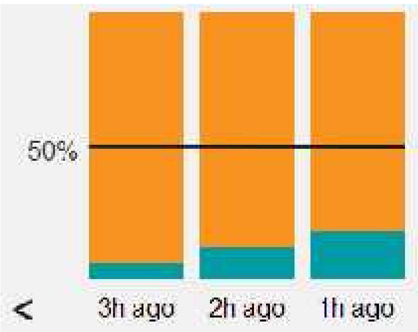


Figure 91: Vertical bar chart (Us'em UI)

These charts are divided into two parts, each of one representing each arm-hand. The right arm-hand is represented by the top and orange part, and the left one by the bottom and blue part. As mentioned before, this is based on the color of Us’em devices.

The charts have subtitles that inform about the period each vertical bar corresponds. In addition, there is a horizontal line to represent the point where the ratio is 50%, the score that the user should achieve.

Furthermore, it is used a semi-circle chart to show real time moves information (Figure 92).

Figure 92: Semi circle chart (Us'em UI)

This chart is also divided into two parts that respects to both arm-hands. It has legends that refer the ratio percentage of the moves of each of arm-hand.

10.3 Prototype Design

"*Design is about making decisions, progressing from a problem statement to a solution.*" (Iachello & Abowd, 2005, page 3).

Prototyping included several iterations. Throughout that process, prototype's design became more concrete and precise and its implementation got more detailed and with more technical features. That is to say that each new cycle was a mean of improvement and increasing fidelity. In the first stage of each cycle, feedback obtained in the previous iteration was analyzed, new design ideas were brainstormed and started to be implemented – prototype redesign.
It is important to mention that the evaluation of some prototype did end after the following prototyping cycle started. Sometimes, for instance, it was possible to evaluate and discuss a prototype with researcher coaches at the end of the prototyping cycle. As Jamel was available only one or two days after that, the next prototype was started and finished after Jamel's evaluation. This methodology was justified by time constraints.
The prototypes were designed, evaluated and redesigned. This last stage was already the first phase of the following prototyping cycle.
Evaluation was done through discussion and user tests. In the discussions, information was recorded using paper notes, analyzed and then translated in modifications in the prototype. In turn, user tests did comprise a more complex process that will be detailed later in this document.

10.3.1 Low-Fidelity prototypes

Low-fidelity prototypes (Figure 93) were designed in a simple and quick way to be easy to use.

Figure 93: Low-fidelity prototype

This was justified by time constraints, the fact they did not require any costs and because it was aimed to evaluate only some components rather than major usability issues. Prototyping in low-fidelity for mobile devices required particular attention, because if not well implemented, they might affect the evaluation process and produce negative effects (Sá et al., 2014). However, design and evaluation of these prototypes did not take too much time, mainly, due to time constraints but also because high-fidelity ones might be better to obtain more real results as they enable testing of external characteristics. When prototyping in low-fidelity a special consideration was given to the difference between the UI design and the smartphone, as they address different characteristics that need to be evaluated. This attention was justified by "mobile devices' portability and adequateness to *intensive usage and their physical characteristics and peculiar interaction modalities*" (Sá et al., 2014, page 196).

All the low-fidelity prototypes designed in this project can be visualized in appendix *Summary low- and medium high-fidelity prototypes*.

Stage 1

a) Development and goals

The first prototype, following research and brainstorm, was based on inexpensive material such as paper and pencil. Made of rough paper and pencil sketches of the UI, this first prototype represented mobile app's screens and was organized in a paper board, representing possible user interactions. It was a fast way to make clearer mobile app's interaction flow and functionalities. This prototype was evaluated through a discussion between the researcher and research supervisors.

The purpose of this prototype was translating brainstorm outcomes into a visual approach. In addition, it was intent to: 1) to know the amount of elements could be displayed in the screen; 2) to have a better and a physical simulation of what a mobile app could be; 3) to understand the mobile app's interaction flow, and 4) to check if the solutions to display data were the best according with the target group.

b) *Evaluation: discussion with research supervisors*

This prototype was discussed with research supervisors. As they were all aware of the project, the discussion did not require any introduction or explanation. In addition, more bibliographical reading was done and new findings did arise. Hence, information from coaches' knowledge in rehabilitation, well-being and healthcare, and in mobile apps and technologies was collated with research findings and brainstorm's outcomes. This information was, then, used to initiate the second prototyping cycle and, thus, to redesign and improve the first one.

c) Evaluation outcomes

This discussion did enable to conclude that:

- different approaches of some screens should be designed and compared to find out the best and most appropriate design;
- the number of interactions to access some information/screens or to execute some tasks should be decreased;
- some information, such as settings, should be display differently to make it more clear to users.

Stage 2

a) *Goals and Development*

In the second step of the prototyping process, a basic UML use case diagram related to Us'em system was designed. It included system functionalities regarding its stakeholders: patient, rehabilitation team, physical therapist and patient's carer. These are the actors: while patients are primary actors, physical therapist, rehabilitation team and patient' carers are secondary actors. The purpose of this research project is to redesign the UI of Us'em mobile app. However, as it is part of Us'em mobile app and it needs to be designed in accordance to Us'em system stakeholders, UML diagram involves all of them. Hence, the functionalities available to therapists, rehabilitation team and patient's carer represented in the diagram resulted from the brainstorm about Us'em mobile app.
First, this diagram was designed using paper and pencil draws in a paper board. To have a better and clearer representation of it, it was, then, redesigned with a web tool to build diagrams called "*Gliffy*"[186] (see document *System UML use case diagram* annexed to the CD of this dissertation). In this diagram, 'includes' represent an existing requirement to perform a certain task to complete another one started previously. 'Extends' represent a different option from the default that can be taken.
The next step in this stage was the design of a second prototype based on handmade sketches. That had the purpose to adjust the mobile app's prototype according to the discussion's findings about the first prototype (Figure 94 and Figure 95).

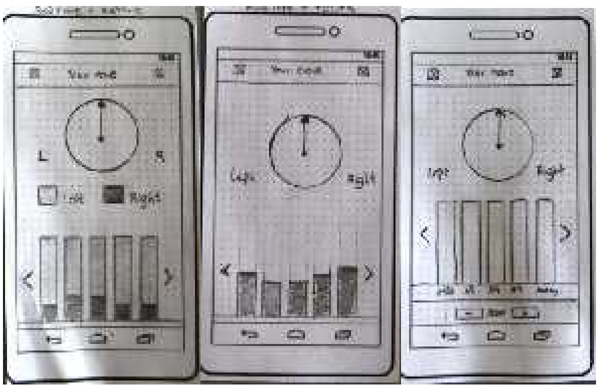


Figure 94: sketches of real moves screen (prototype stage 2)

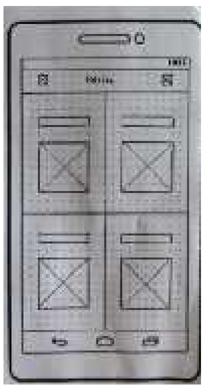


Figure 95: sketches of menu screen (prototype stage 2)

[186] Retrieved June 23, 2014, from www.gliffy.com

A scheme was designed to organize the different approaches designed to the same screen.
In addition, graphs and charts representing real time moves' data and goals were designed (see document *Interviews-Libra Therapists (guide)* annexed to the CD of this dissertation). They were, then, showed to participants on the evaluation stage in order to know which ones were the best to present the information.

b) Evaluation: Prototype Test and discussion with Jamel and Therapists

The new and updated low-fidelity prototype was showed to and evaluated by a post stroke rehabilitation patient, Jamel, during an interview. During this stage, another interview, with physical therapists, was conducted. During it, it was possible to get their feedback on the prototype as well as on the sketched charts. It also did enable gathering relevant information that did contribute to build the next prototype. Both interviews are described in the chapter *Research methodology*.

c) Evaluation outcomes

The result of the evaluation by Jamel was very important to update mobile app features and to understand better stroke patient requirements with regard to Us'em mobile app. However, as he was the only patient who tested the prototype, test's results cannot be generalized.
The guide designed to this meeting can be found in the document *Test low-fidelity prototype (Jamel)*, annexed to the CD of this dissertation. The outcomes, as well as a description, of this meeting can be found in the appendix *Test low-fidelity prototype (Jamel)-results* but a brief summary is given below.
The main facts found with Jamel's test were:

- Us'em user benefit from viewing real time data about his/her moves, a history of moves by last 15 minutes, day, week and month, and by activity;
- According to Jamel, providing data about a specific activity might represent a lot of information for some users; tracking activities might be a boring process if users are not progressing;
- A bar chart represents better the progress of users; It should have lines representing each percentage level so user can easily understand how far he is from the desired level (50%);
- Goals should have a weekly deadline; they should be present in one list without dividing them by activity;
- Rewarding should include an image or an icon related to victory or achievement;
- Data should be shared continuously with patient's therapist but not with his/her carer(s) (in this case, patients should be able to define it).

The discussion with the therapists did show that some other improvements should be done in the mobile app. On one hand the number of interactions/screens should be decreased, on the other hand, in some charts, moves ratio is not well represented.

It was also concluded that stroke rehabilitation is a one-person process, so there are no two equal patients, every patient is unique. In addition, therapist and patient cannot be separated during rehabilitation progress. This process aims to make patients come back to their previous life and routine and not only to enable them to regain their body part functionality. Regarding smartphones usage by patients, they did say that as most of them are old, only a few are used to use a smartphone. A bigger group uses already computers and tablets. The appendix *Interviews-Libra Therapists (results)* describes this visit to Libra clinic: therapy sessions' observation and the discussion with therapists.

10.3.2 Medium High-fidelity prototypes

After prototyping with low-fidelity, the prototype became more detailed, more precise and interactive – medium-fidelity prototype (Figure 96).

Figure 96: Medium-fidelity prototype

Stage 1

a) Development and goals

After feedback and evaluation of UML diagram and sketched charts, with more bibliographic and on-site research conducted in the previous stage, new conclusions were drawn. Thus, the third stage of prototyping did intend to modify the prototype according to new information gathered.
It did comprise the following actions:

- adjustments to UML diagram;
- adjustments to mobile app sketches;
- design of an interactive prototype;
- design of a diagram representing Us'em mobile app functionalities;
- design of a diagram representing functions of Us'em system;
- design of a UML activity diagram (document *UML Activity Diagram* annexed to the CD of this dissertation) and
- icons' study.

During this stage there was a visit to Adelante clinic that did enable to gather relevant information for the prototype development. This visit did comprise an interview with a clinical researcher and observations that are described in the document *Observations Adelante (results)* annexed to the CD of this dissertation.

The new UML diagram is represented in document *UML Use Case* (annexed to the CD of this dissertation). Its elements have different colors: blue represents the patient, mobile app user, and mobile app features that he can use; white color boxes represent options that can be selected; elements with orange color indicate the available functions of Us'em system to therapist; green color is related to rehabilitation team and what they use in Us'em system; and violet color shows patient carer's role in the same system.
Comparing with the previous version, the modifications made on UML diagram were:

- There is one less step, that is to day one less interaction need, to set the time frame of moves' history;
- Goals' screen will not present 'general and 'by activity' goals;
- Parameters that can be set in Us'em mobile app by the user are: sound, language, privacy and font size;
- There will be no possibility to connect Us'em mobile app to digital social media networks;
- Color-based representation of Us'em stakeholders and system's functionalities available for each of them;
- Therapist will be able to view patient such as time/date, activity, measurements (moves' ratio) and training period.

In order to make UML diagram information clearer, two diagrams were designed: one with respect to Us'em mobile app functionalities (document *Diagram Usem Mobile App Functionalities*, annexed to the CD of this dissertation) and another one with regard to Us'em system, including its stakeholders and functionalities (*Diagram Us'em system overvie*w (available tasks for each Us'em system stakeholder)*).*
The first one represents mobile app's screens and the actions can be done in each of them. It is organized in three levels that correspond to the levels of navigation. In other words, the first level, which has only the menu screen, will be the first one with which user can interact. Then, depending on user's choice/action, the next screen might be one of the second level (*real time*, *activities*, *goals*, *rewards* or *settings*). The third level is reached through *activities*, *goals* or *rewards* screens.
The second diagram represents all Us'em system's stakeholders and all functionalities available for each of them. It was built to have a clearer overview of the system and its stakeholders' functions.
From a technical point of view, a UML activity diagram (document *UML Activity Diagram*, annexed to the CD of this dissertation) was designed to represent graphically the work flows of user actions, including iterations and possible choices.

Mobile app sketches
Handmade sketches were redesigned and the main modifications were as showed in Table 7.

Table 7: Changes in handmade sketches

Screen		Prototyping stage: 2	Prototyping stage: 3
Real time moves and moves' history	Chart of real time moves	Circle	Semi-circle
	History chart	Without subtitles	With subtitles
	Navigation in history's chart	Arrows	Touch events
	Charts' title	No	Yes

Figure 97 shows some new approaches that were designed to represent the screen with data of real time moves and its history.

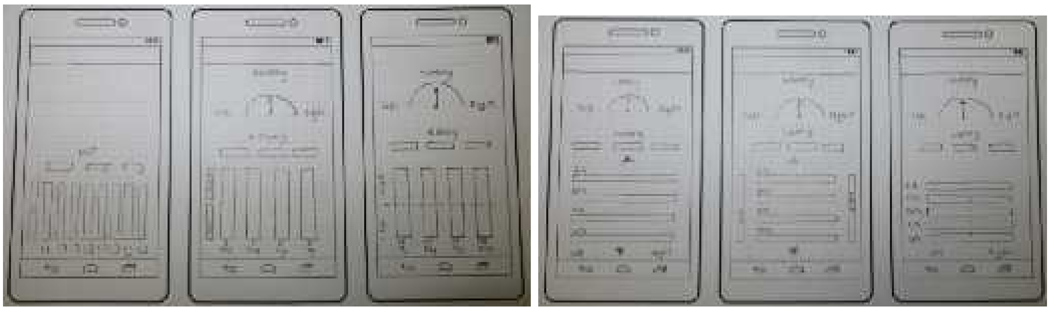


Figure 97: Sketches of real times moves screen (prototype stage 4)

Next, UI sketches were wireframed in mockups and translated into an interactive prototype using the web tool Balsamiq[187] (Figure 98).

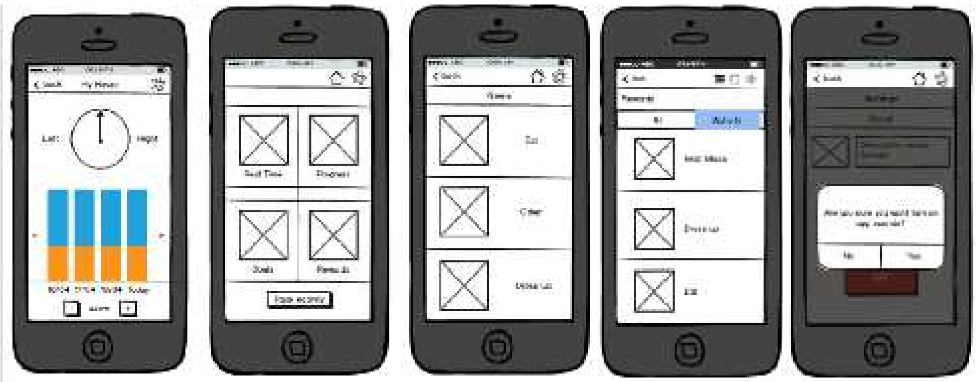


Figure 98: Screenshots of the balsamiq interactive prototype

With this prototype, a *.pdf* file, it was easier to have a better perspective of what the mobile app would look like and how would be its interaction flow. As it enabled already the use of color, elements representing data of Us'em devices, for instance, were painted with orange and blue to respect to each Us'em device.

[187] Retrieved June 07, 2014, from http://balsamiq.com/

b) Evaluation: Discussion with research supervisors outcomes

To evaluate this prototype and the new ideas different discussions with the supervisors had occurred.
The outcomes of these discussions were:

- the need to reduce the number of interactions to execute certain tasks;
- the need to test with real users;
- users should be aware with who and which information they are sharing;
- “Settings” should include defining text size;
- Real time moves should be represent with other type of chart, instead of a circle;
- Information about tracking activities must be provided.

10.3.3 High-Fidelity Prototypes

High-fidelity prototypes were already on the smartphone, so it was possible to evaluate it in more real context. For instance, contrary with low-fidelity prototypes, it was possible to test UI elements’ size and legibility, smartphone’s time response to touch events and user actions as well as screen resolution.
UI design of each prototype can be seen in appendix *Summary high fidelity prototypes*.

Stage 1

a) Goals and development

The first high-fidelity prototype was designed with *.png* images designed in *Illustrator* and using *JavaScript* to make those images interactive. These images were uploaded to the smartphone via USB.
It was aimed to:

- Redesign the interface according to the feedback received;
- Then, transform sketches and the balsamiq prototype into digital sketches,
- See the look and feel of low prototype on the smartphone, and
- Check up the consistency of UI including colors, contrast, icons’ size, buttons and other elements.

There were several changes in interface design that were not sketched in paper or with Balsamiq tool, but using *Illustrator*. Hence, this first high-fidelity prototype presents already a significant difference.

b) *Evaluation: Discussion and test with research coach Prof. Panos and Jamel*

The first high-level prototype was tested by Jamel and discussed with the supervisors.

Test with Jamel
The test with Jamel was based on a thinking aloud method and it was used an evaluation guide (appendix *Test high-fidelity prototype (Jamel)-results*).

Discussion with research supervisors
This prototype was presented to the research supervisors. The first one had occurred in a face-to-face meeting, the second via skype.

c) *Evaluation outcomes*

The outcomes of the test with Jamel are described in appendix *Test high-fidelity prototype (Jamel)-results*, but they can be summarized as follows:

- User's moves should be represented by vertical bars charts with horizontal lines to show the levels of percentages (ratio). Its history should be presented by day, week and month;
- Information about *Rewards* must include the date they were received and the ratio of the moves that enable the reward;
- In *Share*, user must know with who user is sharing information;
- Instead of having *Back* and *Menu* buttons, only the first one should be presented and enable the access to the previous screen user viewed;
- Screen's title should comprise text and an icon:
- Rectangular buttons are better;
- The white background is too bright;
- The mobile app should be personalized and set by user's therapist;
- *Activities* and *Goals* are less important, while *Moves* are the most relevant.

The outcomes of the discussion with research supervisors are described below.

- *Share* (in *settings*): referring *Activities* instead of *M*oves' *history* in the options of the content that can be shared;
- The *tracking* button, in activities, should be green. When clicked, a feedback message should be provided asking user to confirm his/her action. This will reduce the error;
- User should be provided by tips along the mobile app or screen with help and support information; and
- The mobile app should be customizable by the user (through *settings* screen), or personalized by the therapist that defines some settings before patient starting using it.
- The list's items in *Share* screen must address people rather that devices, to make the mobile app more credible. It is important to provide users the information about which information and with whom they are sharing their data.

Stage 2

a) *Goals and development*

The third stage's goals were:

- Redesign the interface according to the feedback on the previous prototype; and

- Build the prototype with *HTML*, *CSS* and *JavaScript* to increase its fidelity.

At the end of this stage, the prototype was already functional and based on *HTML*, *CSS* and *Javascript*.

b) *Evaluation: Discussion and test with research supervisors*

This stage counted with the evaluation of the prototype by the *research* supervisors and, like in previous stages, it was done via *Skype*.

c) Evaluation outcomes

The discussion with research supervisors did conclude the need to review and redesign some aspects. Their feedback was as follows:

- Interface's background color should not be so dark. It cannot be white but it still needs to make possible a contrast with interface elements;
- It should be tried to design some icons and without the outline to make them simpler. It should tested, then, if they are still readable and understandable;
- Some text elements should be increase in size;
- It is important to design a different method to define font size and, then, compare and conclude which is the best. For instance, it can be a horizontal with a mark that users can slide between the two ends that represent the minimum and the maximum size of the text.

Stage 3

a) Goals and development

In the third stage of high-fidelity prototypes, it was aimed to brainstorm and implement a new design according to previous feedback, using *HTML*, *CSS* and *Javascript*.

In addition, we aimed to implement a guide tour in the mobile app and dynamic charts to increase prototype's fidelity. This process was time consuming and demanded great efforts, mainly due to the restrictions the *Android* version (2.1) imposes in implementing certain features. After 2.1 version there were more 6 *Android* updates, being the most recent version the 5.0 (Lollipop). So, simple functionalities implemented in current *Android* smartphones are not supported by version 2.1. It was required, thus, to search and confirm which features could be implemented. However, sometimes it was not possible to verify it before implementation, so as the mobile app was developed in a web browser on the computer, only when it was run in the smartphone it was possible to verify that. Some functions were working correctly on the web browser but not in the smartphone. Thus, it was required using a different method to develop the same feature, which consumed time. Implementing a dynamic chart to represent real time moves was the most complex task. First, it was developed using *jQuery* and then *SVG* (Scalable Vector Graphics) images, but both methods did not result. *Android* versions that support *SVG* graphics are only

version 3.0 and above. The solution was designing this chart with the canvas *HTML5* feature[188].
Furthermore, in this stage, the research work was reported and presented to the User Centered Engineering research group of Tue. It was relevant to receive feedback on the UI design as well as to rethink some issues not only about the interface but also about Us'em system and its users.

a) *Evaluation: discussion and test with research supervisors*

Just as in previous stages, there were face to face discussions and *Skype* meetings.

b) Evaluation outcomes

The results of the discussion were the following:

- Buttons should be designed in order to be more contrasting with the other elements and background;
- Users should be informed about a new goal to achieve already in the first screen (main menu);
- Information of *Moves* screen might be too much. Real time moves and its history, at least by day, week and month, should be in different screens to be more readable;
- Real time moves chart should be larger;

Stage 4

a) Goals and development

The fourth prototyping stage concerned the development of the last and final Us'em mobile app prototype. The purpose was, thus, deploying important features that were not implemented, and redesign some aspects feedback in the previous stage.
One of these features, the most complex, was the implementation of a data storage method. The project had the purpose to connect Us'em devices to mobile app and use their real values from the database created in the mobile app, but it was not possible because of time constraints. Thus, it was required to find a solution that enabled generate values that would represent the ratio of user's moves. Different methodologies and programming languages were approached to settle this need: *Json*, *XML*, *Ajax*, and *Python*[189]. These were not successful due to *Android* 2.1 specifications. The solution adopted was a *HTML5* feature that is supported by *Android* version 2.0 and above[190]: Web Storage. Further details about the implementation of this feature are presented in *Technical issues*, in chapter *Prototyping*.

---

[188] Retrieved June 16, 2014, from http://mobilehtml5.org
[189] Retrieved July 09, 2014, from https://www.python.org/
[190] Retrieved July 09, 2014, from http://mobilehtml5.org/

In addition, this stage had the purpose to test the prototype. It involved (Dutch and Portuguese) patients and (Dutch) therapists. In order to test it with Portuguese patients, all the entire mobile app was translated to Portuguese. This raised some questions. For instance, while in English there is only one way to refer the user ("you"), in Portuguese there are two: formal ("*você*") and informal ("*tu*"). It was used a formal approach considering the diversity of the target group. Other example respect to the check/confirm button. Some Portuguese people use the term "ok" in daily conversations. However, elderly people are less likely to use it. Thus, it was used the Portuguese term "*Continuar*" that is commonly used in web and mobile apps in Portuguese language in the same type of button.

b) *Evaluation: therapists and patients from the Netherlands and from Portugal*

Testing this last prototype was very important to assure its usability and adequacy to its target group. Hence, it was tested by two therapists and four patients from the Netherlands and three patients from Portugal, using a cognitive walkthrough method (for further information about this method, see *Evaluation* in chapter *Research Methodology*). Dutch participants were professionals and clients of Libra clinic, where the tests were conducted. In doing that, 50% of the tests comprised the researcher and the patient, while the other 50% included three participants: the researcher, the patient and his/her therapist. The later assumed a relevant role in translating the communication (from English to Dutch) and supporting and guiding the patient. In turn, Portuguese patients were clients of CRPG, so the test occurred in that clinic. In this case, tests' participants were only the researcher and the client. The low number of participants does not enable to generalize tests' results. However, testing with potential users of the mobile app was very relevant as they are the most indicated to expose feedback on UI usability. Additionally, it was important to compare some cross-cultural aspects regarding interaction with mobile apps as well as with respect to patients' concern about upper limb rehabilitation.

However, it was not possible to acquire information on the relevant question about how participants hold and use the smartphone. Indeed, only two participants did hold it to interact with it during the test. Both did it with only one hand. To one participant the hand was the dominant before stroke, but the other used the impaired hand, yet already almost full recovered.

The guide used in these tests is the document *Usability Tests Guide* annexed to the CD of this dissertation. Tests with Dutch participants are reported in the document *Usability Test Libra (results)* and those with Portuguese participants in the document *Usability Test CRPG (results)*, both annexed to the CD of this dissertation. The outcomes of these tests are described below.

c) Evaluation outcomes

The usability tests conducted in this final prototyping stage led to conclusion that Us'em mobile app designed in this research project has positive aspects but also others that need to be improved. Additionally, their results enabled to identify some differences concerning rehabilitation procedures. Hence, the performed tests were relevant to define

which aspects will potentially cover users' requirements, those that must be modified and other that will be positive to implement in the future.
However, tests did not cover all the tasks that were intended to test due to patients' characteristics, status or condition. Thus, and given the low number of cases covered, tests' findings are only representative of the target population and cannot be generalized. Furthermore, it was not possible to identify cross-cultural differences regarding UI interaction, as it was aimed.
Before conducting the tests, participants were provided with a brief explanation about mobile app's purposes and main characteristics and features. Still, in some cases, participants could not understand or execute the right action, so the researcher clarified their questions. After they perform an action that required an explanation, they could execute it or a similar one without help. One hypothesis for this is that they cannot interact properly for the first because they do not know the mobile app. If so, they will be more likely to understand and to know what to do. Hence, it is envisaged that before using Us'em mobile app, patients require a demonstration on how to use it.

The most frequent problem was the physical interaction with the smartphone with respect to its screen. It hardness makes it less sensitive, requiring a certain way of touching to trigger some function. Sometimes, it was necessary help the patient in doing that. Yet, this help was given only after he/her tried to do it.

As expected, in general, the individuals used already smartphone faced less problems in interacting with Us'em mobile app. Those used to use a cellphone had more difficulties, mainly due to their inexperience with the touch screen. In fact, these individuals, even after explained the need to click on the smartphone's display, tried to interact with Us'em mobile app through the hardware (physical buttons on the bottom of the smartphone). As example, two participants clicked those buttons when asked to define Us'em mobile app settings. One of them did not understand the meaning of 'settings'. Thus, he was explained that that was a similar procedure taken when he defined his cellphone settings, such as its volume. Hence, it might be a reason why he to execute that action immediately.
In general, as the tests were conducted, the participants were more capable to interact with the mobile app.

C.1) Credibility Expectancy Questionnaire and Intrinsic motivation inventory

Regarding the *Credibility Expectancy Questionnaire* and the *Intrinsic motivation inventory* concerning Us'em mobile app, participants' answers are described below. For further details of these results see appendix *Usability Tests (results-charts).*
With respect to the *Credibility Expectancy Questionnaire*, conducted after a brief explanation of Us'em system and mobile app and before the usability test, the results were as described below.
Half of the participants think Us'em will help them reducing their hand-arm impairments a little. The other 50 per cent think that it will help them a lot.
Furthermore, their opinion of the improvement will have occurred at the end of the therapy in their hand-arm symptoms using the Us'em mobile app varies. Overall, one rated this

improvement between 20%-40%, other said it will be 40%-60%, three of them said 60%-80% and 80%-100% of improvement was mentioned by two of them.

The results of *Intrinsic Motivation Inventory*, conducted after the usability tests, are described below.

Regarding how pleasure is Us'em mobile app, more patients did like to use Us'em mobile app and they found it fun interesting, pleasant and not boring. However, it did not catch attention of most of them. Furthermore, while using the mobile app two of them did not think about how good I was feeling, and other two did.

Six of all participants said the mobile app is a relevant product.

Five of the participants said that having a good performance of interaction with Us'em mobile app would be not difficult.

The same proportion affirmed Us'em mobile app would help them in improving their arm-hand abilities and in training and using their arm-hand in daily activities. Two Dutch participants said no to this last fact. But only four of seven think it will be relevant in learning how to use their arm-hand more and better.

The same number of patients (five in six) felt capable to use Us'em mobile app and would like to try it again. Four of six want to use it in the future. Two, tests did show two of them would not use the mobile app at the moment. One justified it saying his arm was already almost fully recovered, so he would not need it. Still, he said he would use it in the first stages of his recovery, as it would help him to be more aware of his upper limb activity. The other said it was because his rehabilitation process was still in the stage of therapists' evaluation. Because of that, he was not training yet, so not recovering and not moving his limbs. Hence, if would use Us'em system, the mobile app would show him a huge difference between their both arm-hand moves and a low or any progress. Consequently, in his opinion, his motivation would decrease and he would feel even worse. Yet, despite being negative for him given his circumstances, he thinks the mobile app has a great potential to increase some patients' motivation and engagement in their recovery process.

In addition, six of all participants trust in the mobile app and five are attracted by it.

Apart from these questions, it was possible to conclude that patients found this mobile app very valuable for their rehabilitation process when discharged to home. The reason they mentioned was the fact they can have a clearer and real idea of their upper limbs moves. One said that, despite being already highly motivated to exercise at home without needing any incentive from others, it would use it to know the real ratio of his moves.

c.2) Evaluation outcome by screens

Screen: Main menu (index)

In the first screen, the main menu (Figure 99) there was a question about the icon of the button to access the *moves* screen.

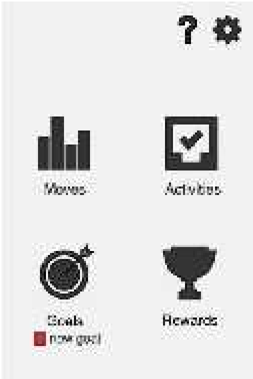


Figure 99: Main menu screen (index) (Us'em mobile app)

For some participants, it did not represent graphically well its meaning. A participant mentioned that, for him, that icon represented statistics. Thus, at a first glance, he though the button would give him access to his moves' history. However, he mentioned that after a brief analysis, he could understand it because of the button's text element, the word "moves". Only this patient mentioned this problem, perhaps because he was the more extroverted. Yet, it is considered that it might have affected some others given their time of analysis, comparing with all participants of the test.
This fact shows that it was relevant to design Us'em mobile app buttons with both graphic and text elements for a better understanding of its meaning.

Screen: Real time moves
Real time moves screen (Figure 100) had positive and negative feedback.
It was one of the screens that required a longer period to be fully understood for tests' participants. It may have to do with the higher number and complexity of some interface elements and information, such as charts.

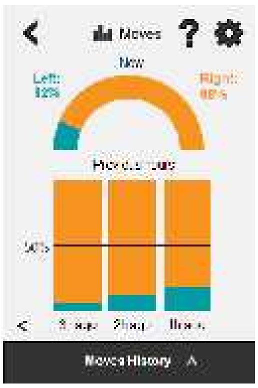


Figure 100: Real time moves screen (Us'em mobile app)

With respect to real time moves chart's title, a participant proposed to change it from "today" to "now", as it refers to real time data. Additionally, tests showed the subtitles of these screens should be increased, according to some users.

With respect to the moves history bar chart's navigation, a participant suggested a different approach, though he found the current one easy to understand. He mentioned that the information about history by hour, day, week and month could be in the same screen. For that, the more the users navigate backward in the chart, the more extended will be the time frame (first, hours, then days, week and finally months). This idea is detailed in document *Usability Test Libra (results)* (task id: 1; user id: 3), annexed to the CD of this dissertation. In fact, another subject clicked more times in the backward arrow in order to see moves of previous weeks. He/she had the same idea the previous one suggested. Still in this chart navigation, tests showed buttons (backward and forward) are small and have a small sensitive area.

Most of all patients did not notice the Moves' history button. Some referred they focused on the rest of the screen and did not notice that button, maybe because it was black. This also happened in the screen with activity's detail. However, some subjects that did not notice the first time could detect it in the next interactions in the same or in a different screen. This show, again, that errors occurred in the first interactions might be diminished in next experiences by remembering what they did. Users require first a learning stage and, after it, they are more likely to interact with mobile app with fewer problems. Yet, it cannot be forgotten that stroke disorders may affect their ability to remember, so they will be not able to remind their previous experiences. This button has a text element and an arrow. Two users clicked only on this arrow, being not aware that all the black area (the entire button) was clickable. One of the participants clicked it during a long period because, given the hardness of the screen, his action did not trigger buttons' action with a simple click.

A positive feedback about this screen was given. A participant said it has a good combination of the information. It requires a longer period to be analyzes given its quantity of information, but it is easy to understand.

Screen: Moves history

In this screen (Figure 101) the navigation buttons (backward and forward) are small and it was difficult for almost all the participants to click them.

Figure 101: Real time moves history screen (Us'em mobile app)

They did not click those buttons in the same way than other buttons, making lot of efforts to see the button and to make sure they clicked. While for some of them, these buttons

concerned interaction problems because of their inability to coordinate their limbs, for other it was found as a good way to train his coordination.
Additionally, some participants found difficult to understand which color of the chart's bars represented their left and right arm. They could not remember color meaning from the previous screen.
There were more participants that understood real time chart than those who did not.
One participant thought there was a link between each button to change the time frame (day, week, month) with each bar of history chart. These buttons are, thus, not perceived as buttons.
Although the subtitles on this screen were readable, they could be increased.

Screen: Activity detail
Overall, it was very easy for all to perform the task asked in this screen (Figure 102).

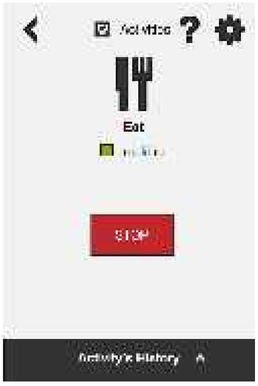


Figure 102: Activity detail screen (Us'em mobile app)

It is considered, thus, that the easy interaction with it is support by the low number of interface elements and the less information provided.
Two patients, when in this screen and asked to access Activity's history screen, returned to the main menu with the purpose to click in "Moves" button. They though activity's history information, as it also respects to his moves, would be in *Moves* screen.
Most of the participants did not notice Activity's history button on the button of the screen. Yet, they said they will in the next interactions. They did not do it that time because they did not know the mobile app. One stated "*Probably I did not notice the bottom button to access to activities history because it is black. My attention is in the rest of the screen. For me it is an inactive part of the screen.*" (see document *Usability Test Libra (results)* annexed to the CD of this dissertation).

Screen: Activity's history
This screen did not address many problems to tests participants. Moves' history screen has a similar structure to this screen. As the former was tested first in all the tests, all the participants showed they recognize the structure and in the latter screen they could perceive the information easier and faster. Still, some users had the same difficulties interacting with both screens.

In fact, accessing to it was more difficult because most of them did not perceive Activity's *history* button in *Activity detail* screen.

Screen: Goals
For some participants, this screen (Figure 103) was confused given its similarity with the *main menu* screen: both have four main buttons, positioned in the same place.

Figure 103: Goals screen (Us'em mobile app)

Screen: Goal's detail
Testes showed this screen (Figure 104) was perceived by only a few of the participants.

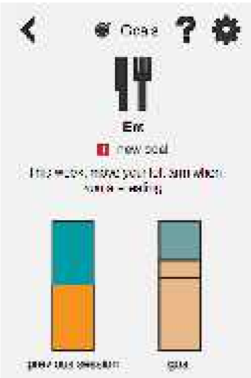


Figure 104: Goals detail screen (Us'em mobile app)

Some of them did not understand how they could interact with this screen. Indeed, this one does not require any user's action, but only displays information. This is about the goal they need to achieve: a brief explanation and two bars representing the latest score of their moves and the one they must achieved in a certain activity.
Furthermore, there was one subject that though the lines representing the goal to achieved and the previous session (on the bars) were not static. He thought he could change them to set, himself, the goal. It was not clear, thus, that the goal was already set.
In addition, there was another patient that could not understand the real meaning of the bars. He thought they were both regarded to past movements. This one mentioned that with subtitles, it would be easier.

Another one did not remember the meaning of the colors, so he could not say which part of the bar corresponded to the left and right moves.
Some subjects could not understand the screen at all. They required a detailed explanation about it.

Screen: Rewards
Overall, this screen (Figure 105) was not very clear.

Figure 105: Rewards screen (Us'em mobile app)

The list of rewards was not clear for some of the participants. Of that list, the bars representing the percentage of the left and the right arm-hand moves of the achieved goal should have different sizes according with the percentage they are representing.
It was mentioned by a patient that this screen could be termed as “Achievements” rather than “Rewards”. For him, the reward is improving. What he will receive through the mobile app will be a means of his achievements.
The numbering of rewards’ list was confused for some participants. For one, they meant the places of a challenge (1st place, 2nd place, etc.).

Screen: Language (settings)
Both the access and the interaction with this screen (Figure 106) were easy for every participant.

Figure 106: Language (settings) screen (Us'em mobile app)

The only possible action here, apart from those related to the top menu, is changing the language between English and Dutch or between Portuguese and English. It is done through two single buttons. Like the screen of Activity's detail, the easy accomplishment of the tasks asked to be performed this screen might be justified by the simplicity of the screen (number of interface elements and quantity of information displayed).

Screen: Sharing list (settings)

At a first sight, the square (green or red) on the right top of each thumbnail representing sharing status (on or off, respectively) was not clear (Figure 107). However, when accessed the screen with sharing details, it was more understandable.

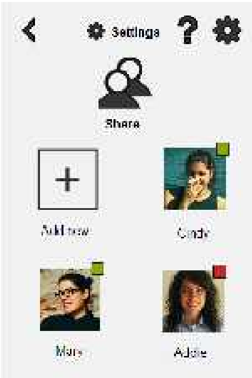


Figure 107: Sharing list (settings) screen (Us'em mobile app)

Screen: Sharing detail (settings)

Almost of participants understood the meaning of this screen (Figure 108) and which actions they could perform with it.

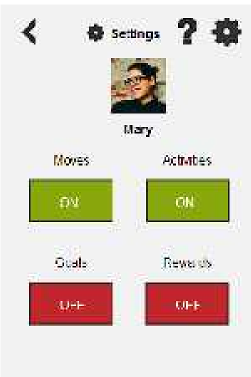


Figure 108: Sharing detail (settings) screen (Us'em mobile app)

Yet, part of them required an explanation about it: it was not clear the meaning of the green (on) and red (off) buttons. After this help, they mentioned it did make sense and the next interaction with this screen would be easy. It was suggested to represent the information is being shared with someone could be represented with tick boxes.

Screen: Text size (settings)
This screen (Figure 109) was clear for all participants.

Figure 109: Text size (settings) screen (Us'em mobile app)

Rewarding feedback alert
Every participant found this feedback message understandable, clear and easy to interact (Figure 110). One mentioned that it was pleasant to receive the smiley.

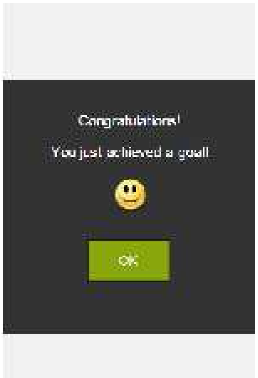


Figure 110: Rewarding feedback alert ((Us'em mobile app)

Tour
It was possible to test this feature only with one participant. Yet, he mentioned it was easy to understand and perceive its information. He did not have any problems.

Given the participants' feedback, it was possible to conclude several issues that somehow influenced negatively their user experience with Us'em mobile app prototype. Table 8 presents these aspects divided by Dutch and Portuguese participants. It shows a comparison between these two groups regarding UI elements of each screen that affected them. Some screens, as described before in this section, did not present any negative aspect, according to the participants. This is represented by "-" in the same table.
This table does not inform the number of tests participants that mentioned the referred aspects. However, the mentioned Portuguese feedback was given, in majority, by only one patient, while Dutch participants' feedback was given by all of them.

Table 8: Us'em mobile app UI (final prototype) negative aspects addressed by tests participants

Screen	Dutch participants	Portuguese participants
Real time moves	- graphs -"move's history" button (click on its arrow; difficult to perceive) - time navigation buttons - time navigation approach - chart's title	- subtitles text -"move's history" button (not understood as a button; difficult to perceive)
Moves' history	- buttons (small) - bar chart colors meaning - access to the screen (button in "Real time moves")	- time frame changing buttons - navigation buttons (small) - access to the screen (button in "Real time moves")
Activity detail	-	-
Track activity	-	-
Activity's history	- access to the screen (button in "Activity detail")	- access to the screen (button in "Activity detail")
Goals	- similarity with main menu	-
Check goal detail	- information displayed - bars and its lines - text size	- difficult to understand screen's information - bars colors meaning - previous session and goal's bars - legends (missing)
Check rewards	- screen's title - list numbering - rewards list - percentage of the achieved goals	- difficult to understand screen's information - list numbering - percentage of the achieved goals
Settings: sharing	- which information is shared - small icon on the thumbnails	- meaning of sharing buttons
Settings: language	- access to the screen	-

Apart from the feedback on each screen, testes showed other relevant aspects.

For instance, some patients did not know which button use when asked to go back to the previous screen. Two of them, when asked to go back for the first time, clicked on the smartphone buttons (hardware) instead of on the mobile app. The same did happen with some patients when asked to define settings, because they were used to setting smartphone's definitions.

When asked to return to the main menu, one clicked in *Settings* button on the top menu. Some would like to view their progress in other chart.

According to Dutch therapists, the difficulty of some patients has to do with the number of steps they need to do to execute certain task. It was due to their cognitive disorders. Additionally, buttons may have been a barrier, as some of them were not seen as buttons by patients. For instance, those enable the access to moves' history and activities' history should have another color to be more perceivable.

They referred the section of *Activities* as a very positive component. They mentioned patients' specific rehabilitation plan and training as a very relevant aspect of their treatment. Having their training activities detailed in Us'em mobile app is also valuable. Additionally, they purposed setting Us'em mobile app with certain and specific features adequate to each user before using it. They mentioned it during a test conducted with a patient with low technology literacy. The subject did not even understand that the interacting with the mobile app required touching the screen.

As a review, Table 9 represents screens were less and more problematic screens for tests participants.

Table 9: Comparison of level of difficulty of Us'em mobile app prototype screens

Screen	**Easy**	**Medium difficulty**	**Difficult**
Real time moves		X	
Moves' history		X	
Activities	X		
Activity detail (track)	X		
Activity detail (history)		X	
Goals	X		
Goal detail			X
Rewards	X		
Reward detail			X
Settings: sharing		X	
Settings: language	X		
Settings: text size	X		
Settings: sound	X		
Tour		X	
Feedback message	X		

10.4 Discussion and Conclusions

The evaluation of the final Us'em mobile app prototype, the usability tests, made possible ascertaining the adequacy of Us'em mobile app prototype concerning its users.
We conclude that several elements suit their requirements, enabling an easy user interaction and providing understandable information. Yet, there are aspects that must be redesigned. These conclusions are described below.

The responses of the *Credibility Expectancy Questionnaire* and the *Intrinsic motivation inventory* were analyzed and used to compare Dutch and Portuguese subjects.
Regarding their opinion about their hand-arm improvement at the end of the therapy using the Us'em mobile app, and with a purpose to conclude the differences of these answers, some aspects were considered and compared as indicated in Table 10.

Table 10: Comparison of data for concerning participants' rating on their future improvement if using Us'em mobile app

	Age	Nationality	Condition	Rehabilitation period	Technology literacy level	Mobile app experience	English level[191]
20%-40%	30	1 Portuguese	Chronic	3 years	Medium	No	-
40%-60%	72	1 Dutch	Chronic	1 year	Low	No	Middle
60%-80%	40 40 51	2 Portuguese 1 Dutch	Chronic; Subacute	One (subacute) with 2 months. The others, more than 6 months.	Low; medium; high	Yes; No	Low
80%-100%	43 45	2 Dutch	Chronic; Acute	5 months and 1 week (chronic); 3 weeks (acute).	High	Yes	High

The tendency of tests participants to give a higher rate to the potential improvement of upper limbs function with Us'em mobile app may be related with users' age. According to the results, higher rates were given by five subjects aged between 40 and 51 years old.

Concerning the nationality, it is verified that Portuguese patients rated lower (20%-40% and 40%-60%) than Dutch (40%-60%, 60%-80% and 80%-100%). One hypothesis for this fact is the technology development in both countries. In average, Dutch population has been introduced more with technology. That may means that technology acceptance is higher, so they will be more likely to see it as good tool in their rehabilitation. Other aspect that supports this hypothesis is the fact that the Dutch subject who gave the lowest rate among Dutch participants was the oldest (72 years old). Given his age, and also his low technology literacy, it is expected that his acceptance by these novel devices will be low as well.

Respecting the level of technology literacy in particular, it is not possible to draw any conclusions because the results show that it seems there is no relation between this aspect and the rates. Yet, it is possible to mention that high rates correspond to higher level of technology literacy. Another hypothesis for this idea is patients' desire of recovering. Acute and subacute patients are starting their rehabilitation while chronic ones are already doing it for a longer period. In this way, the latter can have already faced an improvement and find Us'em mobile app not so relevant, as they could recover without it until this moment. Contrary, the former individuals, because they are starting their rehabilitation, may be more likely to try different methodologies for their treatment.

In relation to patients' condition, all chronic patients rated from 20% to 100%, but acute and subacute ones did it with the higher rates. The hypothesis for this fact may have to do with the relation between rehabilitation stage and the need for exercise. That is to say that

[191] in the case of Dutch participants

acute or subacute patients have a shorter period to recover, so they need to exercise more. Using this mobile app might be, thus, more valuable for them. However, an aspect against this idea is the difference between stroke patients even in the same stage of rehabilitation. So, it may happen that both acute and chronic patients have the similar needs for exercising their upper limbs.

Consideration was given to the fact that the level of English of Dutch speakers may influence the way participants understand the real purposes of Us'em. As mentioned before in this section, the fact that the researcher/tester was Portuguese, despite the support of a Dutch therapist in these matters, may have affect the communication between the different participants. Thus, Dutch subjects could have given lower rates than the Portuguese because they were not provided with detailed information as the others. However, the results do not show any evidence that makes possible a conclusion on this issue.

In conclusion, the results do not show any relation between the mentioned patients' characteristics and their opinion with respect to the potential of Us'em mobile app in helping in their rehabilitation.

According to the participants, in particular to their responses on the "Intrinsic motivation inventory", after the test, Us'em mobile app is more relevant in increasing training and the using their arm-hand and improving their abilities than learning how to move it.

Before the test, three of six participants were positive respecting Us'em mobile app potential in helping them to reduce their arm-hand impairments. Yet, after the test, five of seven said the mobile app is helpful to improve their arm-hand disabilities. Hence, after the test, there were two more participants with a positive idea of Us'em mobile app potential. This may mean that the interaction with the mobile app changed their opinion and suggests that their experience with Us'em mobile app was valuable. Or, in other way, that only interacting with mobile app they clearly understood its purposes and its potential advantages.

Tests showed that post stroke patients a better user experience with a simpler and cleaner UI. Screens with fewer and less detailed elements were better perceived. They addressed less or any interaction experience concerns by tests participants. Likewise, screens with less interaction possibilities were better.

The easiest tasks to perform were track an activity and change mobile app language, text size and sound (settings). One hypothesis for this fact is the simplicity of the screens. In fact, these screens have, in maximum, three buttons and a short text that indicates the screen purpose. Thus, there is less information, enabling users perceiving the screen and its information. In addition, these screens require only one type of interaction: clicking a button. There are no other elements such as charts or navigation elements that require more attention and focus from the user. Hence, screen's meaning and purposes are clear and straight forward.

Moreover, tests participants' performance when interacting with settings screens, in particular setting language, text size and sound of the mobile app, suggest other hypothesis. The tasks executed in these screens are similar with tasks normally executed with mobile phones or tablets. Hence, is not new for users with experience in using these devices defining mobile app's settings. Although the screens and the way to execute the

tasks may be different, the purpose is the same. Thus, users are more likely to spend less time apprehending the screen and the tasks they can perform on it.
Simplicity is, thus, a requirement in Us'em mobile app, as concluded with data gathering before the design stage of this research.
As mentioned before and showed by Table 9, the difficulty of interaction with the mobile app did vary between screens.

Respecting to severity, the screens that are in the greatest need of a redesign are two of the most complex of the mobile app: *Goals* and *Rewards* screens. In particular, regarding (Dutch) therapists' feedback, *Rewards* screen is the most problematic. Therapists think it is not so understandable and it requires a new design. These two screens - *Goals* and *Rewards* - comprise more information and, because of that, require more attention and focus to be well perceived. Apart from that, tests showed that the interface elements used to display that information are not clear, hampering users understanding and interacting with the screen.
Other screens addressed less interaction problems: *Real time moves*, Moves' history, *Activity detail*, *Settings (sharing)* and the *Tour.*
Finally, *Activities*, *Activity* detail, *Goals*, *Rewards*, *Settings* (language, text size and sound) screens need fewer modifications.
All of these aspects that require adjustments are listed in Table 8.
The time of analysis of the screens did vary between participants. According to tests' results, it seems this did not vary according to their age, gender or nationality. It may have been influenced by the complexity of the screens or depended on their cognitive impairments or technology literacy. Nevertheless, these facts cannot be concluded, given the low number of covered cases.

Few icons of Us'em mobile app prototype are not clear and understandable for some patients. According to a therapist who participated in this research, the adequacy of the icons also depends on each patient. However, tests show that clearer icons are those that make contrast with the text and the background of the mobile app. In addition, tests results show that this question may be related with users' technology literacy. Participants with smartphones and/or mobile devices experience can recognize more easily certain icons. They were designed based on standard mobile apps icons and so were similar with those that tests participants are used to see in their devices. These icons refer to settings part of Us'em mobile app (buttons to settings, sharing, text size, language and sound). This is related to participants' age: younger participants have more experience interacting with technological devices. Thus, this is fact is considered a reason why this group had less difficult perceiving icons, as well as other interface elements and functions.
Understanding the icons may be also influenced by users' culture, because the same graphical information may have different meanings across cultures. However, tests conducted in this research do not enable drawing conclusions about this.
Additionally, users' background may also influence their perception of icons. This hypothesis is justified by the feedback of a participant working on a technical field. He referred, for instance, that the icon of *Moves* button meant, for him, statistics. Without the button's text, we would not think it could mean that.

Therefore, further research is needed to understand these issues and come up with an effective design that communicates the same information regardless users' culture, background and technology literacy. It might be a complex task given the variances of users' requirements that these issues address.

It is important to underscore the relevant role therapists may have in helping Us'em mobile app users understanding how the mobile app works and perceiving its information. As mentioned before in *Requirements and features* in chapter *Prototyping*, given the potential characteristics (due to stroke) of users, it is important they receive an explanation about how Us'em mobile app works, which information it provides and which is its benefit. This information may be provided by their therapists before start using Us'em mobile app. In this way, users will be more likely to better know how to interact with it and understand its graphic and textually information. Before the tests, participants were explained about the main issues of Us'em mobile app. It was only a brief explanation regarding tests' purposes though. Therapists would provide a more detailed explanation as well as a demonstration of how to use the mobile app. In this way, some problems addressed in the tests would be partially solved.
As it is known, there is an extended variety of stroke patients given the potential consequences of stroke. There is no way to find a unique solution for all of them. Thus, it might be positive to solve only the usability/interface design problems that affect a big group of users. The components that address barriers for a small group of individuals should be changed only if that modification will not affect negatively those who already perceive that element or information.

In general, Portuguese patients showed fewer difficulties in interacting with Us'em mobile app. This might be justified by different reasons:

- It is a mere coincidence and it does have any meaning;
- The researcher, who conducted the tests, is Portuguese. This fact may have influenced the design of Us'em mobile app. Despite the research about cross-cultural differences concerning rehabilitation, it was not done regarding mobile UI design or information visualization. Thus, though a subjective work, it may have been influenced by the culture and background of the researcher;
- Also due to researcher's nationality, tests may have been easier conducted as both tests' participants shared the same language. It enabled, thus, an easier communication. Contrary, some tests conducted in the Netherlands require the intervention of a Dutch speaker therapist to translate the information to the patient;
- Influence of the patients' characteristics: 1) age (Portuguese patients were, in average, younger than Dutch), 2) technology literacy (Portuguese patients had medium and high literacy, while Dutch had low and high), 3) cognitive impairments (any Portuguese participant had cognitive disorder, but there was one Dutch patient with it).

As mentioned before, tests findings show it is required to modify the device where Us'em runs. For instance, smartphone's screen was very hard and difficult to interact. In addition, participants mentioned it would be better to use this mobile app through a tablet or a PC. This was justified by their customary usage of these devices, the screen size that would

enable display the information with a bigger size making it clearer and, thus, the better interaction they would provide. Yet, one said it is positive to use this mobile app through a smartphone because it is easier for outdoor use.
Other conclusion about technical issues is Us'em devices might be too big for some users, so they should be decreased in size.
A final version of Us'Em mobile app was designed with a simplified interface, enabling different post stroke rehabilitation patients exercising and motoring independently, having a better, funnier and a more engaging experience.
The mobile app was approved by Dutch therapists and Dutch and Portuguese patients as a useful tool to support post stroke rehabilitation of upper limbs. Yet, the prototype resulted from this project still requires future developments and research, as described in the section *Future work*.

10.5. Future work

After the evaluation of Us'em prototype, we conclude Us'Em system's components still require future work. In this section future developments are described with particular focus on Us'em mobile app, as it is the scope of this dissertation project.

Us'em *mobile app: UI and features*
In the future, Us'em UI design requires adjustments, considering results of the tests conducted in this research. They are described in the previous sections.
Regarding its features, there are several aspects require adjustments and improvements and others should be implemented.
The final prototype has a screen which respects to sharing users' data (settings), but it is only a representation. In the future, it is necessary to structure, define and implement it in Us'em mobile app. This will require research about the more feasible communication protocol which, in turn might be relevant to determine interface design of that screen.
The prototype also comprises a representation of tracking data. It must be developed and implemented in order to really track an activity of the user.
This possibility concerns some issues about quality of data. User may tracks wrongly an activity. For instance, they may select the wrong activity or forget to stop tracking when they stop to perform that activity. In these situations, collected data will not coincide with reality. Hence, it should be possible to delete or edit that information. This, in turn, will lead to other questions. In fact, it is important to determine if the user is cognitively able to decide if information is real or not. Perhaps this possibility could be set by the therapists before the patient use the mobile app. Just as goals, therapists are the most appropriate stakeholders of Us'em to decide either patient is sufficiently responsible to do it or not. Additionally, it will require introducing new interface elements that enable users to perform this task. Thus, screens that provide it might need to be redesigned.
Us'em mobile app enables customization (users define some aspects of the app based on their preferences), which is very important for its users, given their uniqueness. The final Us'em mobile app prototype represents, in *settings* screen, the aspects that user can defined: text size, language, sound and people with who user shares data. However, the functions of setting these aspects were not implemented. Regarding language used in the mobile app, and in order to extend mobile app's target group, it is important to make

possible to define other languages than English, Dutch and Portuguese. But, should the mobile app offer the possibility to set one of two or more languages? This is another question that must be answered before. Moreover, Us'em mobile app enables change the size of its text but not the other interface elements such as graphs or buttons. Hence, it is required to analyze this question and determine if it is beneficial to make possible increase their size too.

Additionally, according to Us'em system defined in this project, therapist is responsible by the personalization of the mobile app. He is responsible to set user's goals, activities and available features. As explained before, according to patients' characteristics, therapist will define a set of features which the former is able to use. There will be a basic set of features, common to all users, to which more features can be added. As a future work, it is required to define these sets and assure they will be well integrated.

Furthermore, according to a therapists interviewed in his research, some users might be not able to define these settings though the mobile app. Thus, it might be needed to transfer this reasonability also to therapists.

Us'em mobile app does not enable customization according to which hand is used to interact with it. In this project research about these matters was done, but little information was found. Hence, it was not possible to design the mobile app based on these concerns. Yet, it is an important question as it influences user interaction and experience. For instance, using certain hand may hide parts of the screen, so user may not see some information. Additionally, this research does not approach issues related to the dominant hand of the user. A user whose impaired hand is the dominant is more likely to find more barriers interacting with the smartphone and mobile app. It is relevant to research about these matters and to determine how it influences user interaction with the smartphone and mobile app.

The present prototype does not provide users information about their progress towards their goals (how much/how often they need to move their arm-hand). First, it is necessary to research on this question and to find out if this information is relevant for Us'em users. Then, if they find this information relevant, it is necessary to find the best approach to represent it graphically.

With respect to the UI, the Us'em app prototype was designed to be used in a vertical/portrait orientation. However, using Us'em mobile app in a horizontal/landscape orientation may be a user's requirement. So, it is important to design the app in a landscape orientation and, thus, increase the ways users can use it and the number of end users.

Furthermore, this mobile app was designed according with dimensions and characteristics of smartphone's display used. Hence, in other devices, it might be visualized differently. The UI must be responsive, so its elements will be adjusted according to device's display.

Integrating speech recognition for input and enabling vibration, as a feedback method might be relevant to extend the target group of users. However, based on the findings of the interviews, they also address some concerns as they can represent a great amount of information provided to users. As there was no time to research about these issues, these features were not implemented. However, in the future is important to research about it because it may introduce benefits to the mobile app, extending its target group (patients with visual disorders).

In addition, regarding to UI colors, it is relevant to search on different approaches to present information about the moves of both arm-hands. Us'em mobile app uses orange and blue to represent, in charts, user's both arm-hands. Despite being complemented by a subtitle some times, these elements may not be correctly perceived by some users (or because they are color blind or because of their culture, background). Hence, it is fundamental to find out a solution that makes it easier to users to perceive this information.

Us'em system *and components*

At a technical level, one of the most important requirements for future research is connecting Us'em devices to the mobile app and enabling it to use and show real data tracked by the devices. The prototype resulted of this research is correctly connected to Us'em devices (Ant+ protocol), but the values they provided are not used. This feature was not implemented due to the lack of time. Currently, Us'em mobile app uses values that are randomly generated to represent users' upper limbs movements. It is required, thus, coding the mobile app in order to make possible using real values of users' upper limbs moves collected by Us'em devices.

According to the definition of Us'em system in this dissertation, this system is based on an internet connection, enabling the development of a new range of beneficial services (see an example of a scenario where Us'em system is used in the beginning of chapter *Prototyping*). Us'em system components (Us'em devices, mobile app, server and therapists and carer's hosts) are, thus, connected via internet. Us'em devices tracked data will not be transferred and stored directly in Us'em mobile app but it is first transferred to and stored in a central server. Future work should include the study, the implementation and test of this communication approach. New findings might emerge and contribute to design a better product, with new functionalities, that meets its users' requirements.

Implementing an internet-based strategy in Us'em system will increase the variety of devices where Us'em mobile app can run, as they are not required to have an Ant+ receiver. For instance, tablets might be better solutions for improving user interaction. That, as well as designing the mobile app for other operative systems (such as iOS), will extend the target group of users. Once it runs in *Android* and iOS devices without Ant+ components, it should be designing in order to be adaptable to the various interface conditions such as the screen resolution.

The participants of usability tests of Us'em mobile app prototype mentioned that the screen resolution and the display size of the smartphone used in this project is small, and the surface of its touchscreen is very resistant and not much touch sensitive. These aspects were negative as they affected user's interaction and experience. This situation was expected taking in consideration potential sensibility problems of stroke patients. However, a standard mobile app user (a person who had not experienced a stroke) faced the same problem. He interacted with the smartphone more carefully than usual and was required to make greater cognitive and coordinated efforts. Given that, the barriers are caused not only by stroke consequences but also by the characteristics of the display. So, we conclude Us'em mobile app should run in smartphones with a bigger display.

One relevant question has to do with the sensibility of Us'em devices (sensors), how they change their output when the input (information that is being measured) changes.
Us'em devices are positioned in user's wrist, so they can track moves of users' arm-hand. However, because of that, they cannot track certain users' hand or fingers moves. Hence, Us'em system may not be valuable for stroke victims with impairments on their hand fingers, but only to those who lost some of their arm-hand functions. It is necessary to evaluate this question and, thus, define in detail Us'em system end-users.
Still in these matters, it is necessary to consider what Us'em users are doing when moving their arm-hand. For some Us'em users (with a higher level impairment), slow and with a small range moves may mean they are training towards their recovery and improvement. But, on the other hand, for other users (those less impaired), the same values of movement may represent the moves they naturally execute when walking (while using Us'em devices). This information may not mean they are training and so that is not a means of progress. But, as the devices cannot determine that type of moves they are tracking, they will always count them as user's training. It will be relevant, thus, to design Us'em system in a way that it can evaluate the context of moves and determine if a specific frequency of user's moves corresponds to training or daily activities.

Other research

Apart from this future work, more research needs to be done.
First of all, more tests (with both patients and therapists from both countries) must be conducted to enable more concrete conclusions.
Us'Em users and its interaction with the mobile app must be observed in-home placement to have a more concrete idea about the performance of Us'em mobile app and system.
Furthermore, tests flow must vary between tests. Indeed, those conducted in this research show that, in some situations, participants have less difficulties interacting with certain screens similar with other already tested. As they learn how to interact, they are more likely to face fewer interaction problems. Hence, these screens should be tested without any previous learning process to comprehend its usability.
In addition, further research about cultural differences is required, not only with respect to rehabilitation patients, but also to information, graphics and content meanings and user interaction with mobile apps.
Additionally, future research should include tests in which participants are required to wear and use Us'em devices. It is important not only to verify if these conditions influence user interaction with Us'em mobile app, but also to test the usability of these devices. As they were not part of the scope of this project, it is not possible to present the improvements they might need as a physical product. However, based on the conducted usability tests, it is verifiable that its size should be decreased and they should become more ubiquitous.
Another issue about this Us'em system component is its range. It is important to know how far a user (devices) can be from the smartphone still enabling data transfer.
Other research path might be related to the psychological and cognitive effects on Us'em mobile app users when interacting with it. For instance, it might be important to study their cognitive state capacity. That is to say to know how much of cognitive activity is used to interact with it and how much left to perform other activities.

In conclusion, both Us’em system and mobile app are required to evolve over time to meet changing user requirements, markets and technologies.
This research project focused on Us’em interface design and aimed to improve it. It comprised final usability tests to verify the adequacy of the interface designed regarding its end-users. Tests showed the design meet part of users’ requirements. It needs, thus, future improvements and development. It gives its contribution for the improvement of Us’em but further research is needed.
Additionally, Us’em system as a whole, including its stakeholders and components, was also approached and defined, given Us’em mobile app reliance on it. According to its definition in this research, its components also require some modifications.
This project is, hence, part of an important path towards the design and development of a feasible and adequate product with a great significance for post stroke self-rehabilitation.

11. Final conclusions

The research project here described was based on the UCD methodology which comprised different stages: 1) End-users and Context identification, 2) Concept Development, 3) Product Design and 4) Evaluation. The implemented methodology was essential for developing a feasible final prototype of Us'em mobile app that meets its users' requirements. It allowed a better understanding of the problem, rapid testing and validation, end-user engagement throughout the project development and provided a clear vision of the reality. Hence, it contributed to achieve project's goals and to answer to the research questions.
However, there were challenges and constraints that have determined the path of the project and, consequently, have slowed down the research process and restrained the results obtained.

In this research, data was collected through literature readings and analysis, interviews, questionnaires and observations. It is concluded that they have contributed to have an ample perspective on rehabilitation after stroke. In addition, they have provided the opportunity to outline the potential that a mobile app may have in supporting post stroke self-rehabilitation. In particular, using these instruments was of great relevance for conceptualize and design a proposal (prototype) of Us'em mobile app UI.
Interviews and questionnaires were used to gather information from Dutch and Portuguese rehabilitation therapists, respectively. Due to their open structure, interviews enable collecting more data comparing with questionnaires. Hence, obtaining information with respect to Dutch reality of post stroke rehabilitation was an easier task. On the contrary, the questionnaires are a close and structured set of questions, and there is no space to adapt it according to participants' answers. Therefore, less and less detailed information was obtained from Portuguese therapist, even though the number of questionnaires participants was higher than those who were interviewed.
This strategy of using different techniques to gather information from therapists has to do with the fact that the project took place in the Netherlands. Because of this fact, the only way to obtain information from Portuguese therapists was through online questionnaires.
Moreover, during this stage, it was only possible to interview one post stroke patient. It was not a representative sample so, although the information gathered was relevant to this research, it is not possible to draw conclusions.

The research project phase that addressed more constraints was the *Product Design*.
One of them respects to the smartphone used in this project. The use of this smartphone was a requirement of this project as it was already part of Us'em research. Technically, it has certain components (such as the ANT+ technology) that are necessary for correct Us'em mobile app function. In addition, Us'em mobile application was developed to run on the 2.0 *Android* version. So, designing the Us'em mobile app in this research project relied on this fact as well. Smartphone's physical components, technology, the *Android* version that it runs limited the developments of this project. The smartphone is outdated and discontinued. Its touch interface is harder, very resistant and not much touch sensitive and its display has a lower resolution from those of current smartphones. Hence, it requires different interaction and visualization. In turn, the *Android* version is old and because of

that it is not possible to design certain features that are common in current smartphones. In addition, the *Android* version required made necessary to search for outdated *Android* functions. Thus, the final prototype was designed with functions that are no longer available to the latest *Android* versions.
Given these facts, it is of great importance to research, brainstorm and readapt the Us'em mobile application UI designed to the novel smartphones. It will, in turn, increase the number of devices where this app can run and, thus, of end-users.
This research stage was the most challenging. As Us'em mobile application was already developed and it was crucial for the design of its UI, it was necessary to understand how it works. It was a tough and time consuming process because it included learning a new programming language (Java) and about *Android* mobile apps, and a detailed understanding of the technical issues. In addition, it was necessary to deal with some problems on Us'em devices and assure they were working correctly and sending real information to Us'em mobile application (function not implemented in the final prototype).

The final evaluation (usability tests) was of great relevance since it enabled testing the adequacy of its UI. Evaluation results show that the final prototype is a feasible solution of great potential for supporting self-rehabilitation after stroke. Still, there were also some constraints in this stage.
The participants of the final usability tests were real potential end-users, which allowed drawing real conclusions. However, the sample used in this stage comprises 8 subjects (it is not representative), so it does not allow a generalization of the conclusions.
Moreover, tests participants had not interacted with Us'em mobile app prototype before the test. In this way, tests are not sufficient to ensure the mobile app can engage its users in the long term. Yet, some tests participants mentioned that are likely to use the mobile app during all their rehabilitation process and become engage in using it.
It is also considered that the results of the tests may have been influenced by the language of the participants. Tests were conducted by the research of the project, a Portuguese native speaker. Tests with Portuguese subjects were conducted in Portuguese, so the communication was not influenced by the language. Contrary, tests with Dutch participants were conducted in English, a language that was not native of any of them so it required other method. Dutch participants who do not understand English were supported by a therapist that translated the information. Those who can understand English it as easier, but, as it was a foreign language there may have been some misunderstanding that did not allow participants to understand clearly.
On the other hand, tests were conducted at rehabilitation clinics, in a meeting room, which may have been influenced the results. In fact, the potential real context of Us'em mobile app use is patients' personal settings, where the prototype should be test to obtain more reliable results.

It was of great importance for this study to interview post stroke patients from Portugal and the Netherlands and rehabilitation therapists. It allowed gathering information about some differences between these two countries regarding rehabilitation procedures and healthcare systems. However, due to the low number of interviewees, it was not possible to draw conclusions concerning the usability of Us'em mobile app prototype. Thus, further research in this sense is required, as mentioned in section *Future work* in the previous chapter.

This document comprises a description of both technical and design issues of this research project. Despite not being the focus of the research, technical issues were described because they were relevant for the understanding of Us'em research project (and its previous developments). In the same way, it is important to the next researcher of Us'em project having a detailed overview and report about what has been made in this project. Hence, regardless his research focus (technical or design aspects of Us'em devices or mobile app), he will have a better understanding project and it will be easier to continue Us'em project path. Thus, including technical issues in this document has the purpose to have this document as a base for next Us'em projects.

This research project shows Us'em mobile app as the potential to support post stroke rehabilitation. In addition, it is considered that the research results are important contributions for post stroke rehabilitation and mHealth fields. Yet, there are some constraints during the project that do not allow drawing conclusions. Thus, further research is required to assure an effective design of this app UI.

11.1 Original contributions and achievements

We believe that the work that supports this dissertation presents a useful contribution to the mHealth research field, in particular, in what concerns the design of mobile apps specifically developed to support the rehabilitation of stroke victims with upper limbs impairments. Indeed, this research project adds new information about the needs and requirements of those individuals with respect to the interaction with mobile apps as well as an innovative approach to increase rehabilitation outcomes.

12. References

ALERT. (2014). *ALERT*. Retrieved September 26, 2014, from http://www.alert-online.com/

Anderson, C., Rubenach, S., Mhurchu, C. N., Clark, M., Spencer, C., & Winsor, a. (2000). Home or Hospital for Stroke Rehabilitation? Results of a Randomized Controlled Trial : I: Health Outcomes at 6 Months. *Stroke*, *31*(5), 1024–1031. doi:10.1161/01.STR.31.5.1024

Anderson, C. S., Linto, J., & Stewart-Wynne, E. G. (1995). A Population-Based Assessment of the Impact and Burden of Caregiving for Long-term Stroke Survivors. *Stroke*, *26*(5), 843–849. doi:10.1161/01.STR.26.5.843

Anderson, J., & Rainie, H. (2012). *The Future of Gamification*. Retrieved from http://www.pewinternet.org/files/old-media//Files/Reports/2012/PIP_Future_of_Internet_2012_Gamification.pdf

Askim, T. (2008). *Recovery after stroke*. Norwegian University of Science and Technology. Retrieved from http://www.diva-portal.org/smash/get/diva2:124048/FULLTEXT01.pdf

Barakat, A., Woolrych, R. D., Sixsmith, A., Kearns, W. D., & Kort, H. S. M. (2013). eHealth Technology Competencies for Health Professionals Working in Home Care to Support Older Adults to Age in Place: Outcomes of a Two-Day Collaborative Workshop. *Medicine 2.0*, *2*(2), e10. doi:10.2196/med20.2711

Benjamin Franklin. (n.d.). *No Title*. Retrieved October 03, 2014, from http://www.brainyquote.com/quotes/quotes/b/benjaminfr383997.html

Berg, M. Van Den, & Heijink, R. (2011). Health care performance in the Netherlands: Easy access, varying quality, rising costs. … Union Law and Health, *16*(4), 27–29. Retrieved from http://www.lse.ac.uk/LSEHealthAndSocialCare/pdf/eurohealth/Vol16No4/EurohealthV16n4.pdf#page=30

Blaxter, L., Hughes, C., & Tight, M. (2010). *How to research* (3rd ed.). Retrieved from http://books.google.com/books?hl=en&lr=&id=Ow7bYYBA14sC&oi=fnd&pg=PP1&dq=HOW+TO+research&ots=fTUtZkqWXG&sig=bw1zSjdw-6RlbcOmjbnyEu4DSQY

Böcker, M., & Schneider, M. (2014). EHealth Applications for Those in Need: Making Novel Interaction Technologies Accessible. In *Pervasive Health* (pp. 47–68).

Boesten, F., & Markopoulos, P. (2009). Us'em: motivating stroke survivors to use their *impaired arm and hand in daily life*.

Burdea, G. (2002). *Key Note Address: Virtual Rehabilitation-Benefits and Challenges*.

Burke, J., & McNeill, M. (2010). Designing engaging, playable games for rehabilitation. In *Proceedings of the 8th Intl Conf. Disability, Virtual Reality & Associated Technologies* (pp. 195–201). Retrieved from http://www.icdvrat.reading.ac.uk/2010/papers/ICDVRAT2010_S07_N02_Burke_etal.pdf

Burke, J. W., McNeill, M., & Charles, D. (2009). Optimising engagement for stroke rehabilitation using serious games. The Visual …. Retrieved from http://link.springer.com/article/10.1007/s00371-009-0387-4

Burke, J. W., McNeill, M., Charles, D., Morrow, P., Crosbie, J., & McDonough, S. (2009). Serious Games for Upper Limb Rehabilitation Following Stroke. *2009 Conference in Games and Virtual Worlds for Serious Applications*, 103–110. doi:10.1109/VS-GAMES.2009.17

Cameirão, M., Bermúdez, S., & Verschure, P. (2008). Virtual reality based upper extremity rehabilitation following stroke: a review. … CyberTherapy & Rehabilitation. Retrieved from http://iactor.eu/downloads/JCR_spring_2008.pdf#page=61

Cardoso, G., Espanha, R., & Mendes, R. V. (2007). *INSTITUIÇÕES DE SAÚDE E TECNOLOGIAS DE INFORMAÇÃO: MUDANÇA ORGANIZACIONAL E AUTONOMIA*.

CECS - Centro de Estudos de Comunicação e Sociedade. (2012). *Mediatização jornalística no campo da saúde*.

Chen, K. (2013). *HoneyBee Rehabilitation System* (pp. 1–26).

CISCO. (2014). *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2013–2018*. Retrieved April 28, 2014, from http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white_paper_c11-520862.pdf

Claps, M., & Giguashvili, N. (2014). *Taking-on the chronic disease burden in the Hyper-Connected Patient Era*. *IDC Health Insights*. Retrieved from http://www.emc.com/collateral/analyst-reports/h13423-idc-taking-on-chronic-disease-burden-connected-patient-era.pdf

Cockburn, A. (2001). *Writing Effective Use Cases*. Retrieved from http://alistair.cockburn.us/get/2465

Cohn, M. (2004). *User Stories Applied: For agile software development*. Retrieved from http://books.google.nl/books?id=DHZP_YL3FxYC&printsec=frontcover&hl=pt-PT#v=onepage&q&f=false

Coleman, E. a, Smith, J. D., Frank, J. C., Min, S.-J., Parry, C., & Kramer, A. M. (2004). Preparing patients and caregivers to participate in care delivered across settings: the Care Transitions Intervention. *Journal of the American Geriatrics Society*, *52*(11), 1817–25. doi:10.1111/j.1532-5415.2004.52504.x

Constantine, L. L., & Lockwood, L. A. D. (1999). *The Development of a Mobile Monitoring and Feedback Tool to Stimulate Physical Activity of People With a Chronic* (p. 579).

Cunningham, S. G., Wake, D. J., Waller, A., & Morris, A. D. (2014). *eHealth, Care and Quality of Life*. (A. Gaddi, F. Capello, & M. Manca, Eds.). Milano: Springer Milan. doi:10.1007/978-88-470-5253-6

Curatronic Ltd. (2014). *Stroke recovery, stroke rehabilitation and stroke treatment at home.* Retrieved January 19, 2014, from http://www.biomove.com/stroke-rehabilitation-device.html

Deloitte. (2013). *November 18 2013*. doi:10.5555/2013NOV18

Deloitte Development LLC. (2014). *Home health care: New opportunities and challenges for care provided inside the home*. Retrieved from http://www.deloitte.com/assets/Dcom-UnitedStates/Local Assets/Documents/Center for health solutions/us_chs_HomeHealthCare_060214.pdf

Demiris, G. (2006). The diffusion of virtual communities in health care: concepts and challenges. *Patient Education and Counseling*, *62*(2), 178–88. doi:10.1016/j.pec.2005.10.003

Deterding, S., & Dixon, D. (2011). From Game Design Elements to Gamefulness : Defining " Gamification ." In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*. Tampere, Finland. Retrieved from http://85.214.46.140/niklas/bach/MindTrek_Gamification_PrinterReady_110806_SDE_accepted_LEN_changes_1.pdf

Deutsch, J. E., Brettler, A., Smith, C., Welsh, J., John, R., Guarrera-Bowlby, P., & Kafri, M. (2011). Nintendo wii sports and wii fit game analysis, validation, and application to stroke rehabilitation. *Topics in Stroke Rehabilitation*, *18*(6), 701–19. doi:10.1310/tsr1806-701

Di Carlo, A. (2009). Human and economic burden of stroke. *Age and Ageing*, *38*(1), 4–5. doi:10.1093/ageing/afn282

Duan, Y., & Canny, J. (2004). Designing for Privacy in Ubiquitous Computing Environments. *Unpublished Manuscript*. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.200.6385&rep=rep1&type=pdf

Duijvendijk, I. van, & Idzardi, K. (2013). *Samen werken aan beschikbare informatie binnen* de chronische zorg ("Collaborating on available information within the chronic care"). Retrieved from https://www.nictiz.nl/module/360/1001/Samen werken aan beschikbare informatie binnen de chronische zorg DEF.pdf

Duncan, P., Studenski, S., Richards, L., Gollub, S., Lai, S. M., Reker, D., … Johnson, D. (2003). Randomized clinical trial of therapeutic exercise in subacute stroke. *Stroke; a Journal of Cerebral Circulation*, *34*(9), 2173–80. doi:10.1161/01.STR.0000083699.95351.F2

EHEALTHSERVER. (2014). *Philips Expands Benelux Home Healthcare Offering*. Retrieved October 03, 2014, from http://www.ehealthserver.com/

ENSP-UNL. (2014). *Questionário Europeu de Literacia em Saúde aplicado em Portugal (HLS-EU-PT): Apresentação dos resultados preliminares*. Retrieved from http://www.saudequeconta.org/index.php/site/literacia

EpSOS. (2014). *epSOS*. Retrieved October 03, 2014, from http://www.epsos.eu/home.html

European Commission. (n.d.). *European Health Insurance Card*. Retrieved October 03, 2014, from http://ec.europa.eu/social/main.jsp?catId=559

European Commission. (2012a). Commission proposes a comprehensive reform of data protection rules to increase users' control of their data and to cut costs for businesses. Retrieved from http://europa.eu/rapid/press-release_IP-12-46_en.htm?locale=en

European Commission. (2012b). *Commission proposes a comprehensive reform of the data protection rules*. Retrieved September 15, 2014, from http://ec.europa.eu/justice/newsroom/data-protection/news/120125_en.htm

European Commission. (2014a). *GREEN PAPER on mobile He*alth ("mHealth").

European Commission. (2014b). *Protection of personal data*. Retrieved May 07, 2014, from http://ec.europa.eu/justice/data-protection/index_en.htm

Evers, S. M. A. A., Engel, G. L., & Ament, A. J. H. A. (1997). Cost of Stroke in the Netherlands From a Societal Perspective. *Stroke*, *28*(7), 1375–1381. doi:10.1161/01.STR.28.7.1375

Eysenbach, G. (2001). What is e-health? *Journal of Medical Internet Research*, *3*(2), E20. doi:10.2196/jmir.3.2.e20

Eysenbach, G. (2003). The Impact of the Internet on Cancer Outcomes. *CA: A Cancer Journal for Clinicians*, *53*(6), 356–371. doi:10.3322/canjclin.53.6.356

Eysenbach, G. (2008). Medicine 2.0: social networking, collaboration, participation, apomediation, and openness. *Journal of Medical Internet Research*, *10*(3), e22. doi:10.2196/jmir.1030

Feng, X., & Winters, J. (2010). OV Emerging Personalized Home Rehabilitation: Integrating Service with Interface. Medical Instrumentation: Accessibility and …, 1–19. Retrieved from http://books.google.com/books?hl=en&lr=&id=y_GtESjOI5IC&oi=fnd&pg=PA355&dq=Emerging+Personalized+Home+Rehabilitation+:+Integrating+Service+with+Interface&ots=9QlESUQ1nR&sig=toNwlWxAy6GKz3ruj5c0y8cQvOw

Ferreira, L. M. N. (2006). *A Internet como fonte de Informação sobre Saúde*. *Journal of* Health …. Instituto Superior de Ciências do Trabalho e da Empresa.

Ferreira, M. M., & Carmo, H. (2008). *Metodologia de Investigação – Guia para Auto-aprendizagem*. (Universidade Aberta, Ed.) (2nd ed., p. 354).

Ferro, V. A., & Bento. (2012). *SWORD – An intelligent vibratory wearable device to improve rehabilitation in stroke patients*. University of Aveiro. Retrieved from http://ria.ua.pt/bitstream/10773/10166/1/tese_virgílio bento.pdf

Feys, H. M., De Weerdt, W. J., Selz, B. E., Cox Steck, G. A., Spichiger, R., Vereeck, L. E., … Van Hoydonck, G. A. (1998). Effect of a Therapeutic Intervention for the Hemiplegic Upper Limb in the Acute Phase After Stroke : A Single-Blind, Randomized, Controlled Multicenter Trial. *Stroke*, *29*(4), 785–792. doi:10.1161/01.STR.29.4.785

Flaten, R. (2006). *Designing Inclusive Mobile Services*. Retrieved from http://karde.no/Prosjektrapport-Ragnhild Flaten.pdf

Franks, M. (2014). *Use Cases & Scenarios*.

Freitas, G. R. de, Bezerra, D. C., Maulaz, A. B., & Bogousslavsky, J. (2005). Stroke: background, epidemiology, etiology and avoiding recurrence. In M. P. Barnes, B. H. Dobkin, & J. Bogousslavsky (Eds.), *Recovery After Stroke* (pp. 1–46). Cambridge University Press. Retrieved from http://assets.cambridge.org/97805218/22367/excerpt/9780521822367_excerpt.pdf

Google. (2013). *Our Mobile Planet*. Retrieved March 03, 2014, from http://think.withgoogle.com/mobileplanet/en/

Governo da República Portuguesa. (2014). *Governo de Portugal - Ministério da Saúde*. Retrieved October 15, 2014, from http://www.portugal.gov.pt/

Governo de Portugal - Ministério da Saúde. (2014). *Portal do Utente*. Retrieved October 15, 2014, from https://servicos.min-saude.pt/utente/portal/paginas/default.aspx

Gray, D. (2009). *Doing Research in the Real World*. SAGE Publications Limited.

Hall, H. (2014). *Different Strokes for Different Folks: Assessing Risk in Women*. Retrieved March 08, 2014, from http://www.sciencebasedmedicine.org/different-strokes-for-different-folks-assessing-risk-in-women/

Hamari, J., & Sarsa, H. (2014). Does Gamification Work ? — A Literature Review of Empirical Studies on Gamification.

Health Data Exploration Project. (2014). *Personal Data for the Public Good: New Opportunities to Enrich Understanding of Individual and Population Health*. Retrieved from http://www.calit2.net/hdexplore/images/hdx_final_report.pdf

HealthDay. (2013). Stroke Affecting Younger People Worldwide, Study Shows. Retrieved from http://consumer.healthday.com/circulatory-system-information-7/blood-pressure-news-70/stroke-young-people-lancet-release-681368.html

Hernandez, L. M., Rosenstock, L., & Gebbie, K. (2003). *Who will keep the public healthy?: educating public health professionals for the 21st century*. National Academies Press.

HIMSS Europe. (2014). Networking The Eldery. *The Information Technology Journal for Healthcare Leaders*, *2*(4), 76.

Hochstenbach, J. (2000). Rehabilitation is more than functional recovery. *Disability and Rehabilitation*, *22*(4), 201–4; discussion 205. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2542969&tool=pmcentrez&rendertype=abstract

Hochstenbach-Waelen, A., & Seelen, H. a M. (2012). Embracing change: practical and theoretical considerations for successful implementation of technology assisting upper limb training in stroke. *Journal of Neuroengineering and Rehabilitation*, *9*(1), 52. doi:10.1186/1743-0003-9-52

HON. (2013). *Health on the Net Foundation*. Retrieved from http://www.hon.ch/home1.html

Hong, Y. (2012). *PRESERVING PRIVACY IN WEB-BASED E-HEALTH SYSTEMS*. Concordia University, Montreal, QC, Canada. Retrieved from http://www.albany.edu/faculty/hong/pub/master_thesis.pdf

Hossein Taheri, Justin B. Rowe, David Gardner, Vicky Chan, David J. Reinkensmeyer, E. T. W. (2012). Robot-Assisted Guitar Hero for Finger Rehabilitation after Stroke. In *EMBC 2012 - Annual International Conference of the IEEE Engineering in Medicine & Biology Society*. Retrieved from http://embc2012.embs.org/wp-content/uploads/unconference-abstract-3-ht-etw-jbr.pdf

Iachello, G., & Abowd, G. (2005). Privacy and proportionality: adapting legal evaluation techniques to inform design in ubiquitous computing. … Conference on Human Factors in Computing …, 91–100. Retrieved from http://dl.acm.org/citation.cfm?id=1054986

IATSL. (2014). *Intelligent haptic robotic system for upper limb rehabilitation after stroke*. Retrieved January 19, 2014, from http://www.ot.utoronto.ca/iatsl/projects/haptic_stroke.htm

Jara, A. J., Fernandez, D., Lopez, P., Zamora, M. A., & Skarmeta, A. F. (2013). Evaluation of Bluetooth Low Energy Capabilities for Tele-mobile Monitoring in Home-care. *Journal of Universal Computer Science*, *19*, 1219–1241. Retrieved from http://jucs.org/jucs_19_9/evaluation_of_bluetooth_low/jucs_19_09_1219_1241_jara.pdf

Johansson, T., & Wild, C. (2011). Telerehabilitation in stroke care--a systematic review. *Journal of Telemedicine and Telecare*, *17*(1), 1–6. doi:10.1258/jtt.2010.100105

Joubert, J. (2012). How telemedicine enhances stroke patient management: Part I – acute phase. *European Research in Telemedicine / La Recherche Européenne En Télémédecine*, *1*(3-4), 118–124. doi:10.1016/j.eurtel.2012.10.002

Kamel Boulos, M. N., & Wheeler, S. (2007). The emerging Web 2.0 social software: an enabling suite of sociable technologies in health and health care education. *Health*

Information and Libraries Journal, *24*(1), 2–23. doi:10.1111/j.1471-1842.2007.00701.x

Karlson, A. (2006). Understanding single-handed mobile device interaction. … and Evaluation for Mobile …. Retrieved from http://hcil.cs.umd.edu/trs/2006-02/2006-02.htm

Kemna, S., & Culmer, P. (2009). Developing a user interface for the iPAM stroke rehabilitation system. Rehabilitation …, 879–884. doi:10.1109/ICORR.2009.5209507

Ketikidis, P., Bath, P., & Lazuras, L. (2011). Acceptance of Health Information Technology in Health Professionals: An Application of the Revised Technology Acceptance Model. In *ISHIMR 2011* (Vol. 18). Retrieved from http://www.seerc.org/refbase/files/ketikidis/2011/621_Ketikidis_etal2011.pdf

Kofler, B. (2013). EHFG 2013: EUROPE'S MOBILE HEALTH SECTOR IS BOOMING. Retrieved from http://www.ehfg.org/fileadmin/user_upload/EHFG-E-F5-MHealth.pdf

Kramer, A., Fuhrer, M., Keith, R., & Materson, R. (1997). Rehabilitation care and outcomes from the patient's perspective. *Medical Care*, *35*(6). Retrieved from http://www.jstor.org/stable/3766795

Kunst, A. E., Amiri, M., & Janssen, F. (2011). The decline in stroke mortality: exploration of future trends in 7 Western European countries. *Stroke; a Journal of Cerebral Circulation*, *42*(8), 2126–30. doi:10.1161/STROKEAHA.110.599712

Langheinrich, M. (2001). Privacy by design—principles of privacy-aware ubiquitous systems. *Ubicomp 2001: Ubiquitous Computing*. Retrieved from http://link.springer.com/chapter/10.1007/3-540-45427-6_23

Langhorne, P., Coupar, F., & Pollock, A. (2009). Motor recovery after stroke: a systematic review. *Lancet Neurology*, *8*(8), 741–54. doi:10.1016/S1474-4422(09)70150-4

Lippincott, B., Morris, J., & Mueller, J. (2011). Keeping in Touch: Smartphone Touchscreens and Customers with Disabilities. In *Include 2011*. Retrieved from http://include11.kinetixevents.co.uk/rca/rca2011/paper_final/F367_2208.DOC

Lövquist, E., & Dreifaldt, U. (2006). The design of a haptic exercise for post-stroke arm rehabilitation. *Proceedings of the 6th International Conference Disability, Virtual Reality & Assoc. Tech*, (Idc), 309–315. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.109.3954&rep=rep1&type=pdf

Lum, P. S., Burgar, C. G., Shor, P. C., Majmundar, M., & Van der Loos, M. (2002). Robot-Assisted Movement Training Compared With Conventional Therapy Techniques for the Rehabilitation of Upper-Limb Motor Function After Stroke. *Archives of Physical Medicine and Rehabilitation*, *83*(7), 952–959.

Ma, M., McNeill, M., Charles, D., McDonough, S., Crosbie, J., Oliver, L., & McGoldrick, C. (2007). Adaptive virtual reality games for rehabilitation of motor disorders. *Universal*

Access in …, 681–690. Retrieved from http://link.springer.com/chapter/10.1007/978-3-540-73281-5_74

Maclean, N., Pound, P., Wolfe, C., & Rudd, A. (2000). Qualitative analysis of stroke patients' motivation for rehabilitation. *BMJ*, *321*(7268), 1051–4. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=27512&tool=pmcentrez&rendertype=abstract

Markopoulos, P., Timmermans, A. a a, Beursgens, L., van Donselaar, R., & Seelen, H. a M. (2011). Us'em: the user-centered design of a device for motivating stroke patients to use their impaired arm-hand in daily life activities. *Conference Proceedings : ... Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Conference*, *2011*, 5182–7. doi:10.1109/IEMBS.2011.6091283

McAdam, J., Leathley, M., Crichton, M., Dickens, J., Jack, C., & Watkins, C. (2013). Evaluation of a rehabilitation support service after acute stroke: Feasibility and patient/carer benefit. *Health*, *5*, 8. doi:10.4236/health.2013.57152

Mctear, M. F. (2002). Spoken Dialogue Technology: Enabling the Conversational User Interface. Retrieved from http://www.ling.helsinki.fi/kit/2002s/ctl190net/materiaali/spokendialoguetechnology.pdf

Myers, B., Hollan, J. I. M., Cruz, I., & Al, E. T. (1996). Strategic Directions in Human-Computer Interaction, *28*(4), 794–809.

MyFitnessPal Inc. (2014). *MyFitnessPal*. Retrieved January 20, 2014, from https://www.myfitnesspal.com/apps/show/125

National Health Service. (n.d.). *NHS*. Retrieved from http://www.nhs.uk/Pages/HomePage.aspx

National Institute for Public Health and the Environment. (2010). *Dutch Health Care Performance Report 2010*. Retrieved from http://www.gezondheidszorgbalans.nl/object_binary/o10229_DHCPR-2010(def)[1].pdf

National Stroke Association. (2014). *National Stroke Association*. Retrieved March 08, 2014, from http://www.stroke.org/site/PageNavigator/HOME

National Stroke Foundation - Australia. (2014a). *Effects of Stroke*. Retrieved from http://strokefoundation.com.au/what-is-a-stroke/effects-of-stroke/

National Stroke Foundation - Australia. (2014b). *What is a stroke*. Retrieved from http://strokefoundation.com.au/what-is-a-stroke/

Neil, T. (2012). *Mobile Design Pattern Gallery: UI Patterns for Mobile Applications* (p. 261). "O'Reilly Media, Inc." Retrieved from http://books.google.com/books?id=nneIitxjqUMC&pgis=1

Nictiz, & NIVEL. (2013). *eHealth monitor 2013*. Retrieved from http://www.nictiz.nl/uploaded/ehealth_book_en/Summary-eHealth-monitor-2013.pdf

NIKE INC. (2014). *NIKE+ RUNNING APP*. Retrieved January 21, 2014, from http://nikeplus.nike.com/plus/products/gps_app/

Pang, M. Y., Harris, J. E., & Eng, J. J. (2006). A community-based upper-extremity group exercise program improves motor function and performance of functional activities in chronic stroke: a randomized controlled trial. *Archives of Physical Medicine and Rehabilitation*, *87*(1), 1–9. doi:10.1016/j.apmr.2005.08.113

Pantelopoulos, A., & Bourbakis, N. G. (2010). A Survey on Wearable Sensor-Based Systems for Health Monitoring and Prognosis, *40*(1), 1–12.

Park, S., & Jayaraman, S. (2003). Smart textiles: Wearable electronic systems. *MRS Bulletin*, 585–591. Retrieved from http://journals.cambridge.org/abstract_S0883769400018881

Peeters, J. M., Wiegers, T. A., & Friel, R. D. (2013). How Technology in Care at Home Affects Patient Self-Care and Self-Management: A Scoping Review. *International Journal of Environmental Research and Public Health*, *10*(11), 5541–5564. doi:10.3390/ijerph10115541

Pestana, S. E. F. S. da C. (2011). *Saúde WEB 2.0 – O papel das comunidades virtuais de doentes na área da saúde: um estudo de caso para Portugal*. Retrieved February 10, 2014, from http://run.unl.pt/bitstream/10362/5369/1/TEGI0272.pdf

Pfarr, N., McColgin, D., & Jordan, M. (2014). Whats Next for Quantied Health: In-Context Decision Support for People with Chronic Conditions. In *CHI*. Retrieved from http://beyondqs.offis.de/wp-content/uploads/2014/04/proceedings.pdf

Phillips. (2014). *Phillips*. Retrieved June 05, 2014, from http://www.philips.pt/

Phiriyapokanon, T. (2011). *Is a big button interface enough for elderly users? Towards* user interface guidelines for elderly users. …. Mälardalen University, Sweden. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Is+a+big+button+interface+enough+for+elderly+users+?#0

Piron, L., Tonin, P., Trivello, E., Battistin, L., & Dam, M. (2004). Motor tele-rehabilitation in post-stroke patients. *Medical Informatics and the Internet in Medicine*, *29*(2), 119–25. doi:10.1080/14639230410001723428

Portal da Saúde. (2011). *Prescrição electrónica de medicamentos*. Retrieved October 21, 2014, from http://www.portaldasaude.pt/portal/conteudos/a+saude+em+portugal/noticias/arquivo/2011/8/pem.htm

Portal da Saúde. (2012). *PDS/PHR - Plataforma de Dados de Saúde*. Retrieved October 03, 2014, from http://www.portaldasaude.pt/portal/conteudos/a+saude+em+portugal/informatizacao/PDSenglishm.htm

Proot, I., Abu-Saad, H., Van Oorsouw, G., & Stevens, J. (2002). Autonomy in stroke rehabilitation: the perceptions of care providers in nursing homes. *Nursing Ethics*, *9*(1), 36–50. doi:10.1191/0969733002ne479oa

Público. (2014). *Só 838 mil utentes se registaram na Plataforma de Dados da Saúde*. Retrieved October 15, 2014, from http://www.publico.pt/sociedade/noticia/so-838-mil-portugueses-se-registaram-na-plataforma-de-dados-da-saude-1670996

Quivy, R., & Campenhoudt, L. Van. (2005). *Manual de Investigação em Ciências Sociais*. (Gradiva, Ed.) (4th ed.). Lisboa.

Rama, D. (2001). *Technology generations handling complex user interfaces*. Retrieved from http://www.narcis.nl/publication/RecordID/oai:library.tue.nl:545793

Rechel, B., Grundy, E., Robine, J., Cylus, J., Mackenbach, J. P., Knai, C., & Mckee, M. (2013). *Health in Europe 6: Ageing in the European Union* (Vol. 381).

Rijpma, G. (2014). *Three trends that support better patient engagement*. Retrieved May 08, 2014, from http://www.microsoft.com/health/ww/blog/Pages/post.aspx?postID=213

Roupa, Z., & Nikas, M. (2010). The use of technology by the elderly. Health Science …, *2*, 118–126. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=11087366&AN=51189636&h=K987QS8MFV9riBKc3wbViF9kdRsBi7Qf9ywsq1WsL9%2BlAVwASw3ml0cjozd%2Bby3%2BfcFFGq1HO6mlUho%2FRMRgOA%3D%3D&crl=c

Sá, M. de, Carriço, L., & Duarte, C. (2014). *Mobile Interaction Design: Techniques for Early Stage In-Situ Design*. Retrieved April 28, 2014, from http://cdn.intechopen.com/pdfs/5545/InTech-Mobile_interaction_design_techniques_for_early_stage_in_situ_design.pdf

Sacco, R. L., Kasner, S. E., Broderick, J. P., Caplan, L. R., Connors, J. J. B., Culebras, A., … Vinters, H. V. (2013). An updated definition of stroke for the 21st century: a statement for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke; a Journal of Cerebral Circulation*, *44*(7), 2064–89. doi:10.1161/STR.0b013e318296aeca

Sears, A., & Jacko, J. A. (2007). *The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications*. (C. Press, Ed.) (2nd ed.). Retrieved from http://books.google.pt/books?id=A8TPF_O385AC&num=16&hl=pt-PT&redir_esc=y

Seffah, A., Donyaee, M., Kline, R. B., & Padda, H. K. (2006). *Usability measurement and metrics: A consolidated model*. Retrieved from http://www-psychology.concordia.ca/fac/kline/library/sdkh06.pdf

Serviços Partilhados do Ministério da Saúde. (2014). *Serviços Partilhados no Ministério da Saúde*. Retrieved October 21, 2014, from http://spms.min-saude.pt/

Shen, S.-T., Woolley, M., & Prior, S. (2005). *Towards culture-centred design*. Retrieved from http://ac.els-cdn.com/S0953543805001165/1-s2.0-S0953543805001165-main.pdf?_tid=a62e0c30-fe06-11e3-bb3a-00000aab0f27&acdnat=1403879206_f6a46e899ea3ecfa0c4e1f468bbb6e29

Silverman, D. (2011). Research and theory. *Researching Society and Culture*, *13*(October). Retrieved from http://books.google.com/books?hl=en&lr=&id=jLAjZJGNGgAC&oi=fnd&pg=PA29&dq=Research+and+Theory&ots=vWhjHBTfVm&sig=C-5IfgFAUGwVpsH8X_21VNjPKi8

Simões, J. (2010). 18 . Tecnologias de informação e Comunicação na Saúde. In Almedina (Ed.), *30 Anos do Serviço Nacional de Saúde - Um percurso comentado*.

Singh, I. (2014). Ubiquitous Computing - Everywhere at the Same Time. *International Journal of Research in Computer Applications & Information*, *2*(2), 20–27. Retrieved from http://www.iaster.com/uploadfolder/5UbiquitousComputing-EverywhereattheSameTimeOL3Apr14Copy/5Ubiquitous Computing - Everywhere at the Same Time OL3Apr14 Copy.pdf

Stepánková, O., & Engová, D. (2006). *Professional competence and computer literacy in e-age, focus on healthcare*.

Steven, H. (2013). *How Do Users Really Hold Mobile Devices?* Retrieved May 08, 2014, from http://www.uxmatters.com/mt/archives/2013/02/how-do-users-really-hold-mobile-devices.php

Struijs, J. N., van Genugten, M. L. L., Evers, S. M. a a, Ament, A. J. H. a, Baan, C. a, & van den Bos, G. a M. (2005). Modeling the future burden of stroke in The Netherlands: impact of aging, smoking, and hypertension. *Stroke; a Journal of Cerebral Circulation*, *36*(8), 1648–55. doi:10.1161/01.STR.0000173221.37568.d2

Tacconi, D., Tomasi, R., Costa, C., & Mayora, O. (2013). A system for remote orthopedics rehabilitation. In *7th International Conference on Pervasive Computing Technologies for Healthcare and Workshops*. Retrieved from http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6563954

Talbot, L. R., Viscogliosi, C., Desrosiers, J., Vincent, C., Rousseau, J., & Robichaud, L. (2004). Identification of rehabilitation needs after a stroke: an exploratory study. *Health and Quality of Life Outcomes*, *2*, 53. doi:10.1186/1477-7525-2-53

Taub, E., Uswatte, G., van der Lee, J. H., Lankhorst, G. J., Bouter, L. M., & Wagenaar, R. C. (2000). Constraint-Induced Movement Therapy and Massed Practice Response. *Stroke*, *31*(4), 983–991. doi:10.1161/01.STR.31.4.983-c

Taylor-Powell, E., & Steele, S. (1996). Collecting Evaluation Data: Direct Observation. Retrieved from http://learningstore.uwex.edu/assets/pdfs/g3658-5.pdf

Teng, X.-F., Zhang, Y.-T., Poon, C. C. Y., & Bonato, P. (2008). Wearable medical systems for p-Health. *IEEE Reviews in Biomedical Engineering*, *1*, 62–74. doi:10.1109/RBME.2008.2008248

Timmermans, A. (2010). *Technology-Supported Training of Arm-Hand Skills in Stroke*. Eindhoven University of Technology.

Timmermans, A. A. A., Seelen, H. A. M., Willmann, R. D., & Kingma, H. (2009). Technology-assisted training of arm-hand skills in stroke: concepts on reacquisition of motor control and therapist guidelines for rehabilitation technology design. *Journal of Neuroengineering and Rehabilitation*, *6*, 1. doi:10.1186/1743-0003-6-1

Usability.org. (2014). *Use Cases*. Retrieved April 20, 2014, from http://www.usability.gov/how-to-and-tools/methods/use-cases.html

Van der Weegen, S., Verwey, R., Spreeuwenberg, M., Tange, H., van der Weijden, T., & de Witte, L. (2013). The Development of a Mobile Monitoring and Feedback Tool to Stimulate Physical Activity of People With a Chronic Disease in Primary Care: A User-Centered Design. *JMIR Mhealth and Uhealth*, *1*(2), e8. doi:10.2196/mhealth.2526

Van Peppen, R. P. S., Kwakkel, G., Wood-Dauphinee, S., Hendriks, H. J. M., Van der Wees, P. J., & Dekker, J. (2004). The impact of physical therapy on functional outcomes after stroke: what's the evidence? *Clinical Rehabilitation*, *18*(8), 833–62. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15609840

Verónica, A., & Geppaart, G. (2010). *Health Care In The Netherlands*. Retrieved March 04, 2014, from http://www.access-nl.org/media/13949/health_care_guide_completed.pdf

Vliet, R. van. (2013). *No Title* (pp. 1–51).

Wang, Q., Chen, W., & Markopoulos, P. (2014). A Review on Wearable Systems in Upper Extremity Rehabilitation Field. In *IEEE-EMBS International Conference on Biomedical and Health Informatics* (pp. 551 – 555). IEEE. doi:10.1109/BHI.2014.6864424

Wharton, C., Rieman, J., Lewis, C., & Polson, P. (1993). *The Cognitive Walkthrough* Method: A Practitioner's Guide. Colorado. Retrieved from http://www.colorado.edu/ics/sites/default/files/attached-files/93-07.pdf

WHO. (2012). *Are you ready? What you need to know about ageing*. Retrieved September 15, 2014, from http://www.who.int/world-health-day/2012/toolkit/background/en/

WHO. (2013). *Mental health and older adults*. Retrieved September 15, 2014, from http://www.who.int/mediacentre/factsheets/fs381/en/

WHO. (2014a). *Stroke, Cerebrovascular accident*. Retrieved January 06, 2014, from http://www.who.int/topics/cerebrovascular_accident/en/

WHO. (2014b). *The top 10 causes of death*. Retrieved September 15, 2014, from http://www.who.int/mediacentre/factsheets/fs310/en/

WHO. (2014c). *WHO | World Health Organization*. World Health Organization. Retrieved January 13, 2014, from http://www.who.int/en/

Wilkowska, W., & Ziefle, M. (2012). Privacy and data security in E-health: requirements from the user's perspective. *Health Informatics Journal*, *18*(3), 191–201. doi:10.1177/1460458212442933

Willems, L. L. (2013). *Design Of Patient Feedback For Arm-Hand Training With TagTrainer*.

Willmann, R. D., Lanfermann, G., Saini, P., Timmermans, A., te Vrugt, J., & Winter, S. (2007). Home stroke rehabilitation for the upper limbs. *Conference Proceedings : ... Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Conference*, *2007*, 4015–8. doi:10.1109/IEMBS.2007.4353214

Wingen, J. C. W. van. (2013). Us'Em motivating arm-*hand use with wearable technology' a follow-up project of 'Stroke Rehab @ Home*.

Winters, J. M. (2002). Telerehabilitation research: emerging opportunities. *Annual Review of Biomedical Engineering*, *4*, 287–320. doi:10.1146/annurev.bioeng.4.112801.121923

Winters, J. M., Wang, Y., & Winters, J. M. (2003). Wearable sensors and telerehabilitation. *IEEE Engineering in Medicine and Biology Magazine : The Quarterly Magazine of the Engineering in Medicine & Biology Society*, *22*(3), 56–65. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12845820

World Health Organization. (1980). *International Classification of Impairments, Disabilities, and Handicaps*. Retrieved from https://extranet.who.int/iris/restricted/bitstream/10665/41003/1/9241541261_eng.pdf

World Health Organization. (2001a). *Atlas eHealth country profiles: based on the findings of the second global survey on eHealth*. Retrieved from http://whqlibdoc.who.int/publications/2011/9789241564168_eng.pdf

World Health Organization. (2001b). *International Classification of Functioning, Disability and Health*. Retrieved February 11, 2014, from http://www.disabilitaincifre.it/documenti/ICF_18.pdf

World Health Organization. (2008). *HOME CARE IN EUROPE*. Retrieved from http://www.euro.who.int/__data/assets/pdf_file/0005/96467/E91884.pdf

World Health Organization. (2011). *World Report on Disability*. Retrieved January 13, 2014, from http://whqlibdoc.who.int/publications/2011/9789240685215_eng.pdf?ua=1

World Health Organization. (2012). *Management of Patient Information*. Retrieved from http://apps.who.int/iris/bitstream/10665/76794/1/9789241504645_eng.pdf?ua=1

Wottrich, A. W., von Koch, L., & Tham, K. (2007). The meaning of rehabilitation in the home environment after acute stroke from the perspective of a multiprofessional team. *Physical Therapy*, *87*(6), 778–88. doi:10.2522/ptj.20060152

Wressle, E., Eeg-Olofsson, A.-M., Marcusson, J., & Henriksson, C. (2002). Improved client participation in the rehabilitation process using a client-centred goal formulation structure. *Journal of Rehabilitation Medicine : Official Journal of the UEMS European Board of Physical and Rehabilitation Medicine*, *34*(1), 5–11. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11900262

13. Appendices

This chapter presents the appendixes referred throughout the present document.

Appendix 1: *Interviews-Libra Therapists (results)*
Appendix 2: *Summary low- and medium high-fidelity prototypes*
Appendix 3: *Summary high fidelity prototypes*
Appendix 4: Us'e*m stakeholders goals*
Appendix 5: *Test high-fidelity prototype (Jamel)-results*
Appendix 6: *Test low-fidelity prototype (Jamel)-results*
Appendix 7: Diagram Us'em system overview (available tasks for each Us'em system *stakeholder)*
Appendix 8: *Usability Tests (results-charts)*

Appendix 1: ***Interviews-Libra Therapists (results)***

(Important: all the figures mentioned in this appendix are present in document *Interviews-Libra Therapists (guide)* (annexed to the CD of this dissertation).

Place: Libra Revalidatie & Audiologie
Interviewee (s): Marielle Timmermans and Roy van der Meer (physical therapists of stroke patients)

Consent to use information collected in the interview:

1. Do you allow the use of this information in this research project?

Yes [X] No [ ]

2. Do you allow the transcription of this information in this research project?

Yes [X] No [ ]

3. Do you allow to be identified in this research project?

Yes [X] No [ ]

Questions

A. Dutch reality in post stroke rehabilitation and rehabilitation at Libra

1. **When rehabilitation starts at the clinic?**

Usually, after discharge from the hospital, patients move to the clinic where they live. Then, when they are able to live autonomously, they go home. However, they still need to go the clinic 2 or 3 times a week to attend therapy sessions.

2. **What is the first thing to do when a new patients starts rehabilitation at the clinic?**

First of all, according to their condition, patients are classified in: a) Physically impaired; b) Cognitively impaired; c) Physically and cognitively impaired.
It is important to considerate cognitive impairments may be more relevant than physical problems for some patients. Sometimes, even though patients show physical self-reliance, their cognitive damage may be so severe that they may endanger their and other's lives if they go home. Thus, they must stay at the clinic.
If they have upper limb impairments, they are grouped in 3 different categories: a) Patients who cannot move their arm-hand at all; b) Patients who can move a lilt bit their arm-hand; c) Patients who have some function in their arm-hand.

When all of these patients start rehabilitation at the clinic, they have private sessions but they are also integrated in group sessions (which include patients from the 3 groups of upper limb impaired patients).
The groups of patients who have already some ability to perform some tasks are those who require more stimulation because, as they can still perform tasks with the not impaired hand-arm, they do use either train their impaired one.

3. **Who is involved in the rehabilitation?**

There is one rehabilitation team for each patient. This team involves people from different disciplines, such as physical therapy, cognitive therapy, and psychology, among others. Each one defines a rehabilitation plan in his/her field and then they present to the others team members. After an agreement, the all team set a rehabilitation plan for the patient.
In doing that, they need to considerate patients' interests, needs and goals. It is also very important to get to know patients, their impairments, conditions and habits before the stroke and their goals in order to set the proper plan.
Every 4 or 5 weeks they meet and evaluate the patient.

4. **How physical therapy goals are set?**

Physical therapy goals' setting is on the basis of an agreement between therapist and patient, considering therapist and patient's aims. Therapist needs to know patient's previous daily life and habits, his/her personal future goals and which activities (s)he wants to perform in the future. Hence, according to his prognosis and patient's condition, therapist can conclude which goals are achievable. Thus, he can define specific therapy goals. Sometimes, patients have goals that impossible to achieve, such as regain certain ability. In these cases, as soon as therapists realize that is not possible, they are honest and tell them the goals are not achievable.
"*We need to be honest to the patient. If he/she wants to regain a certain function and we know that it is not going to be possible, we tell him/her*".

5. **Which are the rehabilitation goals?**

Each patient is different, so each of them has different requirements, needs and goals to achieve.
However, usually, the first rehabilitation training goals are gaining mobility, not feeling pain and taking care of the impaired hand-arm.
Then, it is aimed to regain the ability to perform basic and daily activities such as eating, dressing up or grab objects.
The next goals are related to recover arm-hand function as much as possible.

6. **Which type of physical therapy is provided to patients?**

Physical therapy is provided by sessions which exercises are targeted to patients' goals. Thus, they perform exercises which moves are similar to those that are done daily or in specific activities that patients want to be able to perform, even if those activities require the use of both arm-hands.
These exercises vary to avoid patients get bored and to exercise arm-hand in different ways.

To those patients who cannot do any move with their arm-hand, electrodes are used to "revival" their muscles.
Sometimes, CIMT technic is used in order to force patients to use their impaired arm.

7. **How are sessions held?**

Therapists schedule therapy sessions with patients. At the session, patients are required to perform the exercises are planned and therapists supervise their performance. Then, therapists note his/her findings in patients' record.
These sessions' duration may vary, according to patients' rehabilitation plan. Usually, it takes 30 minutes. They are kept short to avoid patients feel tired or bored.
Therapists need to be very focused on patients' performance and feelings during the session. For instance, when patients get bored, frustrated or tired, it may be need to change the exercise.

8. **What does motivate patients?**

Each person is unique, so each one has already different ways to get motivated.
In addition, each patient experiences a stroke in different way. Which type and intensity of stroke he/she experienced, which part of the brain was affected, how he/she accepts his/her new condition, and others.
Usually, patients are more motivated when they perform exercises which moves are similar to those they will need to do in certain activities they want to perform again.
In addition, they may also get motivated if they received positive feedback.
Some patients are highly motivated to recover which, sometimes, may be prejudicial. Indeed, exercising too often or too hard may have negative outcomes. Thus, sometimes it is need to calm down them and make them train in a proper way.
The rehabilitation process is a long process and it has "*small steps where significant improvement may take some time*".

9. **How are patients' families involved in the rehabilitation process?**

When a new patient starts rehabilitation, his/her family is provided with information about the consequences of the stroke event, the patient new needs and condition and they are taught how to help him/her at home. For instance, they learn how to move him/her from his/her wheelchair to a car or how to hold them when using stairs.
During the process, they can accompany the patient on clinic visits or/and sessions once a week.
When needed, they may ask therapist for more information.

10. **Do you encourage patients to exercise at home?**

Patients are provided by an exercises book which shows which type of exercises and how they can do at home. They also may get a tablet app[192] which provides exercises and videos exemplifying how to perform them. In addition, patients can use it to schedule exercising sessions.

---

[192] http://www.dehoogstraat.nl/onderzoek-innovatie/beroerte-cva/diensten-en-producten/oefen-app-beroerte

B. Us'Em system

1) **Do you think Us'Em project may be a potential tool to enhance self and home-based rehabilitation of post stroke rehabilitation patients? Do you think the majority of your patients would use it?**

Both therapists did agree that Us'Em system might be a very relevant tool to help patients exercising at home and to make them to do it more often. "*Patients will feel more autonomous and that is very important in their recovery process*. Thus, I think Us'Em *system will encourage them to train at their home, achieving faster results in their process*". However, they did point out that some patients are over-motivated and they want to exercise more than they should. Excessive exercising may affect negatively rehabilitation process in the way that new problems may arise and recovery may slow down or even stop. These cases need to be careful considered as Us'Em system can further increase patients' desire to exercise more and more.
Therapists were of the opinion that many patients would not use Us'Em system not because they do not want, but because they are incapable to use a smartphone or a mobile application. Some patients with upper limb impairments cannot use their arm-hand to hold a smartphone or to wear Us'Em devices. On the other side, most of patients are aged over 45 years old and, among these, the majority is aged over 65. Because of that they have low technological literacy and are not used to use smartphones. In this way, they would have difficulties in using Us'Em app. Many of them use, yet, computers and tablets. Even that, the use of these devices is increasing among these individuals, so in the future they will be able to use them. "*Young people will not almost certainly have* barriers with respect to Us'Em app and system. In fact, all of them or almost all have a smartphone and use several mobile apps."

2) **Do you think its use may lead to negative consequences in the rehabilitation process of the patient?**

As mentioned in the previous question, therapists did say that for those patients with high levels of motivation, the use of Us'Em may lead to negative consequences. Apart from that, they do not think it is negative. On the contrary, "*with a proper use, it may be very beneficial*".

3) **Which characteristics do you think Us'Em system must have?**

Therapists mentioned that it will be better if the application could run in a tablet, considering low rates of smartphone usage, and in other smartphones. User should be able to download Us'Em app, regardless their smartphone.

4) **Regarding Us'Em app, which features do you think it must have?**

They emphasized that app should be "*simple and easy to use*", bearing in mind patients with cognitive impairments. "*They can have problems in memorizing, reading, seeing,* remembering…(…*). For example, if there will too many details or colors it will be difficult* for them to analyze the application. (…) Some of them can o*nly see some colors or only understand images rather than text...*"*.* The information presented by the app should be understandable, that is to say, that patients should be able to understand its meaning and its relation with this recovery and progress.

C. Graphic elements designed to Us'Em app prototype - analysis

At the end of the interview, therapists were provided by few charts and images designed to represent certain information in Us'Em app (See these materials in document *Interviews-Libra Therapists (guide),* annexed to the CD of this dissertation9. Their feedback was recorded and it briefly described below.

Overall:

- Charts related to patients' moves should make clear that they represent moves' quantity and not quality.
- It should be possible to know patients' moves in a specific activity that they need to train on. It will provide more detailed information, enabling a better patient assessment. "*In rehabilitation, progress has to do more with quality than with quantity*. (…) there is no score, it's abou*t quality*". The most frequent activities are eating, grabbing objects, dressing up, getting up and laying down.
- Regarding app's feedback to patient, using a smiley motivates patients. The important thing to consider in providing feedback is the way it is done: it cannot affect patient negatively.

Regarding charts to represent the ratio of patients' moves, according to therapists, the best approach is a) (in document *Interviews-Libra Therapists (guide)* (annexed to the CD of this dissertation). It represents moves of each arm separately, so patient might be able to see which one he is moving more. However, for their use, they would chose c), in the same figure, as the horizontal direction shows clearly which side represents each arm.

Regarding representing patients' goals, both approaches presented to therapists were positively evaluated. They think that both are understandable and represent well how much is left to achieve the goal.

With respect with the representation of patients' moves history and patients' progress, therapists did agree with the charts presented. In their opinion, it is easy to understand its information. The only think they would modify is the number of days that are represented. If the chart shows many days, there will be too much information to be analyzed.

They did affirm, though, that there is no way to represent certain information that suits every patient. Each of them is unique, with different impairments, different requirements and different ways to perceive information. One approach might be very understandable for only a few of them. Thus, they consider the best way to determine which is best approach to represent information is to understand which one is understandable by the higher number of individuals.

Interview notes:

Apart from these questions, it was possible to discuss with therapists did point out some relevant facts and questions such as follows:

Stroke events affect patients' brain. When it is affected on the right side, patients tend to not see the left side, are more likely to move to the right and to be less sensible or not feel their left limbs. Contrary, if their brain will be affected on the left side, their will face those

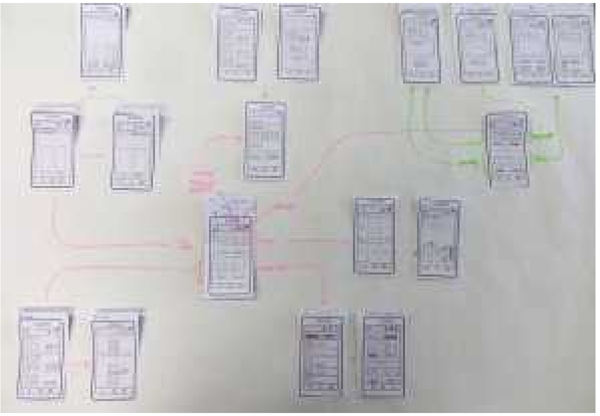
impairments on the right side. These cases are also more likely to present speech impairments.
While some patients did express interest in knowing how much they move their impaired arm-hand, for therapists is more important to know the specific activity patients did move it more. This information enables them to evaluate patient with more detail.
Patients are provided by feedback about their recovery process. It is better to tell them if they are improving or not than to tell them a lie. The important thing is how they are informed. "*In cases that there is no much progress, we need to be careful to not demotivate the patient*".
In general, patients are old, over 40 years old, and therapists do not notice any difference about this fact in the last few years. Mainly because of their ages, most of patients are not used to use smartphones. However, some of them use computers or/and tablets.
Regarding rehabilitation plan and therapy, therapists emphasized the need to know the patient.
Regarding Us'Em, they made some questions and mentioned issues that should be analyzed:

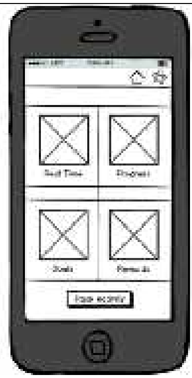
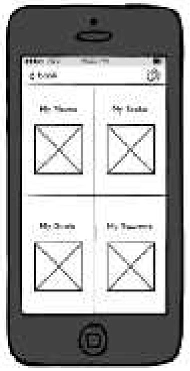
- the sensibility of Us'Em devices sensors. "Do Us'Em devices count patients' *moves when they are walking or when they are wearing the devices?*".
- the fact that Us'Em system maybe should be known by being related only to arm function. In fact, if the patient is just moving their hand, the devices will not sense any move.
- Us'Em aims: "Is it intended to assess the quality or quantity of the patients' *moves?*"
- "*this app might be also relevant to other individuals and in other contexts. For instance, it might be useful for those who experience an accident in the way that can help them to recover their lost motor functions in the upper limbs.*"

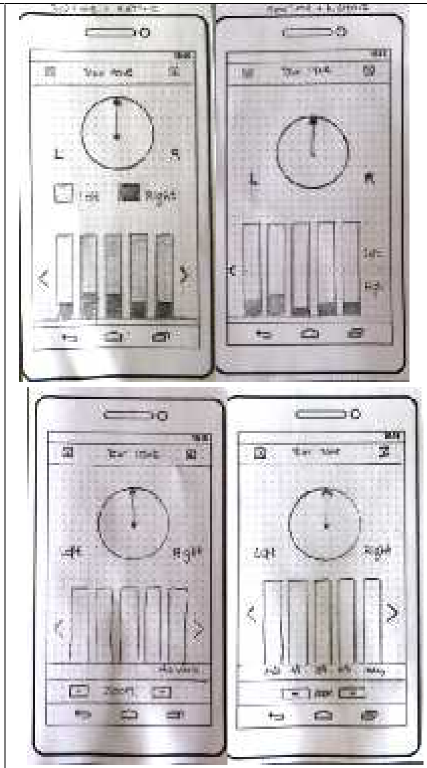
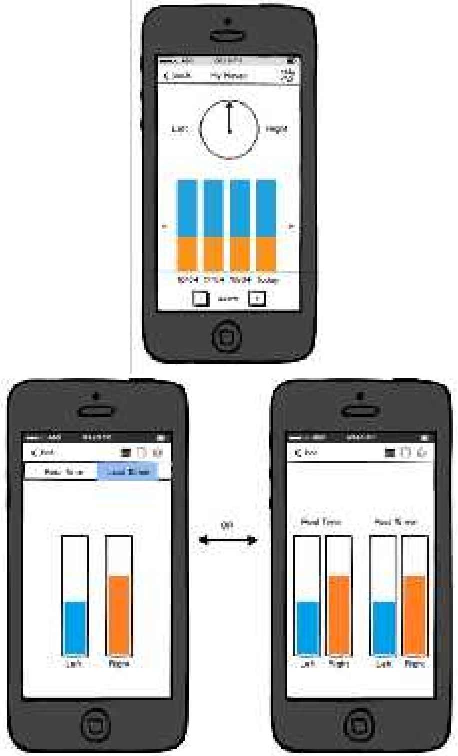
Us'Em could be relevant to know which individuals recover faster: those with impairments on their dominant hand or those impaired on their non-dominant hand.

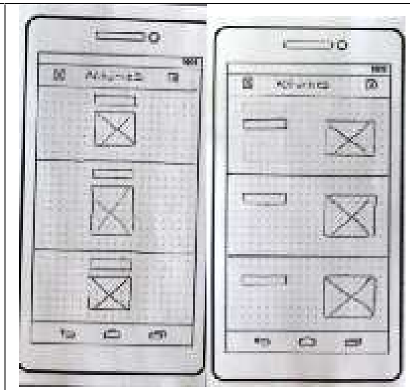
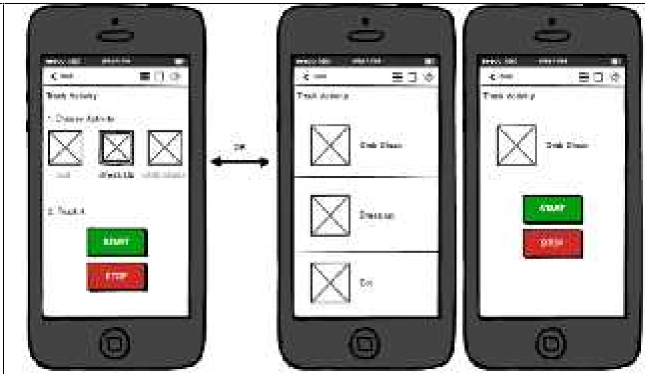
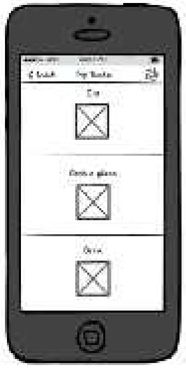
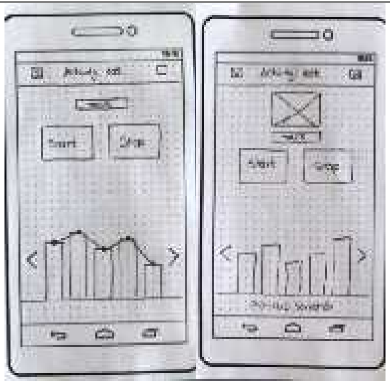
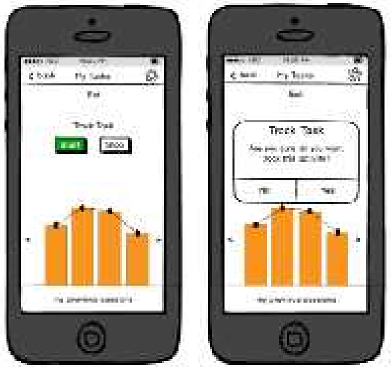
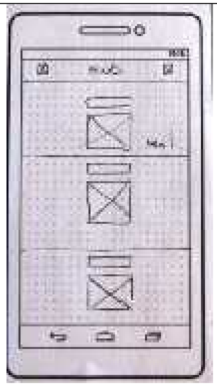
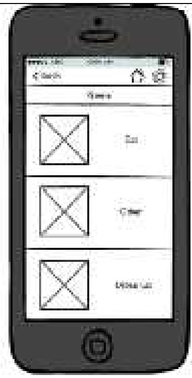
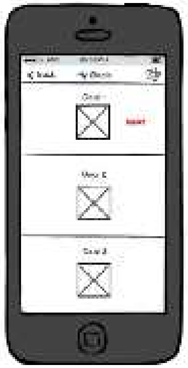
Appendix 2: ***Summary low- and medium high-fidelity prototype***

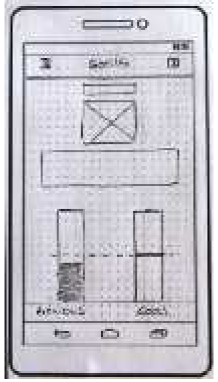
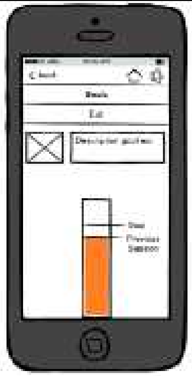
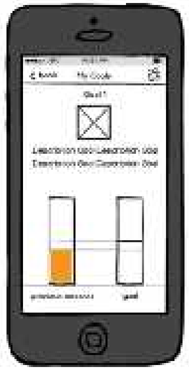
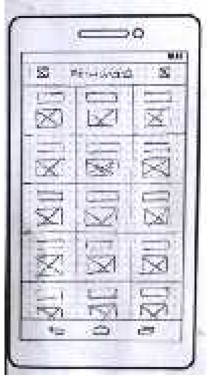
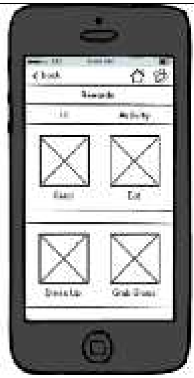
V1 (low-fidelity prototype)

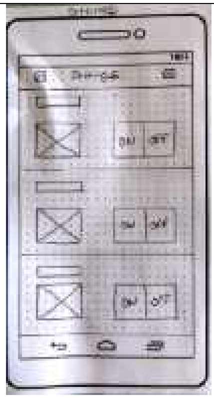
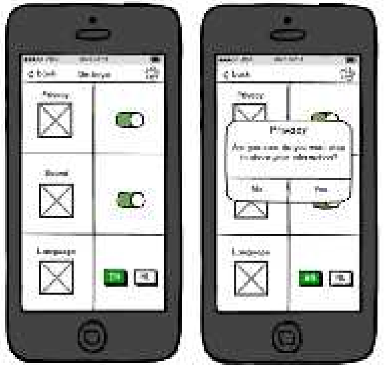
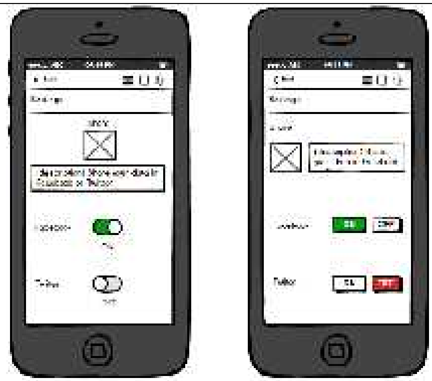
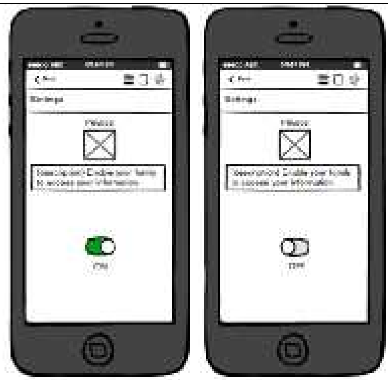


	Prototype version		
Screen	**V2 (low)**	**V3.1 (medium-high)**	**V3.2 (medium-high)**
Menu			

Real time moves / Moves' history			
Moves' history	This screen was not designed because its functionalities were included in *Real time moves* screen (image above)		

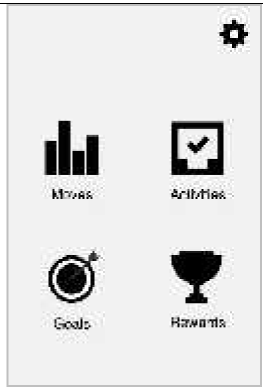
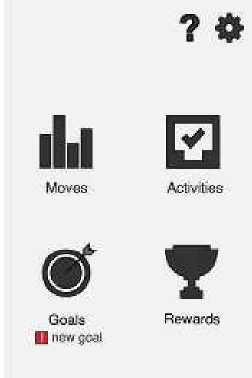
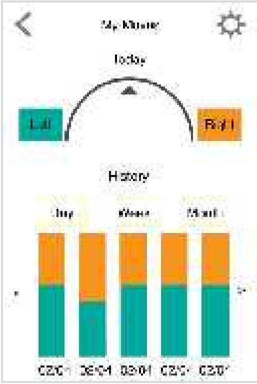
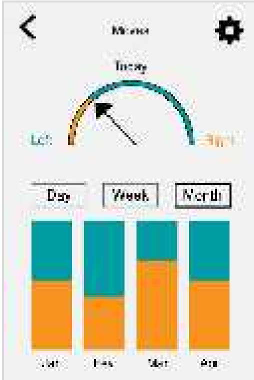
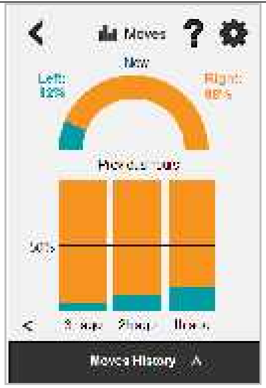
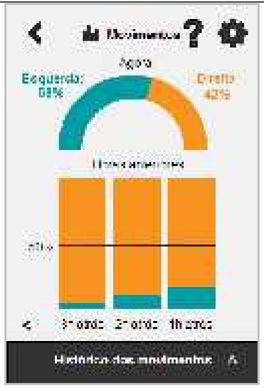
Activities list / Track Activity			
Activity detail			
Goals list			

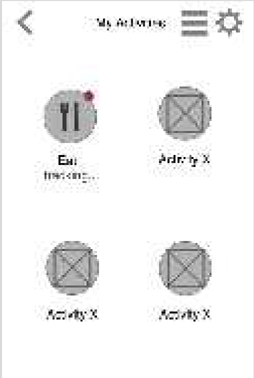
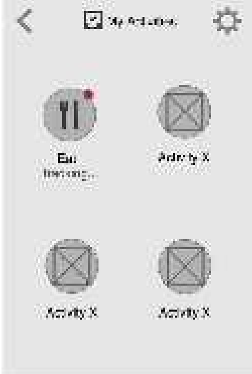
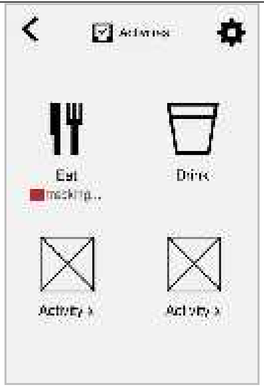
Goal detail			
Rewards list		 	

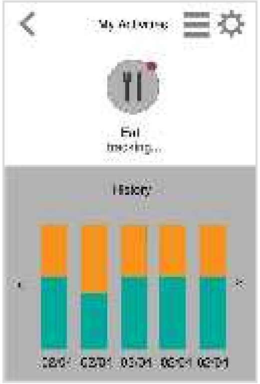
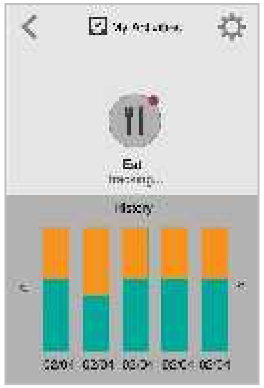
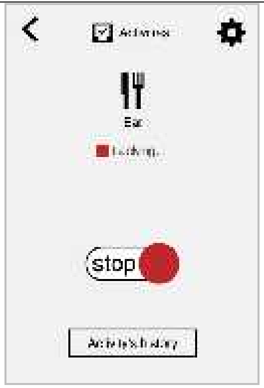
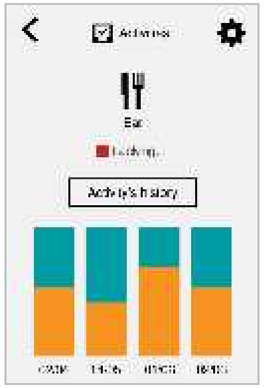
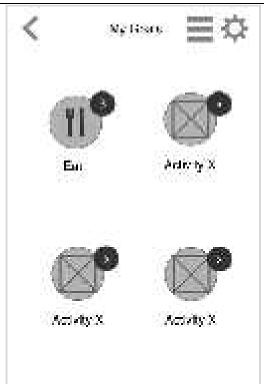
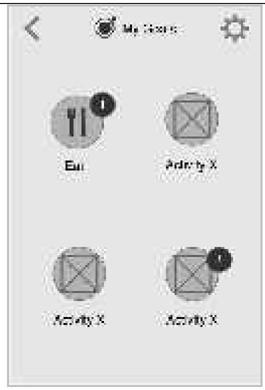
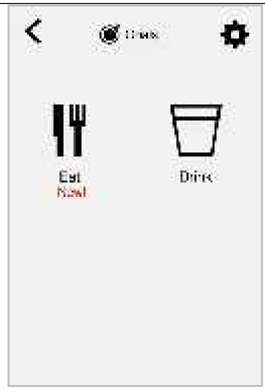
Settings list			
Settings: privacy list			This screen was not designed because its functionalities were included in *Settings list* screen (image above)
Settings: privacy detail			This screen was not designed because its functionalities were included in *Settings list* screen (image above)

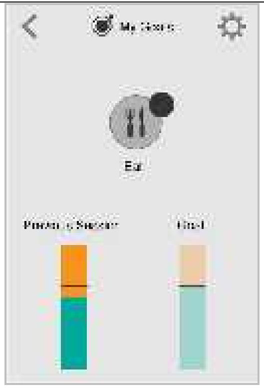
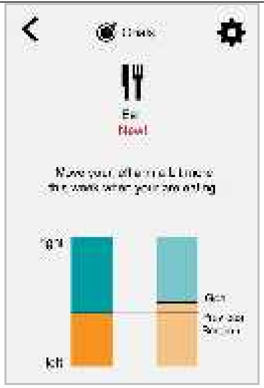
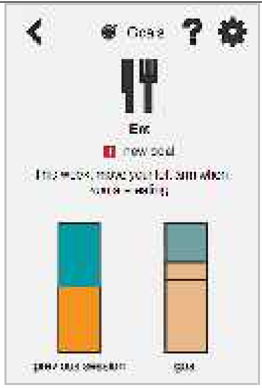
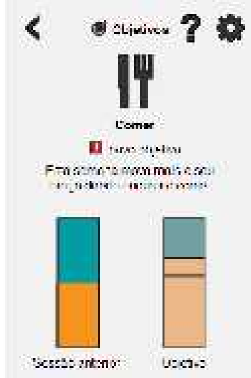
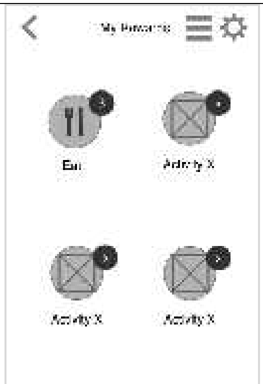
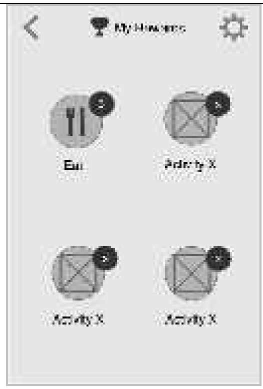
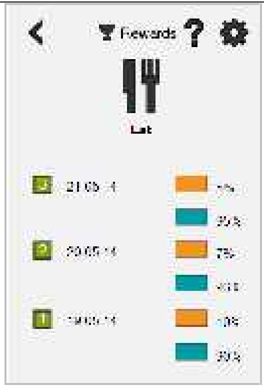
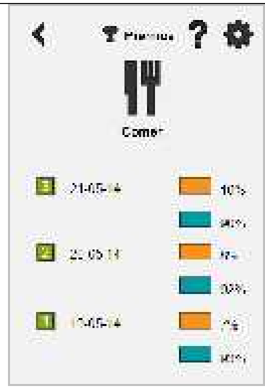
		Settings ON OFF	

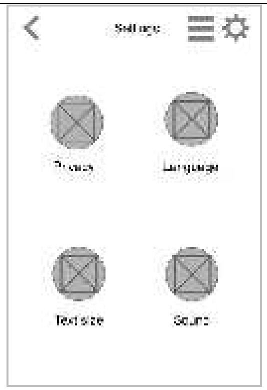
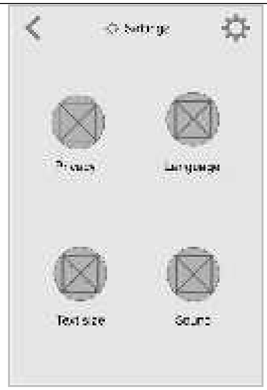
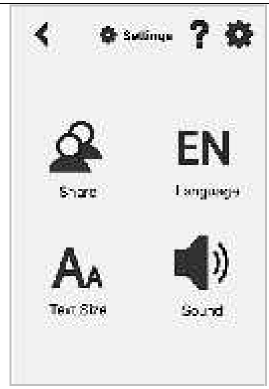
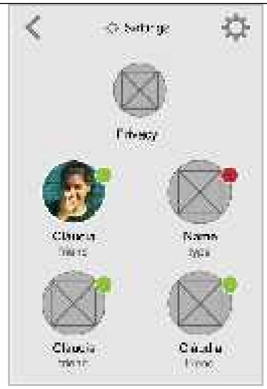
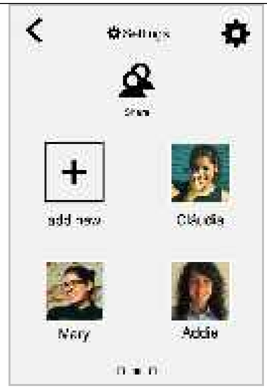
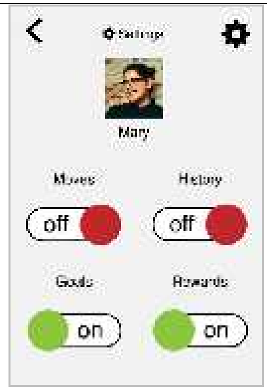
Appendix 3: *Summary high-fidelity prototypes*

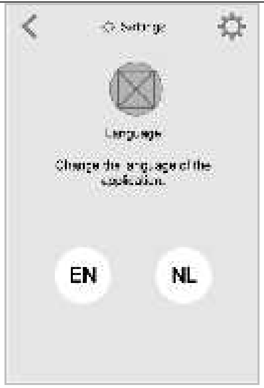
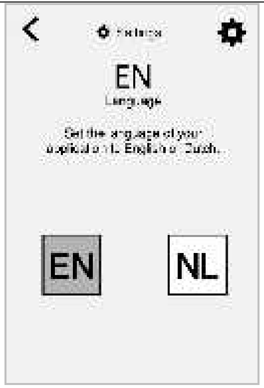
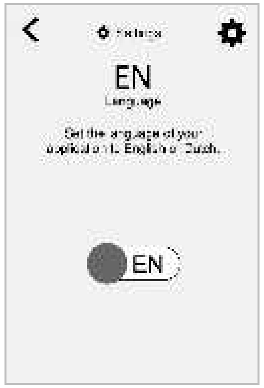
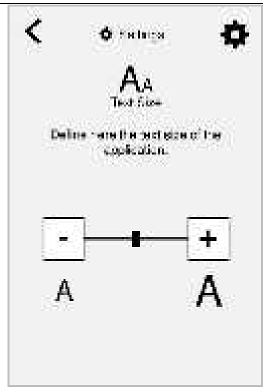
	Prototyping stage				
Screen	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 4 (EN)**	**Stage 4 (PT)**
Main menu					
Real time moves / Moves' history					

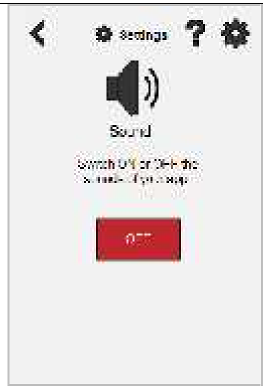
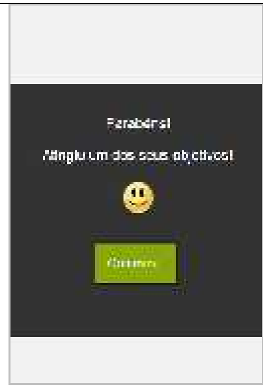
Moves' history (by day, week, month)	Not designed (the *Real time moves* screen comprised information about moves' history)	Not designed (the Real time moves screen comprised information about moves' history)	Not designed (the Real time moves screen comprised information about moves' history)		
Activities list					
Activity detail					

<table>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goals list</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</table>

Goal detail	-				
Rewards list					
Rewards detail					

Settings					
Settings: privacy, share - list	Not designed				
Settings: privacy - detail	Not designed				

Settings: language	Not designed				
Settings: text size	Not designed				

Settings: sound	Not designed				
Feedback message	Not designed	Not designed	Not designed		
Tour					

Appendix 4: *Us*'em s*takeholders goals*

Below are described the defined goals of each stakeholder of Us'Em system. A. respects to the Patient, B. to the Physical Therapist, C. to the Rehabilitation Team and D. to the Patient's Carer.
The one of greatest interest among all the goals is termed as user goal and it is the primary actor's goal. For instance, in this case, the patient, as primary user of the Us'Em system and app, the goal is to enhance his/her rehabilitation progress / to track his/her measurements of arm-hand moves.

Stakeholder Patient
Scope Us'Em app
User goal to enhance his/her rehabilitation progress / to track his/her measurements of arm-hand moves

Table: Representation of Goals' Levels regarding app users (patients)

Level 1	Level 2	Level 3
View real time measurements	View progress by activity	Define settings
View history of measurements	View personal goals to achieve	
View history of measurements by activities	View personal rewards	
View personal progress	Share data	
Track activity		
Achieve goals		
Be rewarded		

Stakeholder Physical Therapist
Scope Us'Em system
User goal to monitor patients' upper limb activity

Table: Representation of Goals' Levels regarding Physical Therapist

Level 1	Level 2	Level 3
View Us'Em devices' measurements by activity and date	View progress by activity View patient's rewards	Define settings
Set Tasks		
Set Goals		
View patient's achieved goals		

Stakeholder	Rehabilitation Team
Scope	Us'Em system
User goal	to monitor patients' recovery progress

Table: Representation of Goals' Levels regarding Rehabilitation Team

Level 1	**Level 2**	**Level 3**
View patients' progress	View patient's goals	

Stakeholder	Patient's Carer
Scope	Us'Em system
User goal	to monitor patients' recovery progress

Table: Representation of Goals' Levels regarding Patient's Carer

Level 1	**Level 2**	**Level 3**
View measurements in real time and by activity	View patient's rewards	
View patients' general progress and by progress		
View patient's goals		
View patient's achieved goals		

Appendix 5: *Test high-fidelity prototype (Jamel) -results*

Date: 5th of May 2014
Place: Public space at the university
Participant: Jamel van Dam
Test: version 3 of high-fidelity prototype

Consent to use information collected in the interview:

1. Do you allow the use of this information in this research project?

Yes [X] No [ ]

2. Do you allow the transcription of this information in this research project?

Yes [X] No [ ]

3. Do you allow to be identified in this research project?

Yes [X] No [ ]

Context characterization (physical surroundings)

Public or privet context	Number of people in the room	Noise (low, medium, high)	Other aspects
Public: public working space	Around 20	Medium	The test was conducted in quiet spot of the public room, without anyone nearby. There was no noise or other events disturbing the test.

Interviewee characterization

Gender	Age Group	Date of stroke event	Impairments
Masculine	12-25	September 2012	Left arm-hand, cognitive, speech impairments (Physical impairments were greater that the cognitive)

Current situation		
Impairments	**Therapy**	**Daily life main challenges**
Some difficulties talking and no independence on the affected arm-hand.	No physical clinical therapy, only attending psychological therapy sessions.	Performing daily activities with the impaired arm-hand.

On 5th of May 2014, there was a meeting with Jamel van Dam at the Technical University of Eindhoven. The purpose of this meeting was evaluating a high-fidelity prototype (stage 1) in terms of information visualization, content and features.
At the time he was contacted to participate, he was informed about the purposes and main procedures of this meeting. Still, before initiating the test, he was provided by test details. The test did start when all his questions were answered and he did feel comfortable to do it.
The feedback and outcomes of Jamel's evaluation were organized by screen and by interface design elements, and are described below.

Screens

Moves

The chart that shows real time moves, a semi-circle, must inform also by text how much is the moves' ratio.
The subtitle "today" is important to inform to which information that chart respects.
The vertical bars chart, that shows user's moves in the last hours, should have more horizontal lines to represent the various levels of percentages. It will help to understand the information. It should have arrows to inform that it is possible to slide horizontally to navigate different hours. Furthermore, it must show, first, only the previous hours and then, perhaps in another chart, the history by day, week and month.
The click on the button to access move's history (by day, week and month) should be changed to a slide up action.

Rewards

Regarding to his rewards, Jamel mentioned that user may want to when (date) he received it and what he did to receive it. For instance, inform user the ratio of his/her moves that enabled him/her to be rewarded.

Goals

Jamel thought that the intended goal was already the achieved one.

Share

Here, on the list of people, its items (people with who user shared or is sharing information) should inform if there is any information being shared with that individual.

Interface design elements

"Back" and "Menu" buttons

He did not understand the function of the "Menu" button. In addition, using both buttons in the same screen is confusing. As the "Back" button is clearer, it is the only one that should be used. It will enable the access to the previous screen user viewed.

Screen's title

Each screen should have a title to inform the user about the content of that screen. The title should comprise text with a bigger font and an icon. According to Jamel, icons enable a better reading and understanding of information and they should be used always.

Interface colors

There should not be more colors because it will make the app less clear, requiring more efforts to read and understand the information.

With respect the interface's background, it should not be white because it makes the interface too much bright, affecting user's vision.

Buttons

Comparing rectangular with slide buttons (type of buttons common in iPhone), the first are better to use.

Those to set *Text size* and *Language* (in *Settings*) should be dark.

Others:

Therapists must be able to set up the app, as he/she is the one that knows better the patient and his/her condition. The app will be, thus, more personalized.

Activities and *Goals* are less important. Hence, the basic app should have only *Moves*, *Rewards* and *Settings*. Consequently, they will be arranged in the app in a different way rather than by activity. *Moves* will be more relevant.

It is need to consider the use of smartphone with respect of the way users hold it. In some situations, their fingers can hide the screen and hamper reading its content.

Appendix 6: ***Test low-fidelity prototype (Jamel)-results***

(Important: all the figures mentioned in this appendix are present in document *Interviews-Libra Therapists (guide)* (annexed to the CD of this dissertation).

Date: 11th of April 2014
Place: University public space
Participant: Jamel van Dam
Test: version 2 of low-fidelity prototype

Consent to use information collected in the interview:

1. Do you allow the use of this information in this research project?

Yes ☒ No ☐

2. Do you allow the transcription of this information in this research project?

Yes ☒ No ☐

3. Do you allow to be identified in this research project?

Yes ☒ No ☐

Context characterization (physical surroundings)

Public or privet context	Number of people in the room	Noise (low, medium, high)	Other aspects
Public: university public space	Around 20	Medium	There is a calm ambience so it is possible to communicate very well with Jamel.

Interviewee characterization

Gender	Age Group	Date of stroke event	Impairments
Masculine	12-25	September 2012	Left arm-hand, cognitive, speech impairments (Physical impairments were greater that the cognitive)

Current situation

Impairments	Therapy	Daily life main challenges
Some difficulties talking and no independence on the affected arm-hand.	No physical clinical therapy, only attending psychological therapy sessions.	Performing daily activities with the impaired arm-hand.

Note: in this document user and patient have the same meaning. Both refer Us'Em app user who is also a post stroke patient.

On 11th of April 2014, Jamel did participate in a user test of low-fidelity prototype second version. This test was conducted at university public space, with a calm environment without perturbations. Jamel had participated in earlier stages of this research project, so he was aware about it. At the time he was contacted to participate, he was informed about the purposes and main procedures of this meeting.

The purposes of this meeting with Jamel were:

1) Explain to Jamel the new features and concepts that were brainstormed after his previous meeting and to get his feedback,
2) Get Jamel's feedback on the charts designed to represent the ratio of patient' moves, moves' history, goals and goals, and
3) To gather more relevant information with regard to users' needs.

The meeting did occur with a separately analysis of each topic. For each of them, Jamel had been informed about new ideas and what was intended to design and, then, he was asked about his opinion about them. The outcomes of this study are described below.

Topic: real time moves and moves' history

- User should be able to see his moves' history by different time frames, but also by activity
- Time frames should include day, week and month – "*this information is very* important because patient can be aware of his progress!". Hour is not necessary because it relates to a very short time to be meaningful improvements. Thus, as it will not show any or almost any difference between days, user may get demotivated.
- It is very important to be provided by real time information. Data about the last 15 minutes is also relevant because patient can know his "*moves in a short period of* time like during a certain activity…"

Topic: Activities' detail

- It is not important to know the data of an activity. As Jamel stated: "*it is too much informati*on and the app should be as simple as possible!"
- Tracking an activity is not, according to Jamel, a boring task. Although, if patient is not progressing it may bother him.

Topic: Progress

- Patient's progress should be represent by time and by activity
- Patient should be able to see his progress since he started to use Us'Em app. Jamel did justify it with the following intervention: "*you are getting curious all the time!*"
- Charts representing patient's progress may be approach in a different way. One of the charts showed to Jamel had bars and the other one had a curve line. The first one was, to Jamel, the best approach. However, he introduced a new idea to design this chart. As bars may take much space of the screen, one solution would be design straight vertical lines and dots to represent specific times.

Topic: Goals

- Instead of a list of patient's goals by activity, only one list with all his goals should be presented

- Goal should be set with a deadline of a week. For instance, "*You should move more X this we*ek.". In this way, it will be less frustrating, according to Jamel.

Topic: Rewards

- Rewarding patient should include an image or an icon that represents victory, good feeling like "*a medal, a cup or even a muscular arm, for instance*"

Topic: Sharing

- "*I thi*nk therapist must access patient's data continuously. But, it should be possible *to define if his family may or not view it.* (…) Defining these settings is very *important to patient because it relates to his privacy!*"

Other relevant information:

Welcome screen is not necessary as it will not provide any relevant information. "*As I said, this app should be as simple as possible. When I use it, I want to turn it on and check my* real time moves!", by Jamel.

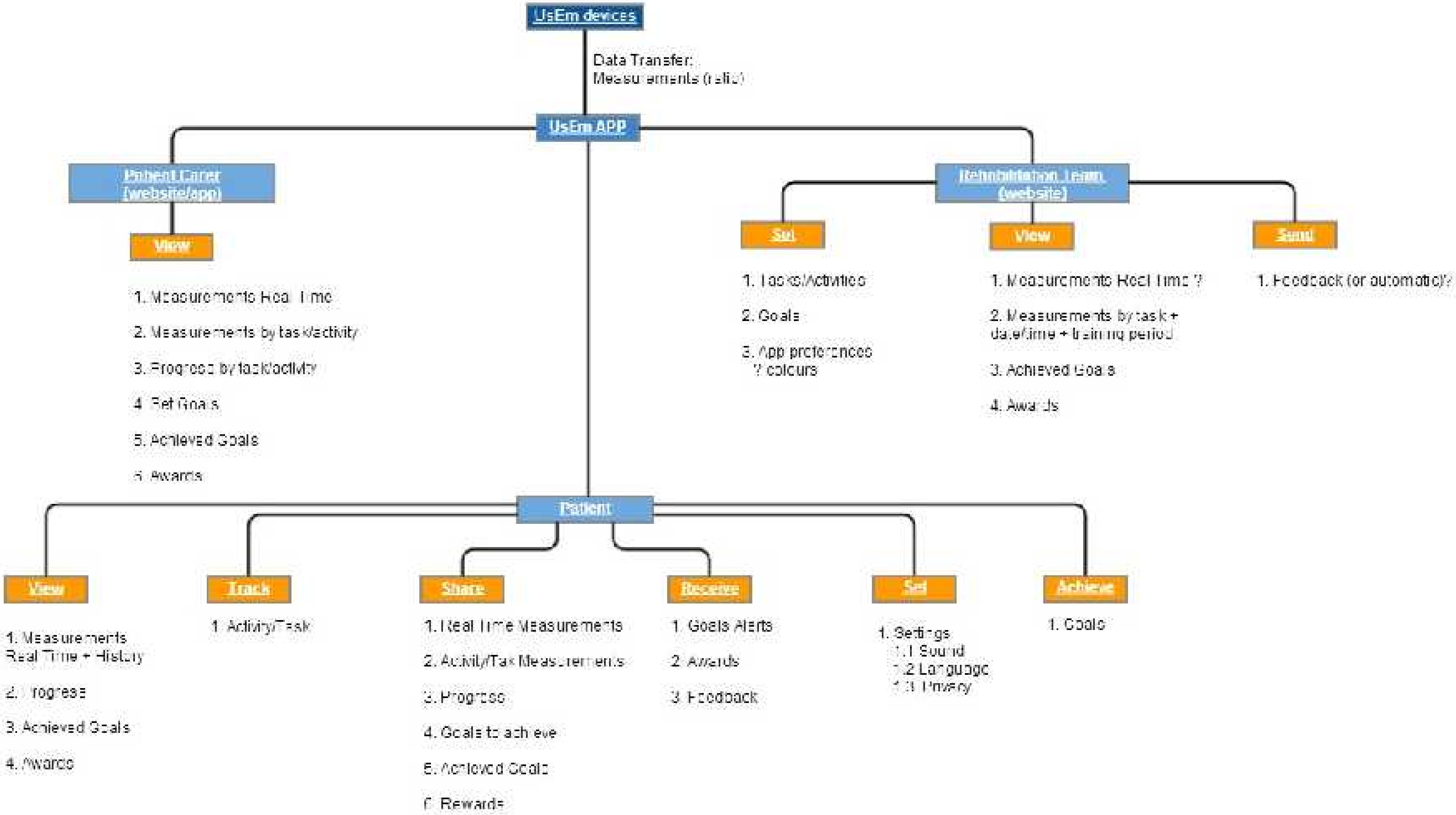
Requiring touch events to interact with the app may be not beneficial. Interacting in that way is more demanding at a cognitive level. Patient will need more efforts to process information. That will happen also if the app will require voice input.

Comparing moves' ratio does not necessarily mean motivation. Jamel stated: "*For me it will be obvious my impaired arm will move less than the other one. But, even if I am aware of this fact, if that difference will be too big, seeing this information may be very frustrating.*" It would be better, though, to provide a chart that shows patient's moves only when he is actually moving his arm-hand.

Charts displayed on the app should have vertical bars and horizontal lines representing levels and making easier to compare moves of the two arm-hands. The horizontal line in the middle showing the level of 50% of ratio is relevant and it enables patients to have a better view of moves' ratio scale.

Jamel did question: "Does the Us'Em system detects my movements when I am walking? *Because, in doing that I am naturally moving m*y arm but not intentionally…".

Appendix 7: ***Diagram Us'em system overview*** (available tasks for each Us'em system stakeholder)



Appendix 8: ***Usability tests (results-charts)***

Legend:

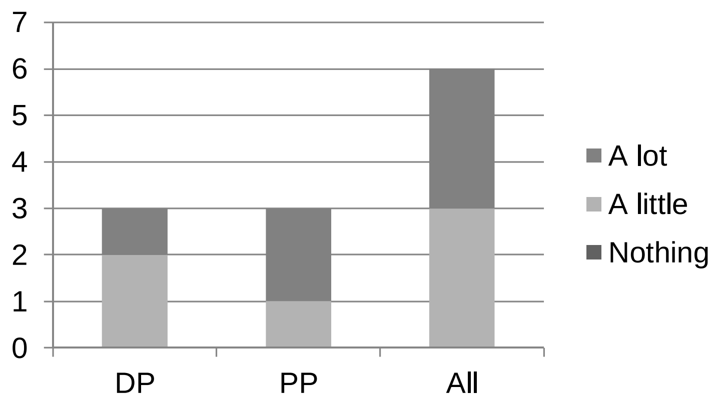
DP – Dutch patients; PP – Portuguese patients; All – Dutch and Portuguese patients

(The usability test had the part 1: Context of use (see *Usability Tests Guide* document annexed in the CD of this dissertation). This information was collect by user id and can be seen in documents *Usability Test Libra (results)* and *Usability Test CRPG (results),* annexed in the CD of this dissertation).

2. Credibility Expectancy Questionnaire

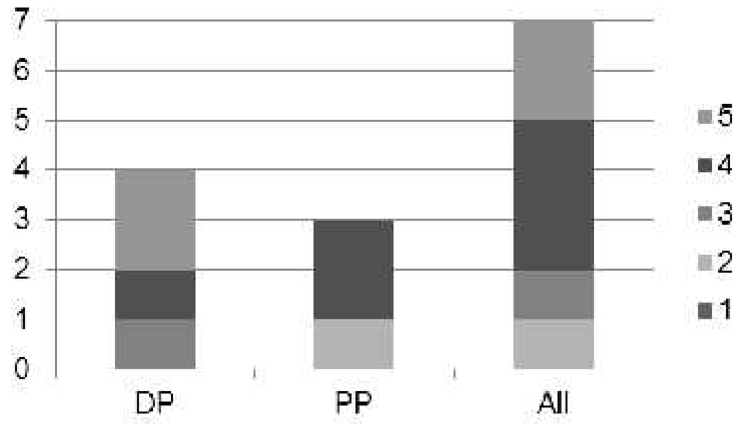
2.1 Questions Set 2

Question A: How do you feel Us'em app will help you reduce your hand-arm impairments?



Question B: How much improvement do you think will have occurred at the end of the therapy in your hand-arm symptoms using the Us'Em app?

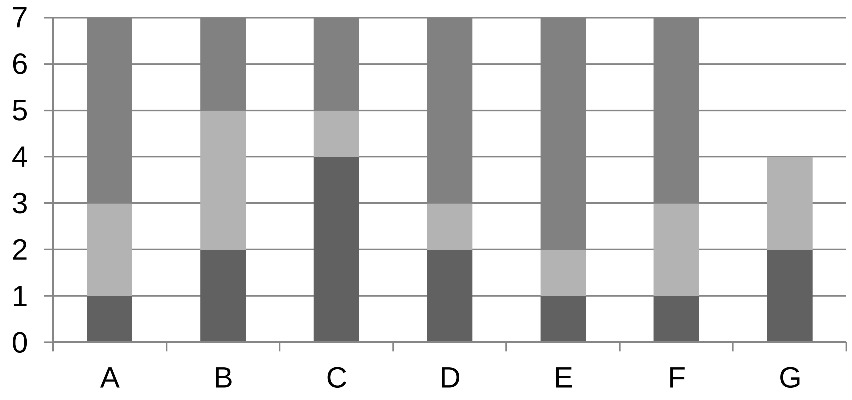
Scale				
0%-20%	20%-40%	40%-60%	60%-80%	80%-100%
1	2	3	4	5



3. Intrinsic motivation inventory (after test)

3.1 Pleasure

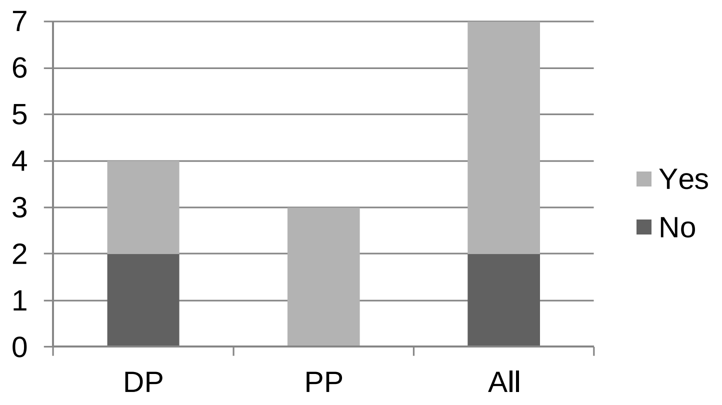
(Dutch and Portuguese patients)



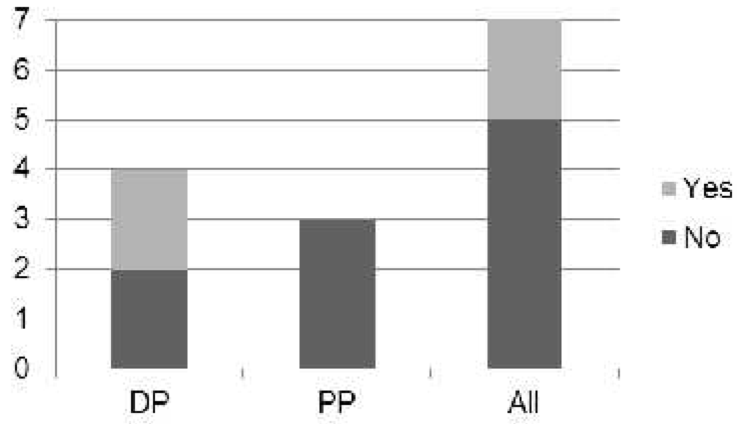
Question ID	Question
A	I did like to use Us’Em app.
B	It was fun to use Us’Em app.
C	It was boring to use Us’Em app.
D	Us’Em app did not catch my attention.
E	Us’Em app is interessant.
F	Us’Em app is pleasant.
G	While I was using the app I thought about how good I was feeling.

3.2 User competence to use the app

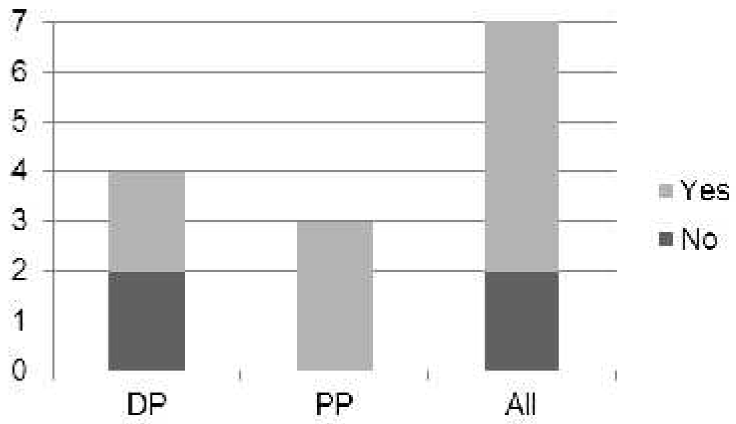
I think I am good using Us'Em app.



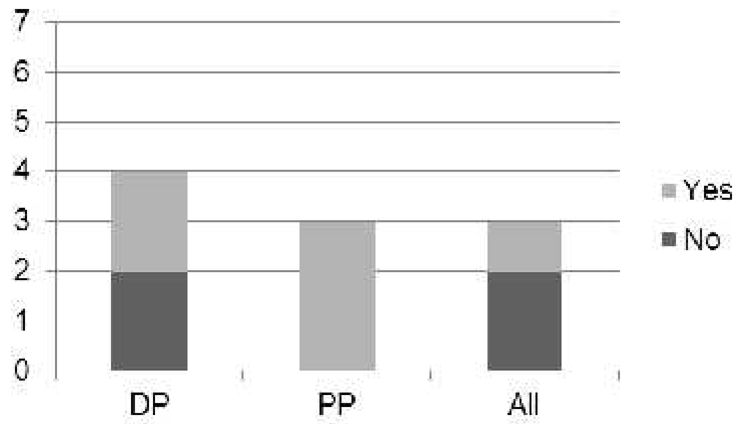
I think I can use Us'Em app *better than other patients.*



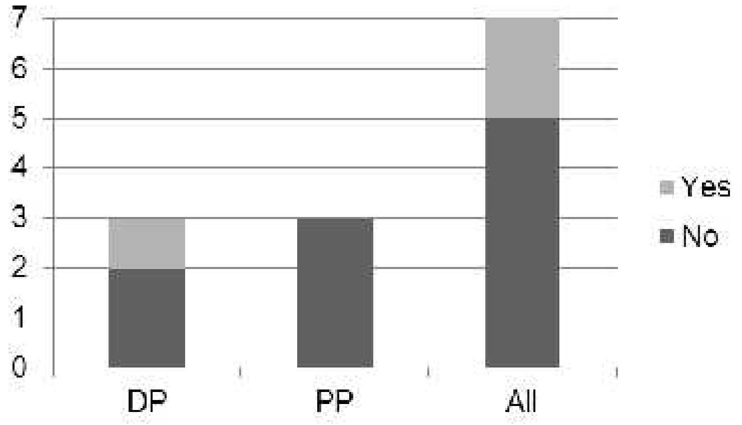
After interacting a bit with the app I felt competent to use it.



I think I am proficient using the app.

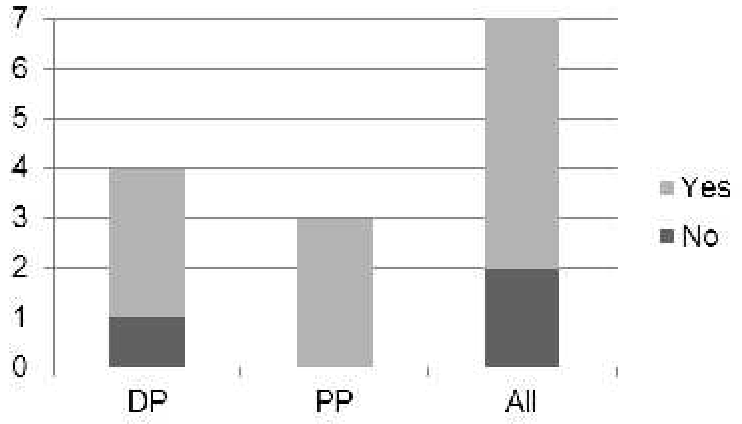


It would be very difficult to me to have a good performance interacting with the app.

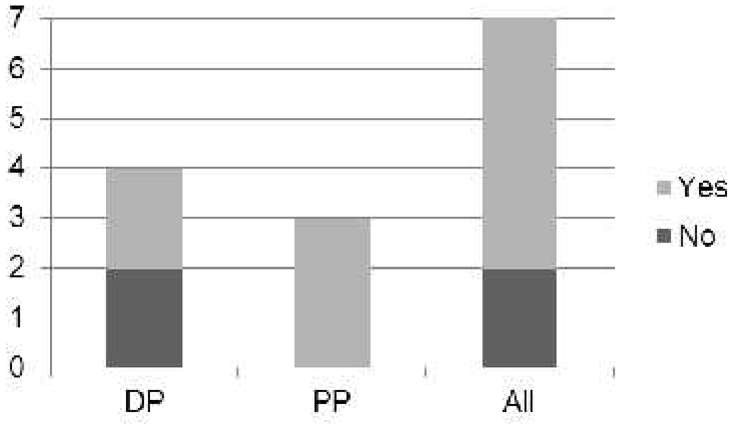


3.3 Value

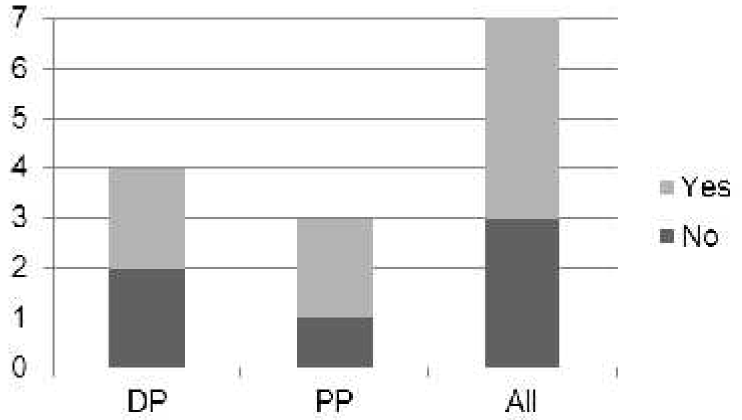
I think Us'Em app can be valuable for me.



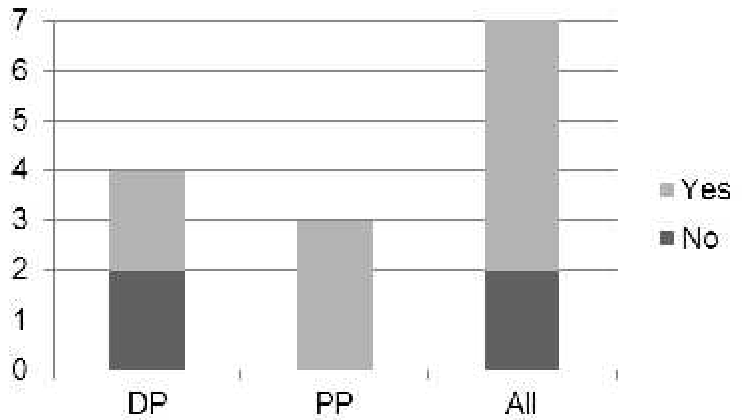
I think Us'Em app is helpful to improve my arm-*hand abilities.*



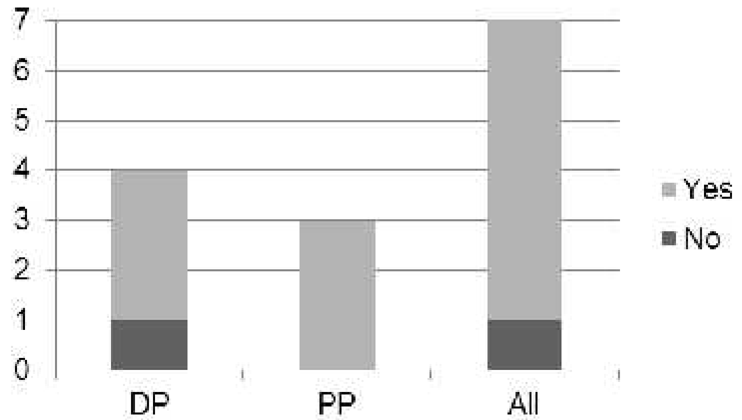
I think Us'Em app is important to me as I can learn how to use my arm-*hand more and better.*



I think Us'Em app would help me to train and use my affected arm-*hand in daily activities.*

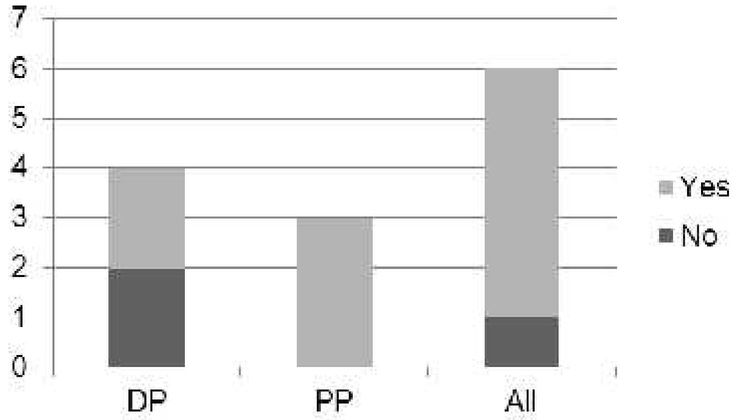


*I thin*k Us'Em app is a relevant product.

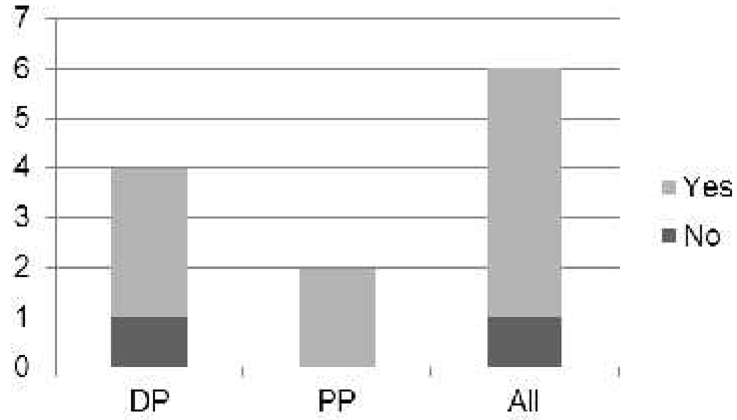


3.4 Us'Em app

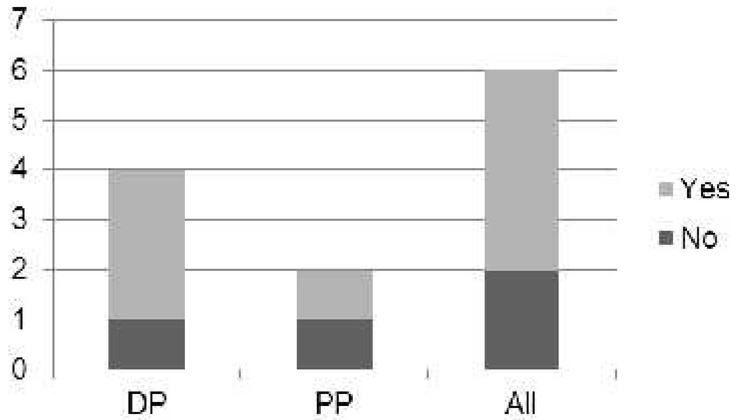
I felt capable to use/interact with Us'Em app.



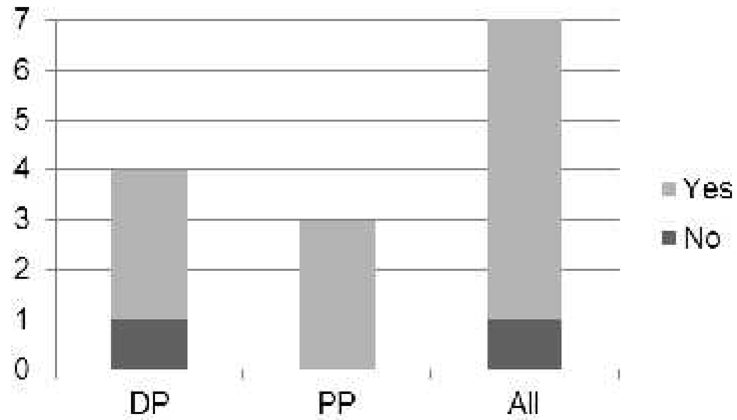
I would like to try Us'Em app again.



I want to use Us'Em app in t*he future.*



I feel I can trust in Us'Em app.



I am very attracted by Us'Em app.