UNIVERSIDAD POLITÉCNICA DE MADRID

ESCUELA TÉCNICA SUPERIOR DE INGENIEROS DE
TELECOMUNICACIÓN

TESIS DOCTORAL

PERSUASIVE SYSTEM DESIGN METHODS TO
DELIVER A CARDIO-REHABILITATION PROGRAM
OF POST MI OUTPATIENTS

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Madrid, 2016

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Madrid, 2016

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“We shape our tools and thereafter our tools shape us”

Marshall McLuhan

Abstract

Noncommunicable diseases (NCDs) cause the death of 38 million people every year. Four major NCDs are responsible for 82% of these deaths: cardio vascular disease, chronic respiratory disease, diabetes and cancer. These pandemic numbers are projected to raise to 53 million deaths in 2030, and for this reason the assembly of the World Health Organization (WHO) considers communicable diseases as an urgent need to be addressed.

It is also a trend to advocate the adoption of mobile technology to deliver health services and to promote healthy behaviours among citizens, but adopting health-promoting lifestyle is still a difficult task facing human tendencies. Within this context, there is a promising opportunity: persuasive technologies. These technologies are intentionally designed to change a person's attitudes or behaviours; when applied in this context, than can be used to change health-related attitudes, beliefs, and behaviours.

Each year there are 32 million heart attacks and strokes globally, of which about 12.5 million are fatal. Worldwide between 40 and 75% of all heart-attack victims die before reaching hospital. Avoiding a second heart attack by improving adherence to lifestyle and medication regimens has a cost saving potential of around €6 billion per year. In most of the cases the cardiovascular event has been provoked by unhealthy lifestyle. Furthermore, after an MI event the patient's decision to adopt or not healthier behaviour will influence the progress of the disease. Cardio-rehabilitation is an individualized program that follows a multidisciplinary approach to support the user to recover from the Myocardial Infarction, manage the Cardio Vascular Disease and the comorbidities, adopt healthy habits, and cope with any emotional distress. Cardio-rehabilitation requires patient participation and willingness to perform behavioral modifications and change the attitude toward the management and prevention of the disease. Participation in the Cardio Rehabilitation program is not high; the home-based rehabilitation program is a promising solution to increase participation.

Nowadays cardio rehabilitation is considered a comprehensive intervention in which models of health psychology are applied to promote the behaviour change of the individuals. Relevant methods that have been successfully applied to foster healthy habits include the Health Belief Model and the Trans Theoretical Model. Studies also demonstrate the importance to promote not only the physical but also the mental well being of the individuals.

The idea of also promoting behaviour change using technologies has been defined by the literature as persuasive technologies or behaviour change support systems, in which the features, the strategies and the design method have been modelled to foster the behaviour change using technology. Limitations have been found in this model: there is still research to be done on the role of the emotions and how psychological health intervention can be translated into computer methods.

This research focuses on three elements that could foster behaviour change in individuals: the physical and emotional status of the person, and the technology. Every component can influence the user's attitude and behaviour in the following ways:

- Physical status: bad physical status could change human attitude toward the necessity to adopt health behaviours; at the same time, good health status reduces the need to adopt healthy habits.
- Emotional status: the attitude has an affective component, negative emotional state can reduce the ability of a person to adopt new behaviours, and mental well being is the ideal situation in which individuals have a predisposition to adopt healthy behaviours.
- Technology: it can help users to adopt new behaviours and can also be support to promote physical and emotional status.

Following this approach the idea driven in this research is that technology that is designed to improve the physical status and the emotional status of the individual could better foster behaviour change.

According to this principle, the Well.Be.Sign framework has been proposed. The framework is based on three views:

- The theoretical framework: it represents the patterns that have to be defined to design the technologies to promote well being.
- The influence diagram: it shows the persuasive forces in the context of health care. The role of the persuasive technologies is contextualized in a wider universe where other factors and persuasive forces influence a patient.
- The design process: it shows the process of design using an iterative, incremental methodology that applies a combination of existing methodologies (Goal Directed Design and Persuasive System Design) and others that are original to this research.

The methods have been applied to design a system to deliver cardio rehabilitation at home: first a prototype has been defined according to the user's needs, then it has been extended with the specific intervention required for the cardio-rehabilitation, finally the system has been developed and validated in a controlled clinical study in which the cardiovascular fitness, the level of knowledge, the perception of the illness, the persistence of healthy habits and the system acceptance (only the intervention group) were measured. The results show that the intervention group increased cardiovascular capacity, knowledge, feeling of control of illness and perceived benefits of exercise at the end of the study. After six months of the study, a follow-up of the exercise habits was performed. Some individuals of the intervention group continued to be engaged in the running exercise sessions promoted in the designed system.

Two other cases have been presented to demonstrate the foundations of the Well.Be.Sign's approach to promote both physical and emotional status:

- People affected by Heart Failure, in which a bidirectional connection between health status and emotions has been discussed with patients. Two correlations were demonstrated: the relationship between symptoms and negative emotional response, and that negative emotional status is correlated with worsening of chronic conditions.

- People with mood disorders: the study shows that emotions could also impact how the user perceives the technology.

Resumen

Las enfermedades no transmisibles provocan cada año 38 millones de fallecimientos en el mundo. Entre ellas, tan solo cuatro enfermedades son responsables del 82% de estas muertes: las enfermedades cardiovasculares, las enfermedades crónicas respiratorias, la diabetes, y el cáncer. Se prevé que estas cifras aumenten en los próximos años, ya que las tendencias indican que en el año 2030 las muertes por esta causa ascenderán a 53 millones de personas. La Organización Mundial de la Salud (OMS) considera importante buscar soluciones para afrontar esta situación y ha solicitado a los gobiernos del mundo la implementación de intervenciones para mejorar los hábitos de vida de las personas y reducir así el riesgo de desarrollo de enfermedades no trasmisibles.

Cada año se producen 32 millones de infartos de miocardio y derrames cerebrales, de los cuales 12.5 son mortales. En el mundo entre el 40% y 75% de las víctimas de un infarto de miocardio mueren antes de su ingreso en el hospital. En los casos que sobreviven, la adopción de un estilo de vida saludable puede evitar infartos sucesivos, y supone un ahorro potencial de 6 billones de euros al año.

La rehabilitación cardíaca es un programa individualizado que aplica un método multidisciplinar para ayudar al paciente a recuperar su condición física, a gestionar la enfermedad cardiovascular y sus comorbilidades, a adoptar hábitos de vida saludables, y a promover su salud mental. La rehabilitación cardíaca requiere la total involucración y motivación del paciente, solo de esta manera se podrán promover hábitos saludables y mejorar la gestión y prevención de su enfermedad. Aunque la participación en los programas de rehabilitación cardíaca es baja, hoy en día existen programas de rehabilitación cardíaca que el paciente puede realizar en su casa. Estos suponen una solución prometedora para aumentar la participación.

La rehabilitación cardíaca se considera una intervención integral donde los modelos de psicología de la salud son aplicados para promover un cambio en el estilo de vida de las personas así como para ayudarles a afrontar su propia enfermedad. Existen métodos para implementar cambios de hábitos y de actitud, y también se considera muy relevante promover no solo el bienestar físico sino también el mental.

Existen tecnologías que promueven los cambios de comportamientos en los seres humanos. En concreto, las tecnologías persuasivas y los sistemas de apoyo al cambio de comportamientos modelan las características, las estrategias y los métodos de diseño para promover cambios usando la tecnología. Pero estos modelos tienen algunas limitaciones: todavía no se ha definido qué rol tienen las emociones en el cambio de comportamientos y cómo traducir los métodos de la psicología de la salud en la tecnología.

Esta tesis se centra en tres elementos que tienen un rol clave en los cambios de hábitos y actitud: el estado físico, el estado mental, y la tecnología.

- Estado de salud: un estado de salud crítico puede modificar la actitud del ser humano respecto al cambio. A la vez un buen estado de salud hace que la necesidad del cambio sea menos percibida.
- Estado emocional: la actitud tiene un componente afectivo. Los estados emocionales negativos pueden reducir la habilidad de una persona para adoptar nuevos comportamientos. La salud mental es la situación ideal donde los individuos tienen predisposición a los cambios.
- La tecnología puede ayudar a las personas a adoptar nuevos hábitos, así como a mantener una salud física y mental.

Este trabajo de investigación se centra en el diseño de tecnologías para la mejora del estado físico y emocional de las personas. Se ha propuesto un marco de diseño llamado “Well.Be.Sign”. El marco se basa en tres aspectos:

- El marco teórico: representa los elementos que se tienen que definir para diseñar tecnologías para promover el bienestar de las personas.
- El diagrama de influencia: presenta las fuerzas de ‘persuasión’ en el contexto de la salud. El rol de las tecnologías persuasivas ha sido contextualizado en una dimensión donde otros elementos influyen al usuario.
- El proceso de diseño: describe el proceso de diseño utilizando una metodología iterativa e incremental que aplica una combinación de métodos de diseño existentes (Diseño Orientado a Objetivos, Diseño de Sistemas Persuasivos) así como elementos originales de este trabajo de investigación.

Los métodos se han aplicado para diseñar un sistema que ofrezca un programa de tele-rehabilitación cardíaca. Inicialmente se ha diseñado un prototipo de acuerdo con las necesidades del usuario. En segundo lugar, el prototipo se ha extendido especificando la intervención requerida para el programa de rehabilitación cardíaca. Finalmente el sistema se ha desarrollado y validado en un ensayo clínico con grupo control, donde se observaron las variaciones del estado cardiovascular, el nivel de conocimiento acerca de la enfermedad, la percepción de la enfermedad, la persistencia de hábitos saludables, y la aceptabilidad del sistema. Los resultados muestran que el grupo de intervención tiene una superior capacidad cardiovascular, mejor conocimiento acerca de la enfermedad, y más percepción de control de la enfermedad. Asimismo, en algunos casos se ha registrado persistencia de los hábitos de ejercicios 6 meses después del uso del sistema.

Otros dos estudios se han presentado para demostrar la relevancia del estado emocional del usuario en el diseño de aplicaciones para la promoción del bienestar.

- En personas con una grave enfermedad crónica como la insuficiencia cardíaca, donde se ha presentado las conexiones entre estado de salud y estado emocional. En el estudio se enseñan las relaciones que tienen los síntomas y las emociones negativas y como un estado negativo emocional puede empeorar la condición física del paciente.
- Personas con trastornos del humor: el estudio muestra como las emociones pueden tener un impacto en la percepción de la tecnología por parte del usuario.

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Preface

The presented research is about designing mobile-based technology to promote health and healthy lifestyle in people that suffer a Myocardial Infarction. The work has been done following a systematic and multi-disciplinary approach in the areas of medicine, health psychology, computer science and design.

This book has been structured into 7 chapters:

- **Background:** it explains the problem from a medical, psychological, technological and design point of view. The conclusions are drawn and problem statement is defined.
- **Hypotheses and Objectives:** the hypotheses and thesis objectives are elucidated.
- **Materials and methods:** this section explains all the materials and methods that have been used in this research.
- **Design methods:** the chapter presents original methods to design technology to help patients manage health status and foster healthy habits. The methods are based on the principle of the promotion of both physical and emotional well being of the user.
- **Program of cardio-rehabilitation:** this section shows the design, development and validation of a tele-rehabilitation system to recover health status and promote healthy lifestyle for patients that suffered a Myocardial Infarction. The design has been performed applying the proposed methods of design.
- **Other studies:** the chapter presents two case studies to discuss the implications in terms of design to include emotional well being as an integral part of the design methods.
- **Conclusions:** finally, the initial hypotheses are discussed and verified using quantitative results. Conclusions and future works of this research are presented.

A photograph of three medical professionals, likely nurses or doctors, in a clinical setting. They are wearing white coats and have stethoscopes around their necks. They are looking down at a tablet computer held by one of them. The image is overlaid with a semi-transparent green filter.

01.

BACKGROUND

The chapter introduces to the medical problem and gives an overview of the available opportunities to promote the health of the individuals.

1 Background

Noncommunicable diseases (NCDs) cause the death of 38 million people every year.¹ Four major NCDs are responsible for 82% of these deaths: cardio vascular disease, chronic respiratory disease, diabetes and cancer. These pandemic numbers are projected to raise 53 million deaths in 2030, and for this reason the assembly of the World Health Organization (WHO) considers communicable diseases as an urgent need to be addressed. Already, in September 2011, an action plan with nine specific goals was designed to address the global burden of NCD. WHO proposes to accomplish the following goals by 2025:

- Goal 1: reduce mortality from cardio-vascular disease, cancer, diabetes and chronic respiratory disease.
- Goal 2: reduce by 10% the excessive alcohol consumption in the population
- Goal 3: reduce by 10% the prevalence of insufficient physical activity / sedentary. (Currently 3.2M death/year)
- Goal 4: Reduce by 30% thistle intake of the population.
- Goal 5: Reduce by 30% the consumption of tobacco in persons older than 15 years.
- Goal 6: Reduce or control the 25% rate of high blood pressure in the population.
- Goal 7: Halt the increase of obesity and diabetes.
- Goal 8: Achieve 50% coverage of drug therapy in subjects with Cardio Vascular Risk.
- Goal 9: 80% availability of basic technologies and essential medicine to diagnose and treat NCD.

The WHO advocates implementing policies to develop systems to monitor the mortality of the NCDs (Goal 1) and to set up cost effective policies and intervention to attain the other goals. In the last report of 2014, WHO reported that some countries are making progress, but the majority are out of the target (WHO, 2014).

Apart from the commitment and the available resources of every specific country, the achievement of these objectives requires a sizeable shift in the worldwide population to adopt healthy behaviour and preventative health approaches (Marteau, Hollands, & Fletcher, 2012).

It is a trend to advocate the adoption of mobile technology to deliver health services and to promote healthy behaviours among citizens, but adopting health-promoting lifestyle is still a difficult task facing human tendencies.

¹ <http://www.who.int/mediacentre/factsheets/fs355/en/>

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Within this context, there is a key role for persuasive technologies, technologies intentionally designed to change a person's attitudes or behaviors, to change health-related attitudes, beliefs, and behaviors. (Chittaro, 2015)

In the context of this research it has been initially chosen to focus on a disease condition in which the promotion of healthy habits and self-care is crucial: patients that have suffered a Myocardial Infarction (MI).

Each year there are 32 million heart attacks and strokes globally, of which about 12.5 million are fatal (Mathers CD & Claudia Stein, 2002). Worldwide between 40 and 75% of all heart-attack victims die before reaching hospital (Chambless et al., 1997; McGovern et al., 2001). It is a major cause of death and disability worldwide. Among patients who survived a first heart attack, most will go on to have further complications in the ensuing years or will develop heart failure (or both). Epidemiological studies suggest that most deaths with MI occur before the patient has had a chance to reach hospital. Indeed, the 30-day mortality of MI from the moment of onset of chest pain may still be about 50%. Avoiding a second heart attack by improving adherence to lifestyle and medication regimens has a cost saving potential of around €6 billion per year (Nichols, Townsend, Scarborough, & Rayner, 2012). In most of the cases the cardiovascular event has been provoked by unhealthy lifestyle. Furthermore, after the MI event the patient's decision to adopt or not healthier behaviour will influence the progress of the disease.

Within this research, four fields have been revised:

- **Medicine:** the CVD are described to explore the relevance of healthy habits for the progression and the onset of the disease. The MI and the Cardio Rehabilitation process are revised.
- **Health Psychology:** this revision focuses on methods to foster behaviour change.
- **Technology:** it presents relevant aspects of the future of communication and technology in health care.
- **Design:** this revision focuses on the methods to design Information Communication Technologies and describe relevant practices in their design to foster healthy lifestyle

This revision concludes with a summary that resumes the key concepts that have been emerged in the next sections.

1.1 Medical background

This section outlines the medical landscape of CVDs with special attention paid to the very common incident known as acute MI. Cardiovascular diseases encompass all the diseases and malfunctions of the heart and the blood circulation systems. They are the leading cause of death worldwide, in the 2008 17.3 million people died from CVD, representing 30% of all global deaths (WHO, 2013). These numbers will increase to 23.3 million by 2030, so the CVD are projected to remain the main causes of death in the world.

The World Health Organization classifies CVDs in the following categories:

- **Cerebrovascular disease:** it is a dysfunction of the blood vessels that feeds the brain. Hypertension is the main cause. This disease mainly affects elderly people or people with one or more of the following risk factors: smoking, diabetes and previous ischemic heart diseases.
- **Peripheral arterial disease:** it is a vessel circulatory problem in which narrowed arteries reduce the flow of blood to the limbs.
- **Rheumatic heart disease:** it is a consequence of rheumatic fever. It mainly affects children in developing countries. It causes a fibrosis in the heart valve that can lead to heart failure and death.
- **Congenital heart disease:** this is a physical problem of the whole heart. It is the most common of birth defects. This type of condition is classified into two groups: cyanotic (depending on the colour of the skin, because the cardiovascular system is not providing enough oxygen to the limbs) and non-cyanotic.
- **Deep vein thrombosis and pulmonary embolism:** this is the generation of a blood clot, mainly in the veins of the legs, and can lead to pulmonary embolism when a clot detaches and travels to the lungs.
- **Cardiomyopathy:** this is the deterioration of the heart muscle, the myocardium. It could depend on factors like ischemia, alcoholism, drug abuse, or a virus (e.g. hepatitis C). In severe cases it can lead to heart failure.
- **Inflammatory heart disease:** the tissue around the heart suffers inflammation (myocarditis, endocarditis).
- **Cardiac dysrhythmias (arrhythmias):** it is an irregular electrical activity of the heart that causes slower (bradycardia) or higher (tachycardia) heartbeats and in some cases also causes the heart to stop beating entirely (sudden death).
- **Chronic Heart Failure:** when the heart is not pumping enough oxygen to the limbs; this malfunction will cause shortness of breath, leg swelling, excessive tiredness. The common causes of heart failure are coronary artery disease, including a previous cardiovascular event (e.g. MI), high blood pressure, atrial fibrillation, valvular heart disease and cardiomyopathy.
- **Valvular heart disease:** this is a disorder that relates to one or more of the heart's four valves; it can be a birth malformation like Fallot's tetralogy or can occur from a rheumatic fever. It can be treated with medication and in some cases surgery is required to replace or repair the affected area.
- **Hypertensive heart disease:** high blood pressure affects the heart. This physical condition can lead to the development of more complex cardiovascular diseases like ischemic heart disease, stroke, peripheral arterial disease and kidney disease. Hypertension is a very common heart disease.
- **Coronary artery disease (CAD):** This is the most common type of heart disease and cause of heart attack. The plaques narrow the arteries of the heart. The most common causes are smoking, high cholesterol and high blood pressure. The development of the disease is asymptomatic; in many cases there is a "sudden heart attack". The symptoms of a stable coronary disease are angina and reduced exercise capacity. This research work will focus on these types of cardiovascular disease.

Aside from the congenital and virus-based diseases, the major cause of these types of cardiovascular diseases depends on risk factors that can be controlled; CVD is the

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number one killer of the non-communicable diseases (NCDs) and an urgent public health priority for the United Nations (UN).

The WHO Programme of cardiovascular disease focuses on the prevention, management and monitoring of the epidemic worldwide. Define these strategic priorities to reduce the disease among citizens:

- Reduce the risk factors that lead to cardiovascular disease and control their determinants.
- Develop cost effective and equitable health care methods for managing CVD
- Track trends and the risk factors in order to assess the impact of the new proposed intervention.

In 2002 the WHO reported the “Integrated Management of Cardiovascular risk” as result of the meeting in Geneva in which the health provider’s needs were stated (World Health Organization Staff, 2002):

- Comprehensive management of the risk factors, not only focusing on one.
- Promote evidence based non-pharmacological treatment for people at risk and support health interventions.
- Manage the cardiovascular risk with affordable approaches and the rational use of resources.
- Empower patients and families to manage and prevent the long-term progress of the disease.
- Inform the policy makers about the need and feasibility of managing cardiovascular risk.

. From these initial considerations the first statement are defined as follow:

The integrate management of the cardiovascular diseases requires a supportive environment that helps the patients to manage comprehensively the risk factors. Patients need to be empowered to manage and prevent the progress of the disease.

The next sections describe indetail the medical problem of the Coronary Artery Disease, the MI and the Cardio Rehabilitation.

1.1.1 Coronary Artery Disease

The Coronary Artery disease (CAD) is caused by an accumulation of plaques within the inside of the arteries that supply the myocardium with oxygen and nutrients. This arterial narrowing causes CVD, stroke, and peripheral arterial disease; this process of plaque formation is called atherosclerosis. (Pesek, Pesek, & Rogini, 2011)

Figure 1: Progression of the atherosclerosis²

The coronary atherosclerosis provokes angina and MI; if it is present in the cerebral arteries it can lead to stroke and transient cerebral ischemia. When it is present in the periphery vessel, it can cause intermittent claudication, gangrene and mesenteric ischemia. The progression occurs gradually throughout the individual's entire life; the progression goes unnoticed in many cases and may become clinically manifest later on in acute or chronic fashion (stable angina, acute coronary syndrome). The risk factors leading to the progress of atherosclerosis and the occurrence of cardiovascular diseases are classified as modifiable and non-modifiable risks.

1.1.1.1 Modifiable risk factors

These are conditions that patients could modify by improving their lifestyle:

- **Arterial hypertension:** this is called a 'silent killer' because it damages vital organs without producing early symptoms. The etiology of this condition is multifactorial and is still not completely understood. Usually the blood pressure increases along with the age of the person because arteries lose elasticity due to vasoconstriction or an increase in the volume of blood being circulated. Obesity, sedentary lifestyle, stress, excessive alcohol consumption and fatty foods are the risk factors associated with hypertension. The treatment of this condition is based on 2 components: pharmacological and lifestyle changes.
- **Cigarette smoking:** this is one of the mayor causes of death in the world³. Cigarette induced fatty build-up in arteries, several types of cancer and lung

² (Pesek, Pesek, & Rogini, 2011)

³ http://www.cdc.gov/tobacco/data_statistics/fact_sheets/fast_facts/

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problems. Furthermore, cigarettes increase blood pressure and decrease exercise tolerance and pulmonary capacity.

- **Hypercholesterolemia:** it is the presence of elevated cholesterol levels in the blood. It is the consequence of unhealthy nutrition, rich in saturated fatty acids.
- **Hypertriglyceridemia:** it is the presence of high levels of triglycerids in the blood and is common in obese people or people with poor healthy habits and sedentary lifestyles.
- **Diabetes mellitus:** this disease decreases the levels of the protective low density lipoprotein (LDL) that make people more susceptible to develop atherosclerosis. People suffering from this disease should reduce the levels of glucose they consume over the long-term.
- **Obesity:** the weight gain increases the blood pressure and the probability of developing type 2 diabetes. Excessive calorie intake has effect on the development of the atherosclerotic plaques in blood vessels
- **Sedentary lifestyle:** regular physical activity protects against the development of cardiovascular disorder.
- **Emotional stress:** the lack of social support, social isolation, unemployment, stress at work, family conflict and depression are critical risk factors. Such people are more likely to adopt unhealthy habits like smoking, eating unhealthy food and consuming alcohol.

The control of the modifiable risk factors reduces the progression of coronary artery disease. The modifiable risk factors can be controlled promoting healthy habits and lifestyle. Negative emotions (e.g. stress and depression) reduce the ability of the individuals to improve their lifestyle and management of the health.

1.1.1.2 Non-modifiable risk factors

No modifiable risk factors contribute to the person's global likelihood to develop CVD. These risks must be assumed and cannot be changed.

- **Family history:** it has been observed a familial predisposition for atherosclerosis, especially if there is a history of cardiovascular disease in family member before 55 (men) or 65 (women). The risk for heart disease can increase even more when genetic predisposition is combined with unhealthy lifestyle choices.
- **Age:** the risk of developing cardiovascular diseases increases as the population ages; since the atherosclerosis process is an accumulation process it is even recommended that prevention begin with at a young age.
- **Gender:** women have a slower atherosclerotic process. However from 65 years of age onwards, the risk is trebled and is comparable to that of men of the same age. This quick worsening from 50 to 65 years of age of the cardiovascular risk is provoked by the hormonal changes related to the menopausal process; women that enter in menopause early are three times more likely to have coronary disease.

CVD or ischemic heart disease occurs due to reduction of coronary blood flow, most commonly caused by coronary thrombus. The results in myocardial lesions, the extent

of which determines the symptomatology, clinical course and outcome of the disease. According to symptomatology and clinical course, ischemic heart disease is labelled as an acute coronary syndrome and a stable angina pectoris. In almost 99% of cases, CVD is caused by obstructive atherosclerosis and less frequently by spasm (usually idiopathic, or caused by drugs like cocaine). Sub-intimal plaques that reduce or obstruct coronary blood flow characterise atherosclerosis.

1.1.1.3 Pharmacological treatment of the disease

CVD have a large range of medications. Usually they either aim to reduce blood pressure or to widen the arteries. There is a very large range of medications available to treat the cardiovascular disease:

- Antiplatelets are a type of medicine that reduces the risk of heart attack by thinning the blood and preventing it from clotting. Common antiplatelet medicines are low-dose aspirin, clopidogrel, ticagrelor and prasugrel.
- Statins: they are used to lower the cholesterol levels. Some types include simvastatin, pravastatin and atorvastatin. They work by stopping the formation of cholesterol and increasing the number of LDL receptors in the liver, which helps remove the LDL cholesterol from the blood.
- Beta-blockers: include acebutolol, atenolol, bisoprolol, metoprolol and propranolol. They are used to prevent angina and treat high blood pressure. They work by blocking the effects of a particular hormone (The Beta receptor, which is present in the cells of the heart muscle and other tissues of the nervous systems), which slows down the heart rate and improves blood flow.
- Nitrates are used to widen the blood vessels. They are available in a variety of forms: tablets, sprays, skin patches and ointments. The typical active principles are: glyceryl trinitrate and isosorbide mononitrate.
- Nitrates relax the blood vessels, and improve the blood's flow through them. They lower the blood pressure and relieve the angina. Nitrates can have some side effects, including headaches, dizziness and flushed skin.
- ACE (angiotensin-converting enzyme) inhibitors, like ramipril and lisinopril medication, are used to control high blood pressure. They block the activity of the angiotensin II hormone, which causes the blood vessels to narrow. They also improve the flow of blood circulation in the body. 10% of the patients have kidney problems as a result of taking the drug: as a result patients following this treatment do regular blood tests as a precautionary measure. The most common direct effects are dry cough, headache, dizziness, fatigue and nausea.
- Angiotensin II receptor antagonists have a similar effect to ACE inhibitors. They are used to lower the blood pressure by blocking angiotensin II. Mild dizziness is the only side effect. Angiotensin II receptor antagonists are prescribed as an alternative to ACE inhibitors, because they do not cause a dry cough.
- Calcium channel blockers decrease blood pressure by relaxing the muscles that make up the walls of the arteries. This causes the arteries to become wider and reduces blood pressure. Examples are verapamil and diltiazem. Side effects include headaches and facial flushing, which are usually mild and decrease over time.

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No adherence to medication has been documented to occur in more of the 60% of cardiovascular patients. (Baroletti & Dell'Orfano, 2010). The barriers of medication adherence can be categorised in three types: socio-economics, communication related and motivational. The socioeconomic barriers are related to inadequate healthcare coverage, unemployment, poverty or concerns about costs. Communication barriers can be to speak a non native language (of the country in which the prescription is done), or caused by internal factors of the users as geriatric, low literacy, mental illness and substance abuse. The personal motivations that can lead to low adherence can be poor understanding of the disease, lack of perceived benefits of the therapy or fear about the toxicity of the prescribed drugs.

The effectiveness of the pharmacological treatment requires adherence from the user. The adherence to the therapy depends on user's behaviours and attitude but also on effective communication of the prescription and socioeconomic factors.

After decades of the coronary disease progressing, some of the plaques may rupture and along with the activation of the blood clotting system limit blood flow to the myocardium, resulting in an acute coronary syndrome (ACS). This may either be an unstable angina (meaning that the patient has persistent or recurrent chest pain in a state of rest but without evidence of myocardial necrosis) or heart attack (MI), meaning that there is a muscle cell necrosis in the affected regions of the myocardium).

1.1.1.4 Angina Pectoris

The most common development of the coronary artery disease starts commonly as a chest pain. The reason for the pain is the build-up of fatty materials that narrow the wall of the arteries. People with this symptom are at higher risk of having a heart attack. Aside from the chest pain symptoms associated with angina, the following symptoms can also be present:

- The pain found in the chest is also present in the shoulder, arm, jaw, neck, back or other area.
- Discomfort that feels like tightness, squeezing, crushing, burning, choking or aching.
- Shortness of breath (dyspnea): the patient has impaired breathing provoking distress and impacting the daily life of the person.
- Sweating

Over time the symptoms are to be considered severe when:

- The pain is more severe, comes more often, and occurs with less activity or even in a state of rest.
- Symptoms last longer than 15-20 minutes
- It happens if blood pressure decreases in case of shortness of breath

Figure 2: Angina pectoris⁴

If angina is a punctual event it is called un-stable and in general the patient's condition worsens in short period of time. Angina is called stable when it is always triggered by a certain amount of stress or activity.

The angina is diagnosed with the following tests:

- Blood pressure check
- Heart sound: the doctor uses the stethoscope and hears an irregular heartbeat
- Biochemical blood tests: the test should indicate the presence of elements that indicate the lesion of heart tissues like troponin I and T- 00745, creatine phosphokinase (CPK) and myoglobin
- ECG
- Echocardiography
- Stress tests like exercise tolerance tests, nuclear stress tests or stress echocardiogram
- Coronary angiography: this test takes a picture of the heart arteries using X Ray technology. The narrowed areas and the blood clots are located.

The progress of the Cardio Vascular Disease is asymptomatic. Angina is one of the first common symptoms that indicates that the condition of the cardio vascular system is critical.

The next chapter focuses on the MI, a more catastrophic event in which this research will focus on.

⁴ <https://www.nlm.nih.gov/medlineplus/ency/images/ency/fullsize/18054.jpg>

1.1.2 The myocardial infarction

A heart attack takes place when the blood vessel that brings oxygen to the heart muscle is severely reduced or stopped. It happens because the coronary arteries that supply the heart with blood can slowly become thicker and harder from a build-up of fat, cholesterol and other substances, called plaque. If the plaque breaks open and a blood clot forms that blocks the blood flow, a heart attack occurs. MI can be recognized by clinical features, including electrocardiographic (ECG) findings, elevated values of biochemical markers (biomarkers) of myocardial necrosis, and by imaging, or may be defined by pathology. MI may be the first manifestation of coronary artery disease (CAD) or it may occur, repeatedly, in patients with established diseases. Information on MI rates can provide useful information regarding the burden of CAD within and across populations, especially if standardized data is collected in a manner that distinguishes between incident and recurrent events. From the epidemiological point of view, the incidence of MI in a population can be used as an indicator for the prevalence of CAD in that population.

The Journal of the American College of Cardiology published the Third Universal definition of MI in 2012. The definition states that an acute MI occurs when there is a myocardial necrosis together with an acute myocardial ischemia (Thygesen et al., 2012). Under these condition at least one of the following situations are presented:

- Changes of the values of the cardiac biomarker cTN (McLean & Huang, 2012) and one of the following :
 - Symptoms of ischemia
 - Significant changes in the ST segment T wave (ST-T)
 - Presence of pathological Q waves
 - Presence of intracoronary thrombus
- Cardiac death: the myocardial ischemia provokes cardiac death (it is confirmed if biomarkers are present in the blood).and an a abnormal contraction of the left ventricle (it can be diagnosed with an ECG)

MI can be diagnosed using ECG, by finding elevated values of biochemical myocardial necrosis markers and by imaging. In general the MI may be the first manifestation of coronary disease. Most heart attacks are caused by blood clots that clog up a coronary artery. These arteries carry oxygen to the heart and when the flow is blocked the heart begins the necrosis process.

Figure 3: Process of necrosis of the heart caused by blood clots.⁵

MI is in the majority of cases the first manifestation of coronary artery disease. There are different types of MI:

- **Type 1:** spontaneous MI, which is related to atherosclerotic plaque rupture, ulceration, fissuring, erosion, and dissection. The result is an intraluminal thrombus in one or more of the coronary arteries leading to decreased myocardial blood flow or distal platelet emboli with ensuing myocyte necrosis.
- **Type 2:** MI secondary to an ischemia from a mismatch of oxygen supply and demand.
- **Type 3:** MI occurs in sudden death.
- **Type 4a:** MI related to percutaneous coronary intervention (PCI) MI associated with PCI
- **Type 4b:** MI related to stent thrombosis MI associated with stent thrombosis is detected by coronary angiography.
- **Type 5:** MI related to coronary artery bypass grafting (CABG) surgery.

Patients who develop symptoms of MI usually present themselves to an emergency department. When the clinical diagnosis confirms the presence of a suspected infarct the following test procedures are performed:

Blood analysis: this is used to measure the concentration of enzymes that are involved during the necrosis process of the myocardial cells. However, in many cases the blood laboratory test results are not available at the time of diagnosis, so the ECG is used to initiate the therapy.

ECG: the electrocardiogram signal should show the following changes: ST elevation or depression. New elevation at point J which elevation depends on the gender of the patient ($>0.2\text{mV}$ in males and $>0.01\text{mV}$ in women)

⁵ <https://www.nlm.nih.gov/medlineplus/ency/images/ency/fullsize/17004.jpg>

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How to measure ST elevation?

Figure 4: ST elevation definition⁶

- Pathological Q – waves are present in the ECG. They are the indicators of the MI. They take several hours to develop. Once pathologic Q waves appear they rarely go away. However, if the MI is treated early by a percutaneous coronary intervention the myocardial cells could recover and the Q waves can disappear.

Figure 5: Example of pathologic Q-wave⁷

- Echocardiogram can be used to compare areas on the left ventricle. An echocardiogram may be performed to compare areas of the left ventricle that

⁶ http://en.ecgpedia.org/images/a/a7/Stelevatie_en.png

⁷ <http://en.ecgpedia.org/wiki/File:PathoQ.png>

are contracting normally with those that are not. One of the earliest protective actions of myocardial cells used during limited blood flow is to turn off the energy-requiring mechanism for contraction; this mechanism begins almost immediately after normal blood flow is interrupted. The echocardiogram may be helpful in identifying which portion of the heart the MI affects and which of the coronary arteries is most likely to be occluded. Unfortunately, the presence of wall motion abnormalities on the echocardiogram may be the result of an acute MI or previous (old) MI or another myopathic process, limiting its overall diagnostic utility.

The following clinical practices are used to treat the MI:

- Oxygen is provided to improve pulmonary performances and increase the oxygen in the heart muscle.
- An intravenous line will be placed in one of the veins. All the medicines pass through this channel.
- Nitroglycerine and morphine are used to reduce chest pain.
- Aspirins.
- A pharmacological treatment to prevent blood clots.

In case of a very acute coronary syndrome the following procedures are followed:

- Angioplasty: this percutaneous process opens the narrowed vessels that supply the blood to the heart.
- Stent: this is a metal mesh tube that expands the coronary artery; it also could be done via percutaneous intervention.
- Thrombotic therapy: patients receive medications to open narrowed or blocked blood vessels.
- Some patients may undergo heart bypass surgery to open narrowed blood vessels that supply the blood to the heart.

The following image shows the surgery details for the stent:

Figure 6: Stent in heart vessel. 8

⁸ <https://www.nlm.nih.gov/medlineplus/ency/images/ency/fullsize/23193.jpg>

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The cardiologists use the heart monitor to see the progress and the changes of the heart's electrical activity. Patients with STEMI (ST elevation during a MI) should have percutaneous coronary intervention within the first 90 minutes.

The treatment of the Myocardial infarction must not be delayed, patient and bystanders should recognise the symptoms early and activate the emergency medical service to save the life of the patient.

1.1.3 The cardio rehabilitation

Cardio rehabilitation has shifted over the past few decades from being a simple assistance tool to recover cardio-vascular fitness to becoming a multidisciplinary approach that focuses on patient education, modifying the risk factors and promoting general well being. The first report of a cardio-rehabilitation was in 1772 when Heberden reported a case of a patient who improved his condition by working in the woods for half an hour per day. Despite this case the medicine proposed to the post MI patient total rest as a therapy to recover from the heart attack. In the 1912 Herrick still reinforced these theories by proposing to prescribe patients with acute coronary events with 6 weeks of bed rest. In the 1940s chair therapy was introduced (S. A. Levine, 1952), in which it was recommended to sit the patient in a comfortable armchair after the onset of the acute event. In the 50s a very short exercise routine consisting of a daily walk between 3 and 5 minutes beginning 4 weeks after the acute event was introduced. The changes started in 1953 when Morris demonstrated that bus drivers in London had a higher probability of developing coronary events compared with ticket sellers (Morris & Heady, 1953), who had a more active lifestyle. Dr. Hellerstein is one of the first people to develop a multidisciplinary approach, demonstrating that the optimal therapy is a composition of medication and lifestyle changes. At the time the vision of Hellerstein was not confirmed by the clinical evidence, the key risk factors for developing atherosclerosis was discovered in 1961 (Bethell, 2000).

In 1968 Saltin demonstrated the benefits of exercising and the potential danger of bed rest (Saltin et al., 1968). A more solid contribution is the work of Naughton and others whose study helped to establish the physiological basis of the benefits of exercising and the need for a multi-disciplinary approach to cardio-rehabilitation (Naughton, Lategola, & Shanbour, 1966).

In that times there has also been significant pharmacological progress in the field of cardiology: new treatments as beta-blockers, thrombolytic and calcium blocker starting being used in the clinical practice. The first comprehensive study on the positive effects of the exercise during cardio-rehabilitation was carried out in the INTERHEART study (Wannamethee, Shaper, & Walker, 2000)(Yusuf et al., 2004). This and many other studies have demonstrated the existence of risk factors that act independently of every geographic location and gender.

Nowadays cardiac rehabilitation is the process by which a patient who suffers from ischaemic heart disease, or who has had a MI, is helped to recover their physical and psychological health. In order to be successful, cardiac rehabilitation is based on the support of a healthcare team and requires a combination of education, psychological support, exercise training and behavioural change (Balady et al., 2011).

Cardiac rehabilitation includes a structured exercise programme and not only does it improve morbidity but also reduces mortality in patients who have suffered an MI (Leon, 2005). All patients, regardless of gender or age, who have ischaemic heart disease and/or cardiac failure, benefit from cardiac rehabilitation (Gordon, 2004). For an optimal outcome, the cardiac rehabilitation programmes should be structured and tailored to the individual patient through an initial assessment. Some computer support systems are also used to assist the decision-making process (Goud et al., 2009). The cardio rehabilitation process is structured into 4 phases:

- **Phase 1:** it starts when the patient is hospitalized (inpatient stage): it includes a medical evaluation and an assessment of the risk factors. During this phase counselling should begin in order to understand the disease, correct any misconceptions and prepare the patient for discharge.
- **Phase 2:** it is the post discharge phase. Patients join a medical supervised exercise training session and avail of other support services like diet recommendations and smoking cessation stress management. Hospitals or medical centres usually provide the service. Patients start the exercise training using a ECG monitor; the exercise levels are individualised depending on exercise capacity and the heart rate performance. During this phase the medical team also introduces exercises for home settings and provides support to foster healthy habits and reduce modifiable risk factors.
- **Phase 3:** the goal of this phase is to persist with the behaviour changes that are required to reduce the modifiable risk factors: patients perform physical activity out from the hospital or clinical centre and receive a tailored programme to improve healthy habits.
- **Phase 4:** it is the long-term phase; it lasts for the remainder of the patient's life. Patients should maintain activity levels and lifestyle changes. In general this phase is not supported by the healthcare system. Public services like gyms and leisure centres provide the support for maintaining healthy habits and fitness levels.

There is evidence of the benefits of the cardio rehabilitation: it reduces the cardiovascular risk and incidence rates, fosters healthy behaviours, and promotes active lifestyles (Leon, 2005).

The duration and nature of the Cardio Rehabilitation is considered as an integrated care service for patients that have suffered cardiovascular events. The American Heart Association and American Association of Cardiovascular and Pulmonary Rehabilitation defined the core elements of cardiac rehabilitation: these guidelines provide specific information about the evaluation, intervention and the expected outcomes of the programme (Balady et al., 2000).

The core components are described in the next sections.

Cardio rehabilitation is a multidisciplinary approach that requires modifications of the habits of the user.

1.1.3.1 Patient assessment

This is a global assessment of the patient's condition. The medical history that should be taken into account includes cardiovascular diagnoses and prior treatments, the risk factors relating to the progression of the atherosclerotic plaques, and their medication adherence. The medical team needs a physical examination of vital signs and a global

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examination of the neuro cardio pulmonary system. The examination is done performing physiological test as ECG at rest and during exercise, angiography, blood analysis; also questionnaires can be used to measure the overall health status of the person (e.g. MOS SF-36⁹). The medical team generates an individualised care plan and communicate it to the patient with risk reduction and rehabilitation being prioritised. The assessment is the first step to define the cardio rehabilitation program. Thanks to this component the short-term care plan is defined and goals and strategies are defined in order to reduce disability and reduce the risk of the disease's progress or acceleration. The care plan is also communicated to the primary care giver and the medical team could also make references to other specific areas to manage further comorbidities (e.g. diabetes).

Cardio rehabilitation is an individualized program that requires a the global assessment of the health status of the user.

1.1.3.2 Nutritional counselling

The medical team estimates the daily caloric intake and content of fat, cholesterol, sodium and other nutrients. The patients provide information about eating habits: number of meals, snacks, frequency of dining out and alcohol intake. The professionals assess the needs of the nutrition intervention depending on the physical condition of the patients: this dimension encompasses variables such as weight, blood pressure and the presence of comorbidities as diabetes, hypertension, heart failure. The health professionals prescribe the patient with a modified diet to reduce saturated fat and cholesterol in the blood. Each patient receives an individualised diet according to other core components (diabetes, hypertensions, weight, heart failure, comorbidities). Patients should receive practical tips to achieve dietary goals. Health behaviour change techniques may be applied to achieve compliance with the diet. The expected outcome from the dietary intervention is that the patient understands the effects of the calories, saturated fat, cholesterol and other nutrients. Unhealthy dietary habits should be addressed within the intervention.

User should adopt healthy dietary habits. Those require the reduction of: salt, fat, alcohol and of the global calories of the food (to control weight).

1.1.3.3 Lipid management

The level of the lipids can be obtained easily with a blood test. There are three main levels that should be controlled: the LDL, the HDL and the triglycerides, and their levels are:

The 3rd revision of the American National Institutes of Health, National Heart, Lung, and Blood Institute provide the following guidelines for the lipid management (National Cholesterol Education Program., 2002) considered that :

- The LDL cholesterol is optimal when it is <100 mg/dL
- The HDL cholesterol is optimal when it is <40 mg/dL .

⁹ http://www.rand.org/health/surveys_tools/mos/mos_core_36item.html

- The elevated serum triglycerides is not a risk factor in itself (Hulley, Rosenman, Bawol, & Brand, 1980) but it does indicate the presence of high levels of LDL and HDL cholesterol and the presence of other risk factors like smoking, diabetes, obesity and hypertension (Grundy, 1998). It is also caused by excessive alcohol intake, a very high in carbohydrate diet, medication (corticoids, protease inhibitors, for HIV, beta-adrenergic blocking agents, estrogen), other diseases (chronic renal failure, nephrotic syndrome) or genetic factors.

The recommended levels of cholesterol are show in the following table:

Total Cholesterol (mg/dL)		LDL Cholesterol (mg/dL)	
<200	Desirable	<100	Optimal
		100-129	Near optimal
200-239	Borderline High	130-159	Borderline High
>240	High	160-189	High
		>190	Very High

Table 1: Classification of level of cholesterol and LDL¹⁰.

The atherogenic dyslipidaemia is a condition in which the subjects have elevated levels of triglycerides; it generally occurs in people with premature CHD (Austin, King, Vranizan, & Krauss, 1990; Chambless et al., 1997). A typical person suffering from these altered levels tends to be overweight, have abdominal obesity and have a sedentary lifestyle. Also diabetes 2 patients have high incidence of atherogenic dyslipidaemia¹¹.

Atherogenic dyslipidemia generally occurs in persons with premature CHD, it is associated with obesity and sedentarisms. Weight control and increased physical activity can mitigate the dislipdemia. The risk factors that influence the modification of the lipid level are classified as following:

- Modifiable risk factors are hypertension, cigarette smoking, thrombogenic / hemostatic state, Diabetes, Obesity and physical inactivity.
- Non-modifiable risk factors are age, being male and having a family history of premature CHD.

Drug therapy is recommended when the LDL cholesterol levels are > than 100mg/dL: they tend to contain fibrates or nicotine acid: in all the cases diet and lifestyle modifications are recommended. The following table summarizes the recommendations of the management of the LDL cholesterol:

Cholesterol level	LDL cholesterol goal	Level at which to initiate therapeutic lifestyle change	Level at which to initiate LDL-lowering drug
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¹⁰ (National Cholesterol Education Program., 2002)

¹¹ The presence of an elevated amount of lipids in the blood.

BACKGROUND

>130mg/dL	<100 mg/dL	>100 mg/dL	Start drug therapy simultaneously with dietary therapy
100-129 mg/dL	<100 mg/dL	>100 mg/dL	Drug is optional
<100 mg/dL	<100 mg/dL	Lifestyle change, emphasize weight control and increased physical activity	Drug is not required

Table 2: Required intervention to reduce LDL¹⁰

The cholesterol level is a relevant information to predict the evolution of the coronary artery disease. From these values the medical team can prescribe or not lowering lipid drug therapy. Patients can use this information to better understand what need to be achieved to be control the progression of the Coronary Artery Disease.

1.1.3.4 Hypertension management

The following diagram shows the recommendations from the American Heart Association (AHA) for managing hypertension:

Controlling Hypertension in Adults¹

Figure 7: Guidelines to manage hypertension from AHA¹²

The treatment of the high blood pressure can be managed using a combination of pharmacological therapy and lifestyle modifications. The typical pharmacological treatment includes a sub-set of the following medications:

- Diuretics: they act on the kidney to eliminate sodium and water and consequently they reduce the volume of blood. A common side effect is increased urination

¹² <http://hyper.ahajournals.org/content/63/4/878/F1.large.jpg>

BACKGROUND

- Beta-blockers: this reduces the workload of the heart and expands the blood vessels.
- ACE (Angiotensin Converting Enzyme) inhibitors block the narrowing of blood vessels.
- Angiotensin II receptor blockers (ARBs): they are similar to the ACE inhibitors
- Calcium channel blockers: they relax the muscles of blood vessels and slow the heart rate
- Alpha and Alpha –Beta blockers: they reduce the nerve impulses that cause tension in the blood vessels
- Central acting agents: they act on the brain's central neurological system to expand the blood vessels
- Vasodilators: they relax the blood vessels

Together with specific pharmacological therapy the high blood pressure can be reduced through the following lifestyle modification that can be summarised in this table (Go et al., 2014):

Modification	Recommendation	Approximate SBP Reduction (Range) ¹³
Reduce weight	Maintain normal body weight (body mass index 18.5–24.9 kg/m ²)	5–20 mm Hg/10 kg
Adopt DASH ¹⁴ eating plan	Consume a diet rich in fruits, vegetables, and low-fat dairy products with a reduced content of saturated and total fat	8–14 mm Hg
Lower sodium intake ¹⁴	a. Consume no more than 2,400 mg of sodium/day; b. Further reduction of sodium intake to 1,500 mg/day is desirable since it is associated with even greater reduction in BP; and c. Reduce intake by at least 1,000 mg/day since that will lower BP, even if the desired daily sodium intake is not achieved	2–8 mm Hg
Physical activity	Engage in regular aerobic physical activity such as brisk walking (at least 30 min per day, most days of the week)	4–9 mm Hg
Moderation of alcohol consumption	Limit consumption to no more than 2 drinks (e.g., 24 oz beer, 10 oz wine, or 3 oz 80-proof whiskey) per day in most men, and to no more than 1 drink per day in women and lighter weight persons	2–4 mm Hg

¹⁴ DASH, dietary approaches to stop hypertension
¹⁵ The effects of implementing these modifications are dose and time dependent, and could be greater for some individuals

Figure 8: Lifestyle modification table to reduce hypertension ¹³

The patient is encouraged to self-monitor in order to achieve and maintain the correct blood pressure levels.

Specific pharmacological treatment and lifestyle modifications are required to manage the hypertension. The patients need to check periodically the blood pressure in order to be in control of the progression of the disease.

¹³ <http://hyper.ahajournals.org/content/63/4/878/F2.large.jpg>

1.1.3.5 Smoking cessation

Health professionals assess the degree to which the patient smokes, the types (cigar smoking, pipe etc) of use and exposure (direct or indirect) and promote the smoking cessation. The recommended intervention is the following (Balady et al., 2000):

1. Propose that the patient stop smoking.
2. If patient wants to quit smoking the following minimal strategies are proposed: provide individual education and counselling and self-learning material, encourage, GP, family member to support the patient and provide tools to prevent relapses.
3. In case of having more resources, the patient could attend a formal smoking cessation programme or an alternative programme (acupuncture, hypnosis).
- 4.

The stages of modification in the smoker's habits follow these processes:

- Patient must demonstrate readiness to stop smoking (contemplation)
- Patient is prepared to start quitting smoking (preparation)
- Patient quit smoking (action)
- Reinforcing strategies or resumption of cessation programmes to prevent relapses.

Smoking cessation or reduction is required in order to reduce the progress of the disease.

1.1.3.6 Weight management

Three variables are used to manage the weight: the height, the weight and the waist circumference. A body mass index (BMI) is calculated as $\text{height}/\text{weight}^2$. Intervention is required when the BMI is greater than 25Kg/m² and the waist is larger than 102cm for males and 88cm for females. In these cases a plan for reducing weight by at least 10% at rate of 0,45 - 0,9 Kg per week is recommended by following a diet combined with an exercise routine that is designed to reduce total calorie intake, maintain the required intake of nutrients and achieve the deficit energy (when the intake of calories is lower than the calories burned) of 500-1000 kCal/day. The health provider can also refer to nutritionists to create a more personalised and structured diet.

Overweight patient has to modify dietary habits and increase the level of physical activity

1.1.3.7 Diabetes management:

The glucose levels should be monitored and when fasting glucose density is more than 110mg/dL patients are referred to a specialist for further evaluation. Patients suffering from diabetes should follow a dietary regimen, control their weight and perform exercise, as well of control other risk factors. The glucose levels should be monitored before and after exercising. People with a very high level of fasting glucose (>300mg/dL) should reduce or avoid exercise.

Diabetes is a relevant comorbidity associated with increased risk of cardiovascular incidence. Also this disease should be managed in order to reduce the risk of cardiovascular complications.

1.1.3.8 Psychosocial management

Any psychological distress with significant levels of depression, anxiety, anger and hostility, social isolation, sexual dysfunction or substance abuse (alcohol, psychotropic) should be assessed and health professionals should:

- Offer individual and/or small group education and counselling regarding adjustment to CHD, stress management, and health-related lifestyle change. If possible, include family members and other relatives in such sessions.
- Develop a supportive rehabilitation environment and community resources to enhance patient and family's level of social support.
- Increase the amount of knowledge about the disease and support self-help strategies.
- Maintain contact with primary healthcare provider; refer patients experiencing clinically significant psychosocial distress to appropriate mental health specialists for further evaluation and treatment.

A supportive strategy needs to be developed to address any psychological distress of the patient.

1.1.3.9 Physical activity

Physical activities are a person's daily activities and encompass domestic, occupational and recreational areas. Therefore they are the activities spanning the entire day produced by skeletal muscles and which produce energy expenditure (Thompson, 2003).

A sedentary lifestyle, with reduced physical activity is a major risk factor for CVD (Warren et al., 2010). In order to assess the risk of the cardiac condition worsening, health professionals should assess patients' activity levels while taking the following into account: age, gender, daily lifestyle, transportation, sexual activity, and social activity.

Modification of daily habits is the key factor to improving physical activity performance: because of this reason health professionals should provide counselling about physical activity requirements. Patients should set goals to achieve at least 30 minutes of moderate physical activity per day on $\geq$ days per week. (Balady et al., 2000) and this could be achieved by changing their daily routines. Some examples of how to increase physical activity are:

- Go out for a walk with the dog
- Take the children for a walk
- Join a team, by taking up an activity with a friend
- Go for a walk with a friend and chat.
- Exercise while watching TV
- Park the car far away from your destination.
- Performing leisure activities that require moderate / high intensity activity (e.g. dancing, trekking).

- Skip dessert and go for a walk after dinner.

The American Heart Association published an informative info graphic about the physical requirements for maintaining the heart into good health status:

Figure 9: Recommendation of physical activity ¹⁴

Physical activity could be a substitute for an exercise activity, it can improve psychosocial well being, reduce stress, facilitate functional independence, prevent disability and increase confidence and help towards independent self-care achieving the recommended therapy goals.

Patient needs to adopt an active lifestyle and perform daily activities to maintain the fitness level.

1.1.3.10 Exercise training

Sport medicine defines the exercise as a type of physical activity consisting of structured, planned, and repetitive movements to maintain or improve one or more components of physical fitness. Physical fitness can be defined as a *set of attributes or characteristics that people have or achieve that relates to the ability to perform*

¹⁴

http://www.heart.org/HEARTORG/GettingHealthy/PhysicalActivity/FitnessBasics/American-Heart-Association-Recommendations-for-Physical-Activity-Infographic_UCM_450754_SubHomePage.jsp

BACKGROUND

physical activity (American College of Sports Medicine, 2014). These features can be grouped into either health-related or skill-related components:

Health-Related Physical Fitness Components:

- Cardiovascular endurance, is the capacity of the circulatory and respiratory systems to provide oxygen during sustained physical activity.
- Body composition: the amounts of muscle, fat, bone, and other vital tissues in the body.
- Muscle strength: the ability of muscles to contract and exert force.
- Muscle endurance: the ability of muscles to persist over time without fatigue.
- Flexibility: range of motion available of the musculoskeletal body.

Skill-Related Physical Fitness Components:

- Coordination: the ability to use the human senses (e.g. sight and hearing) together with body parts to perform tasks smoothly and accurately.
- Agility: the ability to move the body in space with speed and accuracy.
- Balance: the preservation of equilibrium while stationary or moving.
- Power: the ability or rate at which one can perform the exercise task.
- Reaction time: the time elapsed between the stimulation and the beginning of the reaction to it.
- Speed: the ability to move the body in a short period of time.

Quantification of the exercise:

One important dimension of the exercise is the intensity of the activity. The MET (Metabolic Equivalent of Task), also called the metabolic equivalent, is a physiological measure that looks as follows:

$$1\text{MET}=1\text{Kcal}/(\text{Kg}^*)=4.184\text{ kJ}/(\text{Kg}^*\text{h})$$

The definition defines 1 MET as the rest metabolic rate (RMR). The following table shows a list of human activities and their MET correspondent:

	Light activity (<3 MET)	Moderate (3-6 MET)	Vigorous (>6 MET)
Walking	slow: 2	Moderate (4,8 Km/h): 3 Brisk pace (6,4 Km/h): 5	Very brisk pace (7 Km/h): 6,3 Jogging at 8Km/h:8 Running at 11 Km/h : 11,5
Leisure time and sports	Playing card: 1.5 Playing instruments: 2 /2,5	Badminton recreational: 4.5 Basketball shooting a round = 4.5 Bicycling on flat/light effort (10–12 mph) = 6.0 Dancing—ballroom slow = 3.0; ballroom fast: 4,5 Fishing	Basketball game = 8.0 Bicycling on flat /moderate effort (20–22 Km/h): 8 fast (22–25 Km/h): 10 Skiing cross country slow (4 Km/h) = 7.0; fast (5.0–13 Km/h): 9

		from riverbank and walking: 4 Golf walking pulling clubs: 4,3 Sailing boat, wind surfing : 3	Soccer casual = 7; competitive: 10 Swimming moderate/ hard: 8–11 Tennis singles: 8
Household and occupation:	Working with computer: 1,5 Light house work (making bed, preparing food): 2/2,5	Heavy cleaning (washing windows, cars): 3/3,5 Moving lawn: 5.5	Shovelling sand, coal: 7.0 Carrying heavy loads, such as bricks: 7.5

Table 3: Example of MET values of common physical activities ¹⁵

Test before the exercise

It is a consolidated norm to measure the level of fitness of the user and it is closely related to the functional capacity of the heart. It is measured by using the open circuit spirometer. The maximal oxygen uptake is the maximum rate of oxygen consumption (VO_2) measured during incremental physical exercise. When direct measurement is not possible, submaximal and maximal exercises can be used to estimate the VO_2 max, along with other indexes like blood pressure, heart rate and the perceived exertion. These are the possible clinical modes of testing:

- Motor driven treadmills: they provide walking exercises that can be increased continuously.
- Mechanically braked cycle ergometer. They are less expensive, easily transportable. The main disadvantage compared with treadmills is that cycling is less natural than walking. In order to obtain a precise test result it is important to calibrate the device.
- Step testing: this is a cheap test: the heart rate response is measured at fixed rate or a fixed step or after the exercise. It requires little practice from the patients and it has a short duration.

Guidelines for exercise prescription

The exercise prescription is a personalised programme of structured exercise activities to improve the fitness level of the subjects. In order to prescribe it safely, health professional should assess the exercise capacity; an exercise test is required before participation, which is repeated as warranted by changes in the clinical condition. The test includes the assessment of heart rate and rhythm, signs, symptoms, ST-segment changes, and exercise capacity (Balady et al., 2000).

The standard exercise protocols define a combination of aerobic and resistance training sessions. Moderate-intensity exercise training (50% to 80% of maximum heart rate [HR_{peak}]) is recommended for aerobic exercise and will be achieved via continuous or interval exercise sessions. Aerobic interval training requires alternating

¹⁵ (American College of Sports Medicine, 2014)

BACKGROUND

3- to 4-minute periods of exercise at high intensity (90%–95% HR_{peak}) combined with exercise at moderate intensity (60%–70% HR_{peak}) (Kwan & Balady, 2012).

The following types of exercise can be prescribed:

- Aerobic exercise (Frequency 3/5 days/week, 80% of exercise capacity, Duration 30-60 min): walking, treadmill, cycling, rowing, stair climbing, arm ergometer, and others.
- Resistance exercise: it is any form of exercise that forces the skeletal muscles to contract. (Frequency 2/3 days/week, 8-15 repetition upper and lower body muscles): it can be used elastic bands, cuff/hand weights, dumbbells, free weights, wall pulleys, or weight machines.
-

Every exercise session should include warm up, cool down and flexibility exercises.

Therefore, the global structure of the exercise is structured thusly:

Figure 10: Example of exercise structure ¹⁶

The warm up phase includes stretching activities and increased exercise levels; it is recommended for reducing the risk on injuries, angina and arrhythmias. The aim of the cool-down phase is to bring the body back to its rest state and is achieved by reducing the intensity of the activity. This process reduces the risk of dizziness and fainting. The stretching exercise during this phase helps reduce muscle soreness.

Benefits of the exercise

A continuous exercise programme generates several benefits for the human physiology, which can be summarised as follows (American College of Sports Medicine, 2014)

The first direct benefit is the improvement in cardiovascular and respiratory functions in terms of:

¹⁶ <http://www.ouh.nhs.uk/patient-guide/leaflets/files%5C091011cardiacrehableys.pdf>

- Increased maximal oxygen intake resulting from both central and peripheral adaptations
- Decreased heart rate and blood pressure at a given submaximal intensity
- Decreased minute ventilation at a given absolute submaximal intensity
- Decreased myocardial oxygen cost for a given absolute submaximal intensity
- Increased exercise threshold for the accumulation of lactate in the blood
- Increased exercise threshold for the onset of signs of disease or symptoms (e.g., angina pectoris, ischemic ST-segment depression, claudication)
- Increased capillary density in skeletal muscle

The second factor is that exercise is a key component in the reduction of Coronary Artery Disease Risk Factors because:

- It reduces resting systolic/diastolic pressures
- It increases serum high-density lipoprotein cholesterol and decreases serum triglycerides
- It reduces total body fat, reduces intra-abdominal fat
- It reduces insulin needs, improved glucose tolerance
- It reduces the blood platelet adhesiveness and aggregation

Another important aspect of exercise is the decreased morbidity and mortality rates that can be noticed across the world's population. It has a double effect of intervention in terms of reducing the development of the CAD.

- Primary prevention (i.e. interventions to prevent the initial occurrence): higher activity and/or fitness levels are associated with lower death rates from coronary artery disease. Moreover higher activity and/or fitness levels are associated with lower incidence rates for combined cardiovascular diseases, coronary artery disease, stroke, type 2 diabetes, osteoporotic fractures, cancer of the colon and breast, and gallbladder disease.
- Secondary prevention (i.e. interventions after a cardiac event): Based on meta-analysis (pooled data across studies), cardiovascular and all-cause mortality are reduced in post-MI patients who participate in cardiac rehabilitation exercise training, especially as a component of multifactorial risk factor reduction (Mampuya, 2012).

Exercise also generates other wellbeing related benefits such as:

- Decreased anxiety and depression
- Enhanced physical function and independent living in older persons
- Enhanced feelings of well-being
- Enhanced performance at work, recreation, and sporting activities
- Reduced risk of falls and injuries from falls in older persons
- Prevention or mitigation of functional limitations in older adults
- Effective therapy for many chronic diseases in older adults

The exercise is a structured activity that can be prescribed to improve physical fitness and the cardiovascular functions. Exercise has a positive effect on the global health status of the user.

Risk of exercises

BACKGROUND

The incidence of a serious or fatal event during the supervised session of exercise is low, but to reduce the risks it is important to assess the patient's condition before the exercise training session.

The clinical risk stratification is based on the clinical history of the patients, by the examination of the ECG combined with stress tests. In general the risk is high when:

- The MI is complicated by Heart Failure condition, cardiogenic shock or arrhythmias
- Angina and breathlessness occur at a low level of exercise
- The ST segment depression is greater than 1 mm on resting ECG
- ST depression ≥ 2 mm or angina at < 5 METS

Other important factors that increase the risk are the patient's comorbidities as pulmonary and metabolic diseases. (American College of Sports Medicine, 2014)

The health status of the patient determines the risk of doing exercise; also the intensity of the exercise influences the likelihood of having a cardiovascular event provoked by exercise activity.

The exercise and physical activity are key factors to reduce the reoccurrence of the Myocardial Infarction and the evolution of the coronary disease.

1.1.3.11 Required behavioral modifications of CR

CR requires the patient involvement to modify the user's daily routine. The following table summarize the behaviours that are involved in the CR process.

The Cardio Rehabilitation is a complex process in which are required several behavioral modification. Those can be divided in two categories:

- **Management of the disease:** CVD are treated with medication, and patient should control the level of weight, blood pressure and fats in the blood. To do so users have to adhere to the prescribed medication and perform periodic visits and tests (blood tests, blood pressure and weight measure).
- **Lifestyle habits:** they represent the core element for the management and control of the CVD. Healthy dietary habits and increased level of physical activity have positive effects on the progress of the disease. Unhealthy behaviours as smoking and elevated alcohol consumption negatively impact on the global health status. Furthermore exercise is a key component for the recover of the functionality of the heart.
- **Management of emotional distress:** cardio rehabilitation also includes psychosocial support for patient that has emotional distress.

In order to reduce the progression of the CV disease these behaviours should be maintained for the rest of the life of the patient.

1.1.4 Barriers and future of the CR

A systematic review shows that a significant risk reduction of 18% in fatal cardiovascular events in patients following multifactorial lifestyle intervention programmes (de Waure et al., 2013). Although cardio-rehabilitation has been proven

to have beneficial effects, the participation is not high. The main reasons of not attending the cardiac rehabilitation in the center, hospitals, gyms, or community centres (Ades, Waldmann, McCann, & Weaver, 1992) (Andrew et al., 1981) are that patients dislike the group activities (Ades et al., 1992) (Andrew et al., 1981), or they are busy with other activities (work or domestic job) (Pell, Pell, Morrison, Blatchford, & Dargie, 1996) (Nohara et al., 1990) (Evenson & Fleury, 2000). One strategy for overcoming these problems is to provide home-based programmes (Dalal, 2003). Datal et al. used the Cochrane database to perform a systematic review about the effects of home-based cardio-rehabilitation: from a revision of 12 studies it demonstrates that **cardio-rehabilitation at home is equally effective** at improving health outcome and reducing morbidity and mortality (Dalal, Zawada, Jolly, Moxham, & Taylor, 2010). The cardiac-rehabilitation is strongly recommended in order to reduce mortality and reoccurrence; Khattab et al demonstrate that many patients receiving PCI (Percutaneous Coronary Intervention) do not achieve their lifestyle and risk factor goals (Khattab et al., 2013).

The Cardio Rehabilitation's participation is not high, home based rehabilitation better fits in patient's daily life. The home-based cardio-rehabilitation process has comparable benefits to the hospital / clinic based programme.

1.2 Understanding behaviour change

A key component of behaviour change is motivation. The **intrinsic motivation** refers to the performance of a behaviour that is driven by internal rewards. Dennis Coon defined it in this way:

Intrinsic motivation occurs when we act without any obvious external rewards. We simply enjoy an activity or see it as an opportunity to explore, learn, and actualise our potentials (Coon & Mitterer, 2013)

The **extrinsic motivation** differs because there is an external agent that promotes the behaviour using an external reward mechanism or by avoiding punishment. Many studies have demonstrated the relevance of the intrinsic motivation (Cameron & Pierce, 1994).

Another key component is the **attitude** that is a composition of enduring beliefs, feelings and behavioural tendencies toward a specific concept (Eagly & Chaiken, 1993). Attitude as three main components: the affective component (the feeling and emotions about the concept), the behavioural (how user act or behave the concept) and the cognitive (the knowledge and belief about the concept).

Health psychology designs health interventions that can be classified in three categories (Westmaas, GilRivas, & Cohen Silver, 2007):

- Primary intervention: this intervention prevents illness from occurring
- Secondary intervention: this occurs after a disease has been diagnosed.
- Tertiary intervention seeks to control the negative effects of a severe physiological disease.

These interventions use the media and social organisation (especially in policy makers in healthcare, nursery, educators, social support organisations, patient associations etc.) to adopt healthy behaviours and discourage un-healthy lifestyles. The current health polices focus majorly on secondary intervention. The key elements for a successful intervention have also been can be summarized as follow (Coon & Mitterer, 2013):

- The person has a good predisposition to perform the behaviour
- Require minimal effort at a cognitive, physical, logistic and socio-environmental level
- The person feels they have the requisite to perform the behaviour
- Belief in the external help. This is a crucial element because the intervention could leverage only on the extrinsic motivation that is a less powerful motivational force.
- Belief in the normative pressure to perform the behaviour.
- Having positive affect performing the behaviour. This again consolidates the statement about the importance of taking emotions into account in this research.

- Engaging cues: this refers to the capacity of the individual to be engaged through external cues.

From the health psychology two topics are be presented in the context of this research:

- The methods to promote attitude or behaviour change of a person.
- The impact of emotions on health and behaviour change. The focus will be in the area of the coronary heart disease.

1.2.1 Behaviour change theories

The success of health intervention depends on the use of the appropriate theoretical framework. This is also valid when is used the technology to foster behaviour change (Fanning, Mullen, & McAuley, 2012). Some prominent theories related to behaviour change and attitude change like the Theory of planned Behaviour (Ajzen, 1991), Theory of Reasoned Action (Thomas Sarver, 1983) have been successfully implemented. There are a very large number of theories depending on the type and level on intervention. A more extended analysis of behaviour change could be explored through the paradigm of intervention mapping that provides evidence-based techniques. Recently Kok shared an extended taxonomy of effective interventions that could be used to develop specific intervention plans at individual and community level. (Kok et al., 2015).

A relevant approach for health behaviour change is the Social Ecological Approach (McLeroy, Bibeau, Steckler, & Glanz, 1988) that defines different factors that influence behaviours, at different levels, from the physiological, interpersonal factors, to the psychosocial, epidemiological, community factors, policy and media communications. In this approach the individuals have different levels of influence from the environment.

The following table summarises the relevant theories that have been found in literature

BACKGROUND

Theories for understanding behaviours and attitudes	
Theory of Planned Behaviour (Ajzen, 1991)	It is based on the individual's perceptions of ease to perform behaviour. The behavioural control influences the individual's choices.
Theory of Reasoned Action (Thomas Sarver, 1983)	Peoples' behaviour is determined by the behavioural intentions. These are triggered by the attitude toward the behaviour and subjective norms.
Self-Efficacy Theories (Bandura, 1978)	A person that feels capable of performing an action also adopts the behaviour. Individuals are more engaged in activities for which have high perceived efficacy
Social Cognitive (Lerner, 1990)	People learn from others. The individual perception of ability increases observing others humans performing a behaviour .
Elaboration LikeHood Model (Petty & Cacioppo, 1986)	The ELM model is composed of a dual process that describes how humans choose to manage with external stimuli. Cacioppo et al. described two types of routes to persuade: the central route, which manages the stimuli depending on critical thinking, and the peripheral route, based more on unrelated logical qualities of the stimuli. The resulting attitude change is persistent and predictive of behaviour.
Goal Settings Theory (Locke & Latham, 2002)	People need specific and measurable goals to achieve the behaviours. The goals must consider the level of degree of clarity, feedback, commitment, challenge and complexity of behaviour.
Cognitive dissonance theory (Festinger, 2001)	It represents conflicting attitudes, beliefs and behaviours. Humans seek a consistent dimension of harmonies between behaviours and beliefs and it provokes a dissonance. The dissonance is reduced by modifying the importance of the belief or promoting other belief that reinforce the attitude toward the change.
Computer- self efficacy (McDonald & Siegall, 1992)	This deals with the personal judgement to have the capabilities to use the Technology. It is based on the self-efficacy theory and explains the sense of anxiety, innovativeness, and the attitude toward Information Technology
Theories for attitude and behaviour change in health	
Health Belief Model (Janz & Becker, 1984)	It explains the engagement of the patient towards health promotion. It is based on the concept of perceived barriers, perceived threat, self-efficacy and the cues to action that are generated to promote the behaviour.
Trans-theoretical Model (Prochaska & Velicer, 1997)	The process of behaviour change has 6 steps: pre-contemplation, contemplation, preparation, action, maintenance.
Theory of Interpersonal Behaviour (Triandis, 1977)	The intention to perform the behaviour depends on attitude, effect and social factors.

Affective theories	
Slovic's Affect Heuristic (Slovic, Finucane, Peters, & MacGregor, 2002)	Emotions are a shortcut to influence human's decisions. There is an association between positive affect and perceived benefit and negative affect when human perceive a risk.
Risk as Feeling Model (Loewenstein, Weber, Hsee, & Welch, 2001)	It focuses on the experienced affect during the moment of the decision-making.
Need Opportunities Ability Model (Vlek & Jager, n.d.)	The Need Opportunities Ability model measures consumer behaviour, categorises human needs, defines taxonomy for behavioural process and 7 strategies for change. This psychological model has been made following a spiral approach from the individual to an environmental policy decision system.

Table 4: Revision of behaviour change model

1.2.2 The role of the emotions

The affective component of the attitude demonstrates how emotions impact on human decisions. Emotion also impact on the development and evolution of a disease. In this chapter this aspect will be further researched; the focus will be how emotions could impact the evolution and progress of the Coronary Artery Disease.

Moods are emotional states, not related with certain situation (e.g. anxiety after an arrhythmia) but refer with an internal emotional state of the person. Prolonged long-term mood disturbance can lead to mood disorders as depression or bipolar disorder.

There is a lack of scientific evidence about the direct relationship between physiological and emotional status of patients. In recent studies (Khayyam-Nekouei, Neshatdoost, Yousefy, Sadeghi, & Manshaee, 2013) it was stated:

“Although most of the studies on CHD are mainly focused on the biological risk factors and lifestyle, some evidence has revealed that psychological and psychiatric factors have a very important role in the etiology, development, duration, and outcome of this disease”.

In this revision it was found that the prevalence of depression in people with Heart Failure is 20% higher than healthy population. At the same time, the physiological mechanisms of the atherosclerosis may also facilitate depressive symptoms.

The study focuses on three emotional mood disorders that have relevant prevalence in patients with Coronary Artery Disease: depression, stress and anxiety. All the three mood statuses converge towards a tendency of having more complications, fewer self-care habits and an attitude that is less conducive for fostering healthy habits.

1.2.2.1 Depression

The diagnostic of depression is based on the presence of emotional and vegetative symptoms, severe status as the mayor depression is linked also to physical symptoms as head, back, stomach, joint and muscle pain. (Trivedi, 2004).

A prospective studies demonstrate that 13% of males and 17% of females attending a general medical admission have an affective mood disorder (depression rates within the community could be between 4 and 8%) (Mayou, Hawton, Feldman, & Ardern, 1991). In chronic disease this is more complex: patients often had to change their lifestyles, aspirations and employment. A portion of all patients do not respond well to these lifestyle changes and suffer from distress as a result that could lead to the development of a psychiatric disorders, most commonly anxiety and depression (Turner & Kelly, 2000) .

In cardiology it has been demonstrated that psychosocial disorders, including depression, are a risk factor in terms of the development of MI and can ever result in death. At the same time, people with symptoms of depression have an increased risk

of cardiovascular disease and for concomitant cardiac disease cases, patients will receive a double treatment: the Journal “Progress of CVD” published an article this year about the treatment of the cardiac disease with people diagnosed with depression (Teply, Packard, White, Hilleman, & DiNicolantonio, 2015).

Cardio rehabilitation has positive effects on depression, in a randomised controlled study performed by Milani it has been shown that the prevalence of depressive symptoms decrease by 63% following a cardio rehabilitation programme. Depressed patients who performed the cardio rehabilitation have a lower mortality rate from the controlled group that did not join the rehabilitation programme (Milani & Lavie, 2007). **Depression** at the same time **is a significant predictor of mortality** within the first 18 months after an MI (Frasure-Smith, Lesperance, & Talajic, 1995, p. 18). The prevalence of depression in post-MI patients is between 17% and 37%.

1.2.2.2 Anxiety

Generalised anxiety disorder has emotional and physical symptoms: the emotional feelings include unrealistic and intense fear that could affect the person’s daily life. During the situations of fear the body releases adrenaline that increases the body functions and prepare the body to a status of alert. When anxiety is prolonged over time and the worries are not specific to a certain situation of period of life anxiety can lead to nervousness, muscle tension, racing heart bet and stomach problems and light-headedness. The prolonged state of anxiety also impact on concentration and sleep quality (Gosselin & Laberge, 2003).

The association between anxiety disorders and hypertension and CHD has been supposed and studies for years. Nowadays studies that there is a bidirectional association, people with hypertension are more likely to have anxiety and people with anxiety have higher risk to develop CHD (Player & Peterson, 2011).

The HUNT 2 study demonstrates that the risk of having a MI is not associated with punctual symptoms of anxiety and depression. Recurrent symptoms of anxiety been moderately associated with the risk of MI (Gustad, Laugsand, Janszky, Dalen, & Bjerkset, 2014).

On the other side, seems that the MI infarct impact on the emotional state of the patients: there is a high rate of anxiety (more than depression) within the first 18 months after an MI: from 24% to 31% (Lane, Carroll, & Lip, 2003).

1.2.2.3 Stress

There are three types of definition for stress, based on:

- A stimuli: stress is the result of external stimuli. When the stimuli become too great the internal resources collapse. It can refer to physical stress or strain.
- Definition based on response: another definition focuses on the response to an aversive stimuli: in the 50’ Hans observed the General Adaptation Syndrome (GAP) is composed of three phases: the body is alerted , the body is prepared to deal with the stress, stress continue under the capacity of the human. The

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duration and the adaptation to the stress depends on the stimuli and also on the personal characteristics of the person.(Hans, 1957)

- Definition based on stress as a dynamic process: stress *“a dynamic process reflecting both internal and external factors: characteristic of a person and his or her circumstances, as well as the interactions between them”*(Butler, 1993)

The last definition includes questions about the cognitive process on how the stimulus is perceived and the ability to properly respond. Nowadays there are not any clear approach on how to understand the mechanisms of stress: there are studies that demonstrate that stress response depends on coping (Lazarus & Folkman, 2008), cognitive aspects (e.g. reduced attention due to alert activation), environmental aspects and behavioural aspects (Butler, 1993). The working model of stress is based on the “vicious stimuli” which explains how the stress mechanism strictly depends on the stimuli and how humans manage their response (coping), the cumulative effect of the external factors, type of external stimuli and what the mechanisms that make a person more predisposed to have problems with stress. Nowadays, from the clinical point of view, stress is defined in terms of effects of acute situations or in a context of chronic stress because of the exposure to a situation or condition. The negative effects of stress can lead to MI, Myocardial Ischemia, Alteration of the cardiac rhythms and even sudden death (Dimsdale, 2008). There is still epidemiological evidence that acute extraordinary stress can lead to myocardial infarction, it has been studied within context of wars, earthquakes (Leor, Kloner, & The Investigators, 1996) and even sports events (Witte, Bots, Hoes, & Grobbee, 2000).

There is evidence of the negative effects of mood disorders like stress, anxiety and depression on the health status of a person (risk of myocardial infarction, mortality and morbidity).

1.2.2.4 Affective theories

Several models have also been proposed to understand the relationship between emotions and specific behaviours or changes of attitude. The following table summarises some relevant affective theories:

Affective theories	
Analytical rumination hypothesis (Andrews & Thomson, 2009)	It identifies the adaptive features of people with depression with special focus on rumination and the person's analytical functionalities.
Broaden and build theory (Fredrickson, 2004)	It describes how a subset of positive emotions, including joy, interest, contentment and love trigger other positive emotions and attitude. The positive emotions broaden the momentary thought-action resources of the individual: joy sparks the urge to play, interest leads to the urge to explore, contentment leads to the urge to savour and integrate, and love leads to a recurring cycle to need safe and close relationships
Conservation of the resources theories (Alvaro et al., 2010)	Every person has physical and personal resources that when decreased could affect them emotionally. At the

	same time a stressor could saturate the resources and lead to burnout.
Effort recovery model (Drenth, Thierry, & Wolff, 1998)	It focuses on the benefits of rest and recovery for people.
Intuitive affect regulation (Koole & Jostmann, 2004)	It refers to the regulation of emotions to alleviate feelings of dejection and anxiety. It focuses on the idea that people develop this attitude called ‘implicit self’ that is directly connected with emotional regulation
Mood as input (Schwarz, 1990)	There is an emotional response that depends on the performance of behaviour. The environment should address the negative response. They demonstrated that people are more motivated in a supportive environment that identifies and alleviates the problem.
The opponent process theory (Bowling, Beehr, Wagner, & Libkuman, 2005)	Peoples’ emotional responses elicit two affective processes: the primary one, which is consistent with the reality and another that is ‘opponent’ . With repeated exposure of a situation the opponent process is strengthened . (For example: the emotional response of parachute jumpers)
Physiological toughness (Dienstbier, 1989)	This theory focuses on stress and resilience: a reasonably stressful experience improves the physiological response and performance.
Self affirmation theory (Steele, 1988)	People that reflects on values that are relevant for them are less likely to suffer distress and they have an attitude to react defensively in situations in which the values is neglected.
Self validation hypothesis (Petty, Briñol, & Tormala, 2002)	The awareness and recognition of success is a trigger to improve self-esteem. A notable experiment was done asking people to write down 3 positive qualities about themselves on paper.

Table 5: Affective models table

1.2.3 Mental health and wellbeing

The WHO in the 2014 defined mental health as

“Mental health is defined as a state of well-being in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community.”¹⁷

From this definition the mental health is not simply the opposite of a mental illness, it includes skills and attitude of the individuals. Mental illness as depression and anxiety

¹⁷ http://www.who.int/features/factfiles/mental_health/en/

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reduce abilities and attitude of the individuals and has impact on the whole life of the person.

The WHO included the mental well-being in the definition of health:

“Health is a complete physical, mental and social well-being and not merely the absence of disease or infirmity”.

Mental Well-being involves many aspects of the human life. It requires four types of abilities (Vaingankar et al., 2012):

- Confidence: person can realize in own activities
- Adaptability: person manages the normal stressors of the life
- Autonomy: can work productively
- Social: user contributes to the community

The following table shows the details of the required abilities of the persons.

PMH dimensions as defined by WHO			
Realizes his or her own abilities	Cope with normal stresses of life	Can work productively and fruitfully	Able to make a contribution to his or her community
Confidence	Adaptability	Autonomy	Social participation
Education	Age	Creativity	Social role
Motivation	Attachment	Enthusiasm	Social trust
Optimism	Culture and ethnicity	Equality	Volunteering
Self-acceptance	Family and family structure	Health (mental and physical)	
Self-actualization	Financial security	Job satisfaction	
Self-determination	Gender	Life satisfaction	
Self-esteem	Habits	Social acceptance	
Self-evaluation	Hope	Vitality	
Self-presentation	Leisure	Environmental mastery	
Expressivity	Lifestyle		
	Patience		
	Relationships		
	Religion and religiosity		
	Resilience		
	Sense of purpose in life		
	Social support		
	Spirituality		

Figure 11: Revision of the concept of well being ¹⁸

According to NHS recommendations to patients, an improvement of wellbeing could be achieved in this ways¹⁹:

- Connect: by staying connected with communities, friends and family.
- Physical activity: again the physical activity is recommended for maintaining physical and mental well being.
- Interests: people may have some interests in order to keep learning and improving themselves.
- Be socially active, to help and support relatives and communities.
- Be mindful: being more aware and present in the moment. This requires control of feelings and thoughts.

¹⁸ (Vaingankar et al., 2012)

¹⁹ <http://www.nhs.uk/conditions/stress-anxiety-depression/pages/improve-mental-wellbeing.aspx>

1.3 Technologies

The structure of this revision is inspired from the 2016 research conducted by the Institute of The Future, which was founded in 1960 by Paul Barn who envisioned computer networks and their current development worldwide (Baran, 1964). In this report entitled “When everything is Media” a research agenda for the current technological growth of ICT technologies²⁰ is envisioned and proposed. These technologies provide users with a media experience in which the following strategic activities are required:

- **Productivity:** how ICT systems could improve processes, simplify peoples’ daily lives.
- **Engagement:** how citizens could be empowered to improve personal and societal changes.
- **Collaboration:** how ICT technologies could improve human collaborations
- **Intimacy:** how technology could foster more physical and emotional connections
- **Empathy:** how ICT technologies can understand peoples’ emotional statuses and how people correctly perceive external experiences.
- **Control:** how ICT technologies will be a medium to securely manage identity and privacy in a connected world of services.
- **Persuasion:** how the technology can transform society through individual or collective behaviour change

These dimensions have been used to analyse the technologies in the context of health promotion. For this reason the technological strategic activities have been adapted for the context of health care and it has been studied especially the available cardio-rehabilitation technology. The derived dimensions that are analysed in this chapter are:

- Healthcare technology: ICT technologies in health care have a cost saving impact and it is a recommended practice. The future of the ICT system in health care will connect with the patient, share the data, and improve and optimise the health care process.
- Other technologies for the individual engagement: the personal tools that individuals use to promote healthy habits, manage the disease or seek health information.
- Social networks: in the era of social networking the patient and professional communities are creating new additional value to support patients’ diseases.
- Impact of technology in the human intimacy: technology is changing the way to communicate with people and change the way humans perceive intimacy.
- Affective and emphatic technologies: technologies that understand human emotions and react to the situation. In healthcare these tools are mostly used in the area of phycology and psychiatry to manage mood disorders.

²⁰Source:http://www.iftf.org/fileadmin/user_upload/downloads/researchagendas/2016_TechHorizons_ResearchAgenda.pdf

- Tools to manage health data: within the area of healthcare are all the tools that users can available of to be in control of the health and habits.
- Persuasive technologies: they are technologies designed with the intention to change attitude and behaviour.

Figure 12: Topics of this revision

The following table summarises topics that are included in the following sub sections of this chapter.

Topic	Technology	Goal of the State of the Art	Application area
Productivity	Tele-monitoring system, Decision Support system, Big Data, HIS and other tools in the hospital	Tele-monitoring system, Decision support system, Big Data	Healthcare, Cardiology
Engagement	Technologies that engage users	Tools for individuals, Health Care system services	Healthcare, cardiology, wellness
Collaboration	Technologies to foster collaboration and communities	Social Networks	Healthcare, cardiology
Intimacy	Technologies that enhance emotional and physical connection	How the technology change human intimacy.	Sociology and technology, psychiatry
Empathy	Affective and emphatic technologies	Affective technologies to improve mental wellbeing, interventions tools	Psychiatry, wellbeing

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Control	“Quantified self” technologies, Personal Health Record	Technologies to manage personal data about habits and health status	Healthcare, cardiology, wellness
Persuasion	Persuasive technologies	Attitude change, Behaviour change	Healthcare, cardiology wellness

Table 6: Summary of the revised type of technologies

The following sections describe the specific application areas.

1.3.1 Healthcare technologies

The revision of the technology to enhance productivity in healthcare has been done by defining four types of solutions that:

- Manage current and new healthcare processes in the hospital.
- Connect with the patient to provide care, counselling and interventions.
- Share the data between healthcare organisations, to enrich the medical knowledge and experience of the clinical practice.
- Support the decision: medicine needs support tools for the decisions made in several healthcare scenarios (prediction of risks, diagnostic support, policy makers)

1.3.1.1 In hospital technologies

The existing technologies for the cardio rehabilitation mainly focus on the delivery of a monitored exercise programme. During their rehabilitation process in hospital, patients joined a monitored exercise programme that was usually performed in a room together with other patients. Nurses and cardiologists monitored the whole session using specific medical devices and they tailored personalised exercise programmes depending on the cardiac capacity of each subject.

Exercise machines

The aerobic exercise is the key activity for physical rehabilitation and is usually performed using a motorised treadmill or stationary bike as the figure shows:

Figure 13: Treadmill and of recumbent exercise bike ²¹²²

The latest generation of exercise machines tend to have a computer on board that includes exercise programmes (generally not used during the cardio rehabilitation, since the exercise plan is fully individualised) as well as feedback about heart rate, distance, speed, time, calories burned, resistance level, watts and METS.

Monitoring devices

Every exercise session is monitored using a 12-lead ECG, according to medical standards (Drew, 2004). Patients wear a transceiver and the 12 leads. The high resolution of the ECG provides meaningful useful information to the medical team about the progress of the rehabilitation and also tracks any cardiac adversity such as arrhythmias, syncope etc.

²¹ http://www.dickssportinggoods.com/graphics/product_images/pDSP1-12521583dt.jpg

²² http://www.dickssportinggoods.com/graphics/product_images/pDSP1-10911549dt.jpg

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Figure 14: ECG monitoring device ²³

.The physiological signals are monitored in order to grant a safe exercise session.

Safety machines

In general the medical staff that assist the patients during the training session are trained to use a defibrillator in case of an adverse event, and in general the rehabilitation units tend to be located very close to the emergency room in order to reduce the time of intervention in case of a critical and sudden cardio vascular event during the exercise session.

1.3.1.2 mHealth technology for the patients

mHealth is an abbreviation of mobile health and in section the focus is on the solutions for the patients. mHealth systems for patients cover several aspects of the care:

- Emergency situation: when an acute event is occurring
- Disease management and remote follow up
- Monitor the fragility of the person, in a preventative scenario

An mHealth system provide tele-care, and the functionalities can be grouped into three technical categories (Abadie et al., 2012, pag 23):

- 1st generation: these are the typical alarm systems triggered intentionally by the user. The users have to carry the device at all times.
- 2nd generation: this technologies use sensors to measure physiological data and report the changes in the health status.
- 3rd generation: this system is embedded in Smart Homes and Ambient Assisting Living (AAL) technologies. The user is monitored using the 2nd generation

²³ <http://www.lifesynccorp.com/assets/webimages/wireless-main/mt-pt.jpg>

sensors and invisible and environmental monitoring is also enabled, through the connected world of the Internet Of the Things. This generation is in line with the principles of Ambient Intelligence (Ducatel, Bogdanowicz, Scapolo, Leijten, & Burgelman, 2001).

Within cardio-rehabilitation these technologies belong to the 2nd generation. The solutions include phone-call support (Elley, 2003), message system (automated or not) (Maddison et al., 2014), questionnaires (Pfaeffli, Maddison, Jiang, Dalleck, & Löf, 2013), educational content (Dale et al., 2014) and exercise monitoring (Scalvini et al., 2009)(Mesa et al., 2014). Relevant examples of mHealth cardio-rehabilitation are the following:

- A Mayo Clinic mobile application (Widmer, Allison, Lerman, & Lerman, 2014): the users performed phases II and III of the cardio-rehabilitation by monitoring blood pressure, weight, glucose, dietary habits and exercise for three months. The mobile application also provided educational content to reduce modifiable risk factors. The study (N=25) demonstrated that the use of the application could reduce the weight and blood pressure of the patient; there was also a reduction of hospital visits and re-hospitalisation also seems to have reduced (-40%).
- Worringham et al (Worringham, Rojek, & Stewart, 2011) proposed a mobile and a wearable system that together with the GPS technology available of phones was used to monitor exercise sessions in real time. The study (N=7) shows an increase in exercise capacity and quality of life.
- Antypas et al. provided a website about cardio-rehabilitation and provided intervention group-tailored content based on models of health behaviour. The content was provided on the website and also via SMS. The results of the study show an increase in physical activity within the intervention group (Antypas & Wangberg, 2014).
- The most relevant study was performed by Varnifield et al (Varnifield et al., 2014): they provide to patients a mobile app to report symptoms, exercise and physiological data. The system was supported by the health professional with a set of follow up phone calls to mentor the patients during the process of cardio-rehabilitation. The self-management habits were compared at the beginning, after 6 weeks and after 6 months.

Also on the market are tools to enhance mHealth, such as the project Open mHealth²⁴, a toolkit for developers that provides open architecture to create mobile applications to connect with the point of care (Chen et al., 2012). It is a non-profit organisation that provides open architecture software to integrate patient mobile technology into the standardised healthcare process. The architecture relies on 3 simple components: a data processing unit that provides methods for standardised storage (e.g. HL7), statistics, analysis, a Data visualisation unit that provides the view of the clinical data and a set of APIs to integrate 3rd party data. Within this context, Dario Salvi's research proposed a framework to design personalised health applications for patients. The

²⁴ <http://www.openmhealth.org/>

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platform provides tools to develop personalised health systems that are able to collect data from sensors and the environment (Salvi, 2014) .

The presented tele-monitoring technologies provide physical and educational content for the tele-rehabilitation process, but they do not leverage on the persistence of healthy habits and mental wellbeing. Furthermore the published works are not describing specific methods of the health behaviour intervention (e.g. using Goal Settings Theory, TTM).

1.3.1.3 Big Data

Big Data and cloud computing are the emerging promises in healthcare (Chawla & Davis, 2013). They have the potential to collect and provide analytics from a large amount of dispersed clinical data (Belle et al., 2015). In HealthCare they started out by being used in the field of genomics research but nowadays are being proposed more frequently for clinical practice. The field of the genomics still provides the largest amount of data, comparable with astronomy, Twitter and Youtube generated data (Stephens et al., 2015). In cardiology Jeffrey Olgin and his team proposed the Health eHeart study²⁵, an ambitious initiative to gather data from more than 1 million participants worldwide. This study is called the Framingham 2.0 (from the Framingham study (Mahmood, Levy, Vasan, & Wang, 2014), the most important study in cardiology. It started in the 1948) study of cardiology, because the power of Big Data makes possible to execute massive clinical trials. Health eHeart study provides a Web Page with forms to report clinical data and a set of sensors to record physiological variables like heart rate, ECG, sleep, arrhythmias, and activity through the user's mobile phone. They also propose a kit for collecting DNA samples to a sub set of patients. They have already published some studies, with a recent one looking at the relationship between Atrial Fibrillation risk and the exposure to second hand cigarette smoke during gestational development (Dixit et al., 2015).

²⁵ <https://www.health-eheartstudy.org/>

Figure 15: Health eHeart study²⁵

Since healthcare is an issue of public domain, some healthcare organisations have started to publish open data (granting privacy to the individuals involved), to be used by society for further analysis and epidemiological studies. The open data can provide the the following benefits:

- Accountability of medical practice: open data could be an effective way of compare the possible treatment effectiveness.
- Choice: opening the data could help patients make informed decisions.
- Efficiency: it could be measured transparently and be quantified
- Outcomes: the clinical outcomes could be published and made available to the public domain.
- Customer oriented service: open data will provide the possibility of a benchmark in the quality of the service and make healthcare institutions more focused on delivering high quality services.
- Economic: providing open data could fuel new business opportunities to reduce the cost of the healthcare, it could help start new initiatives that are driven by the data.

From the data point of view, the integration of different domain of data will provide new opportunities for improving the health care process. Ghassemi et al. focused on the impact of Big Data in critical care and envisioned the impact if the following data domain were to be merged for clinical purposes (Ghassemi, Celi, & Stone, 2015):

Figure 16: Big Data opportunity for the health care ²⁶

1.3.1.4 Decision support systems

The decision support system provides to clinicians, staff and patients with knowledge about a specific medical problem domain (Osheroff et al., 2007). A systematic analysis of Sahota et al stated that DSS improve the process of care (Sahota et al., 2011). The roadmap to develop the new Decision Support system could be summarised as:

- Best knowledge available when needed.
- High adoption and efficiency.
- Continuous improvement of knowledge.

The most relevant technological contributions in computational intelligence in these areas are the IBM Watson® (Rachlin, 2012) platform, which is based on the cognitive computation paradigm. Currently Watson²⁷ has been used in the field of cancer diagnostics and prognostic for almost a decade. Another similar project is CancerlinQ

²⁶ (Ghassemi, Celi, & Stone, 2015)

²⁷ <http://www.ibm.com/smarterplanet/us/en/ibmwatson/health/>

project supported by ASCO²⁸ in the US. Both systems link dispersed Personal Health Records, research datasets from clinical studies and published knowledge to provide a growing knowledge-based system intended to make evidence-based decisions. In the commercial system (which is mostly used for treatment and risk assessment) there is a high discrepancy between the methods and the gathered information (Wright et al., 2009). From the revised literature the decision support systems that help physicians in clinical practice can be classified as tools for:

- Preventive care: for immunisation, screening, secondary prevention of diseases. In cardiology it was used to identify the risk of thrombosis in patients with Heart Failure (Piazza & Goldhaber, 2009), the risk of atherosclerosis (Zvárová, Tomecková, Stefek, Boudík, & Zvára, 1997). DSS seems to be effective in terms of the control and reduction of hypertension (Anchala et al., 2012). The Community Preventive Service Task Force²⁹ published a revision of what the decision support system should perform (Hopkins, 2015):
 - Reminder for screening of the Cardio Vascular Risk and related preventive care
 - Assessment of the patient
 - Recommendations on evidence based medicine
 - Alert when patient's risk is worsening
- Guidelines: for cardio rehabilitation: In Germany a decision support system (CARDSS) has been defined to support the clinical guidelines for cardio-rehabilitation in a multi-disciplinary team. They assess the methods of rehabilitation for two cohorts of patients: one following the rehabilitation based on exercise and education and another with two additional elements: relaxation sessions and lifestyle change therapy (Goud et al., 2009). They demonstrate that the Decision Support System can improve the team's concordance to guidelines.
- Treatment tools: they have been used to identify diabetic people with high cardiovascular risk in order to prescribe antiplatelet and lipid lowering drugs (Mazzaglia et al., 2014).
- Diagnostic tools: these are consolidated in the hospital technologies, the ECG is a diagnostic tool in case of STEMI (ST wave elevation during MI) (Ripa, 2012), symptoms have been used to stratify the risk for patients with chest pain (Aase, 1999).
- Prognostic tools: relevant examples are the use of echocardiographic data to build a neural network to predict the death of heart failure patients (Ortiz, Ghefter, Silva, & Sabbatini, 1995). It has also been used to predict the death of patients with MI (DeBusk, Miller, & Raby, 2010) using an online-symptoms form.
- Management of tele-monitoring system: The eCare (Amine, Amir, Emmanuel, Mohamed, & Vincent, 2013)(Andrès et al., 2015) project wants to foster disease management and the autonomy of heart failure patients at home. It also provides algorithms to detect signs of cardiac decompensation. Similar

²⁸ American Society of Cinical Oncology

²⁹ <http://www.thecommunityguide.org/>

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platforms are HeartCycle for Heart Failure Patients, which provides a tele-monitoring solution based on the Philips Motiva Platforms with additional tailor-made content and feedback (Stut, Deighan, Cleland, & Jaarsma, 2015). Another state-of-the-art decision support system is FujiFilm's Intelligent Cardiovascular Information System, which provides decision support to follow treatment guidelines.

Figure 17: The Ecare system³⁰

1.3.2 Other technologies for the individual engagement

Thanks to the penetration of Smartphone technologies in the Western world, nowadays third party apps are largely used in users' mobile phones. In 2014 alone, 85 billion apps were downloaded from the Apple Store alone; the usage of third party apps has been estimated at 127 min/day; in the same year, Google reported that the most commonly downloaded categories were Wellness and Fitness³¹. The variety of apps is huge, as indicated in the following chart, which shows the number of apps available in the leading app stores³². The apps related with Cardiology also have a tendency of

³⁰ (Amine, Amir, Emmanuel, Mohamed, & Vincent, 2013)

³¹ <http://www.digitaltrends.com/mobile/google-play-store-2014-most-downloaded-apps/>

³² <http://www.statista.com/statistics/276623/number-of-apps-available-in-leading-app-stores/>

mostly being designed for physicians and students, rather than for patients (Martínez-Pérez, de la Torre-Díez, López-Coronado, & Herreros-González, 2013).

Figure 18: Number of apps available in the leading app stores ³²

Today's the number of existing app related to fitness is very high. In the Apples Store for example the most popular (based on user ranking) categories the fitness related area cover the 16,26% (Considering the Lifestyle, Health and Fitness, Sports and Medical app's categories). There are several tools that help encourage users towards healthy behaviour and engage them to live a better lifestyle. For this study the following types of apps have been analyzed:

- Biometrics and sensor data: this is an emerging market. The market place provides a variety of sensors to measure Blood Pressure, Weight, Glucose, Heart Rate; the most consolidated protocols of communication are ANT+ and Bluetooth 4.0, using a standardised stack that allows a simple integration to third party apps.
- Self-care management: this category includes all the apps that help users to manage health, and are based on the individual motivation. This includes symptom checkers, medication tools, reminders, bio-metric management, educational content.
- Physical activity and exercise: the apps track the user's level of activity, show activity levels and promote increasing levels of activity. Usually there is also support for managing exercise habits with apps that provide assisted exercise sessions, report activities, provide education about sport practice, motivation and training programs.
- Dietary habits: they provide intake control, recipes, and diets.

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- **Wellness:** this category includes cognitive games, relaxing tools, psychological games, educational content, and trackers of healthy behaviours, thereby stopping unhealthy behaviours.

1.3.2.1 Biometrics and sensors

This market has estimated revenue of \$5.6 billion³³. The most relevant sensors for the control of cardiovascular disease are:

- **Weight Scale:** the most advanced model can manage the weight of different people and analyse Body fat and muscle mass. Some of the main manufacturers are: Philips, Tanita, A&D, Withings, Easy@Home. In the field of research a novel method of invisible monitoring of ECG based on plantar monitoring (Gonzalez-Landaeta, Casas, & Pallas-Areny, 2007) has also been envisioned. This device is recommended when users are overweight (Burke, Wang, & Sevic, 2011).
- **Blood Pressure Cuff:** this measures an individual's blood pressure. The key vendors dominating the market are: A&D, GE HealthCare, Omron, Philips HealthCare, SunTech Medical. The use of this device is recommended in clinical practice for patients suffering from hypertension. The AHA recommends the use of a certified (approved by the Association for the Advancement of Medical Instrumentation) automatic bicep (upper-arm) cuff-style monitor³⁴. There are research teams working on creating cuffless blood pressure monitors (Mukkamala et al., 2015)
- **Glucometer:** this market has huge potential, it has a revenue of \$4 billion and an annual growth of 3.6%³⁵ and address the glucose management for diabetic patients. This disease has pandemic dimension as been confirmed in the WHO report of 2014 about non-communicable diseases³⁶. One of the most relevant products is OneTouch (for Iphone). In January 2015 FDA allowed for the marketing of medical apps that use continuous glucose monitors in real time³⁷.
- **Heart Rate Monitor:** Since 2010 it has been feasible to measure the heart rate using a mobile phone camera (Pelegri, Banitsas, Orbach, & Marias, 2010). The first mobile to provide a specific heart rate sensor (based on light-sensitive photodiodes) was the Samsung Galaxy 6 Edge. Even nowadays HRM are embeddable in mobile phones, there are two types of heart rate monitor options: the bracelet (Microsoft Band, Apple Watch), and chest sensors (e.g. wristband, t-shirt). There are three modalities of receiving the signals: one time (usually the user requires rest and silence) as is the case with the Samsung

³³ <http://www.research2guidance.com/wp-content/uploads/2013/04/mHealth-app-sensor-market-2017.png>

³⁴

http://www.heart.org/HEARTORG/Conditions/HighBloodPressure/SymptomsDiagnosisMonitoringofHighBloodPressure/Choosing-a-Home-Blood-Pressure-Monitor_UCM_303322_Article.jsp#.VkdMf9-rRhE

³⁵ <http://www.ibisworld.com/industry/glucose-meter-manufacturing.html>

³⁶ <http://www.who.int/nmh/publications/ncd-status-report-2014/en/>

³⁷ <http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm431385.htm>

Galaxy Edge and in some bracelets (Microsoft Band, the apps that use the mobile phone's camera in example Runtastic Heart Rate Monitor, Vital Signs Camera app by Philips); the in streaming mode using the Bluetooth or Ant+ communication to send data to the mobile device (Polar H7, Garmin, Runtastic, Apple Watch). There are others that have storage capabilities and data will be transferred in non-streaming mode (MIO by Mio Global, FitBit).

- GPS data: nowadays mobile devices and watches easily integrate GPS data that are used most commonly to estimate the level of exercise (distance).
- Movement data: it is a well-established practice to add accelerometers and gyroscopes to all kinds of user gadgets (phones, watches, bracelets etc). This information is used to estimate the user's movements and activity. In the context of exercise, it is used to measure the velocity and the direction of the user.

Commercial sensors are an opportunity for the user to be in control of the health status.

1.3.2.2 Apps for Self-care

The first group of apps to mention is the one that manages the biometrics collected by the sensors. Thanks to Ant+ and Bluetooth 4.0 technology there are apps (together with the sensor vendor apps) nowadays that can receive data from other users' gadgets. Smartphone vendors provide a native service that collects and integrates the data to a Cloud SaaS platform: relevant examples are: Apple Health for Iphone Users, Google Fit³⁸ in Google Nexus Phones, Samsung S-Health, Microsoft Health (integrated with the Microsoft Health Vault platform). These apps provide statistics relating to the gathered data (HR values, blood pressure, weight, movements) and allow for the setting of daily goals (e.g. 10000 steps/day). Also there are specific apps that focus on physiological variables (e.g. blood Pressure Companion, Cardiio, iBP, Instant Heart Rate). There are also some educational apps that address self-care management. One interesting example that provides educational content for patients with CHD is the Australian Heart Foundation's myheartmylife³⁹ app, which provides educational content about the disease and how to control the levels of cholesterol and blood pressure; it also provides a medication tool with reminders.

1.3.2.3 Apps for physical Activity and exercise

RunKeeper, Strava (Cycling and Running), RunTastic, Nike+ and many others support several types of activities and support 3rd party heart rate monitors. They can be classified as monitor of daily activity, monitor of a structured activity

Monitor of daily activity: counter steps are used to estimate peoples' level of activity. Currently they can run 24h on the mobile phone and provide continuous monitoring. They estimate a person's steps and provide goals to improve the level of activity. These

³⁸ It is interesting see that the project of Google Health has been permanently disabled from January 2013 and replaced to this, more focused on end-user service and not to connect to the health care system.

³⁹ <https://myheartmylife.org.au/>

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programs also can distinguish the intensity (exercise, walking) of the activity, the human posture (Apple Watch counts the amount of time standing up), the type of exercise (running, cycling etc).

Figure 19: Apple Watch

Monitor of a structured activity: Digifit I Cardio shows the phases of exercise sessions using the heart rate. Solutions like Runkeeper, Nike+ provide instant information about the performed session showing the relevant information to the user (time, heart rate, calories burned, location, elapsed time, goals etc). They also provide the user with reminders to perform the exercise and provide visualization and statistics about the performed session. They include an important social component, which is sharing data, connecting with friends as well as offering the possibility of receiving messages from the social network during the exercise session (RunTastic, Nike+). They also provide basic information about exercise and best practices (stretching, managing injuries etc). Training programs: some apps have defined a clear business model selling digital training programs to their users: Runkeeper for example offers training plans for every level of fitness, from beginners to people willing to perform a marathon. Another brilliant example is Fitocracy: an app for maintaining the level of fitness: it provides a remote coaching support community (1\$/day and it also includes nutrition plans that will be further described later in the next sections).

Figure 20: Digifit iCardio: monitors the user's workout.

It is notable to see that many solutions provide a social network support, offering the possibility of sharing results of the performed sessions, the achieved goals, the emotional status (using icons), comments. Yang et al studied the use of apps that promote physical activity from perspective of behavioural change. The conclusion of this work is that the apps that promote physical activity usually implement limited behavioural change techniques, but at the same time act as a catalyst for behaviour change (Yang, Maher, & Conroy, 2015).

There are several initiatives from mobile companies that provide a solid and interoperable container for managing health data. Some examples of this are Health by Apple, S-Health by Samsung, Google Fit.

1.3.2.4 Apps to promote dietary habits

There are studies that demonstrate the effectiveness of diet apps using a Smartphone (Beasley, Riley, Davis, & Singh, 2008)(McClung et al., 2009). MyFitnessPal is a calorie counter and diet tracker and it is the most widely used by sports dieticians (Jospe, Fairbairn, Green, & Perry, 2015). It has a huge database of food (over 5 million items). It also integrates with a large set of apps related with physical exercise (Runtastic, DigFit, Polar, and many other) and weight monitoring. It also has a social network component that connects to other users and friends on other social networks (i.e. Facebook).

BACKGROUND

Figure 21: My Fitnesspal⁴⁰

Another highly rated app is Superfoods, which makes food recommendations for speeding up metabolism and losing weight. There is also another app called Low Fat Recipes. Nutrino⁴¹ provides users with a personalised menu that takes their required daily calorie intake into account by collecting physiological data. It also prepares a food shopping list and possesses the functionality to share progress on social networks. My Diet Coach⁴² implements a digital assistant to provide a more supportive and friendly approach.

Nowadays it is also possible to estimate the amount of calories in a meal by using a photo, MealSnap is an app that provides this feature.

⁴⁰ <https://www.myfitnesspal.com/>

⁴¹ <http://nutrino.co/>

⁴² <http://www.mydietcoachapp.com/>

Figure 22: Meal Snap app estimates the calories using photos

Pact is a very interesting app based on the principle of reward and punishment as a strategy for engaging healthy behaviours. Users set weekly goals that have to be achieved otherwise they lose money. They have to post photos, results from exercise sessions using another activity app (Runtastic) to prove they have achieved their goals. If they complete their goals they win money.

Recently published research papers have studied the use of wearable sensors to automatically track ingestion behavior through accelerometers (Fontana, Farooq, & Sazonov, 2014) or by using a special VAS scale called VIMEC, a Visual Meal Creator (Holliday, Batey, Eves, & Blannin, 2014) that has been validated to estimate food intake kcal and detect changes in appetite.

BACKGROUND

Figure 23: VIMEC scale ⁴³

1.3.2.5 Apps to promote wellness

There are a large variety of apps that promote wellness without focusing on exercise and diet. There are tools to promote other healthy habits and tools to promote the mental wellbeing. Thanks to the proliferation of wearable technologies and very affordable sensors, like accelerometers and gyroscopes, new solution has been used to promote other healthy behaviours. One interesting example is the Lumo product that uses a sensor that can be easily plugged into the users belt to monitor their posture. It also provides educational content to improve the body posture.

⁴³ (Holliday, Batey, Eves, & Blannin, 2014)

Figure 24: Lumo helps to adopt correct body posture⁴⁴

Mindfulness and relaxing apps

There are a lot of tools that promote specific techniques using multimedia animations, sounds, voices and videos. Most of them have an educational purpose and provide tutorials; others allow for the reporting of proposed activities (1GiantMind). There are 600 apps available on the market for mindfulness alone and they use several types of meditation techniques (breathing, body awareness, sitting and walking meditation, loving kindness, non-judgmental thoughts and emotions, short meditation practice) (Mani, Kavanagh, Hides, & Stoyanov, 2015).

A relevant contribution for the diffusion of the mindfulness practice is spire an app that also provide a wearable gadget that use accelerometers and gyroscopes to measure activity and respiration; tt provides guided exercises to promote the awareness of the breath.

⁴⁴ <http://www.lumobodytech.com/lumo-run/>

BACKGROUND

Figure 25: Spire app⁴⁵

Users have access to programs that can be installed directly to their personal devices to provide information about the diseases, to control and manage health data (BP, Weight etc) and also promote healthy lifestyle. Healthcare could leverage on this individual initiative to promote healthy habits and management of the disease. Nevertheless the available technologies for the user have some limitations that should be further improved in the next generation of app.

- Most of the apps have not been proven in clinical trials. Since medicine is based on evidence, results have still not been published. Large-scale studies may be required similar to the aforementioned health-eheart study initiative.
- Most of the apps implement services and contents that have not been validated and supervised by health professionals.
- Medical apps need to be certified. These apps to be used in a context of health care must be certified by authorities (FDA, ethical committees, regional authorities etc).

⁴⁵ <https://www.spire.io/>

1.3.3 Social networks

Social tools have a very high potential to fostering self-management and healthy habits. In fact these tools provide encouragement and support from family, friends and other people with the same health or fitness problem.

Nowadays the tools for the individual engagement integrate social components based on networks of friends, similar users and specialists. It has already demonstrated the positive effects promoting physical exercise especially among younger adults (Nakhasi, Shen, Passarella, Appel, & Anderson, 2014). For people seeking information about diseases and health conditions, popular social networks function as social support infrastructures for users. Thousands of Facebook groups about diseases and treatments have been created. A 2014 study attempted to describe the health content available on Facebook groups and found that nearly half of the groups searched have relevant information about the disease (Hale, Pathipati, Zan, & Jethwani, 2014). At the same time more disease specific social networks have been created like 'Patients Like Me' that allow for the tracking of health statuses in order to connect with other patients with similar diseases and learn from their experiences. An article was published in 2010 about the potential of the social networks of patients with special focus on Patient Like Me (Wicks et al., 2010) as a key tool for co-treatment decision. In November 2015 the American College of Cardiology and Patients Like Me started a collaboration to collect information about users' needs and include their findings in the Diabetes Care research agenda⁴⁶.

⁴⁶ <http://news.patientslikeme.com/press-release/american-college-cardiology-and-patientslikeme-bring-patient-focus-diabetes-research-a>

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Figure 26: Patients Like Me ⁴⁷

The social networks represent a new way for users an opportunity for the user to share his/her own experience of health and for the healthcare system to deeply explore the user's health history.

1.3.4 Impact of health technology in the psychological intimacy

The psychological intimacy can be defined as follow:

Psychological intimacy develops between a speaker and a listener. Depending on how individuals fulfill these roles, intimacy may occur or be precluded. Intimacy quickly creates a bond and, if repeated, enhances psychological function. Psychological intimacy is the glue of all important relationships, including professional ones. (S. B. Levine, 1991).

The Smartphone has changed the nature of human relationships and intimacy. While during the 19th and 20th centuries humans engaged in mediated information through newspapers, the radio and televisions, mediated interactions can be performed in a different manner this century through a large number of new services (Twitter,

⁴⁷ <https://www.patientslikeme.com/>

whatsapp, SMS, Facebook, Skype, etc.)⁴⁸. These technologies have the possibility to compress 'time and space' and offer to the user the possibility to connect with people in easy and affordable way. Nowadays it is possible to have intimate experiences (e.g. view a photo of a friend living in other country, videoconferences) using mobile technology. The concept of 'mobile intimacy' has been explored by Anthony Giddens, and assessing the consequences on human behaviour. There are three types of intimacy modalities (Giddens, 1991):

- Face-to-Face interaction: in this case the technology is a transparent medium of real time communication between persons.
- Mediated interaction: technology manages spatial and temporal dimensions of the humans making human connections ubiquitous (e.g. asynchronous communications with emails, SMS, posts on social networks).
- Mediated quasi interaction: a monological interaction from a machine to an indefinite range of target users. A representation of this nowadays is the automatic message that an app could send as a prompt.

This mediated way to exchange intimacy has changed the society. Also it has been demonstrated that mobile telephones strengthen human relationships (Gergen, 2002).

Hjorth and Lim defined mobile intimacy as the overlay of the digital activity of the persons and the private real life (Hjorth & Lim, 2012). They studied (in Finland) the effects of the mobile phone in human communication. They concluded that the capability to share information between the users improve the psychological intimacy. There are skeptics who refer to this as the erosion of the facial community. The relevant facet of this research is that mobile phones are a ubiquitous form of communication in practical and symbolic ways and they allow for the sharing of situations, conversations, decisions, emotions, thoughts and many other human situations

The impact of the health technology in the human intimacy has relevant consequences.

- Mobile intimacy is based on the possibility to compress time and space. In these sense mHealth technologies has been demonstrated to be well accepted by the user and improve patient physician relation ships. Furthermore mobile technologies have been demonstrated to foster the therapeutic alliance in psychiatry (Bucci et al., 2015) . Also recently been shown how the use of virtual counseling spaces encourage intimacy (Yellowlees, Richard Chan, & Burke Parish, 2015).
- Monitoring technologies enters in the daily life of the person. mHealth technologies in some provide continuous monitoring. In chronic disease this technologies give a sense of security.

Mobile technology improves the psychological intimacy between users and health professionals.

⁴⁸ <http://journal.media-culture.org.au/0703/02-raiti.php>

1.3.5 Affective and emphatic technologies

This section focuses on technologies that process and convey emotions.

Nowadays there is an emerging technology research called emphatic technology (Cai, 2006): this is a field of research designed to develop solutions that understand and share human emotions and help people to better communicate and understand one another. For example the Cosense project (New Zealand) uses the e-Health 2.0 board and Google glass to provide an augmented reality service that captures human emotions (Ayyagari, Gupta, Tait, & Billinghurst, 2015). The empathic systems are based on 2 pillars of research:

- One is the detection of the emotion: this field began in 1995 with the definition given by Rosalinda Picard (Picard, 2000).
- The other is how to share emotions through technology. Some examples are the MIT Lumitouch⁴⁹, a picture frame that shares emotions between two users by changing the colours of the photos. Comtouch⁵⁰ tries to do this by using haptic feedbacks and AffectPhone⁵¹ uses a Galvanic Skin Response that transmits emotional recognition through temperature to share an emotional state.

Figure 27: The AffectPhone transmits emotions through temperature

In healthcare the detection of the emotions that have a very interesting meaning because negative mood states such as depression are highly correlated with poor health outcomes. The affect detection is still a very challenging and complex area of research, mostly because emotions have many personal qualities that are difficult to measure. The studies on emotional modelling began in the 1970s when Ekman et al defined six basic and universal emotions. These emotions are: disgust, fear, joy, sadness, anger and surprise. In the 1990s this list was expanded and now includes Contempt, Amusement, Contentment, Embarrassment, Excitement, Guilt, Pride (in Achievement), Relief, Sensory pleasure and Shame (Ekman & Davidson, 1994). From the basis of the definitions of the different emotions, several techniques for emotional recognition have been proposed and are summarised here:

⁴⁹ <http://tangible.media.mit.edu/project/lumitouch/>

⁵⁰ <http://tangible.media.mit.edu/project/comtouch/>

⁵¹ <http://lab.rekimoto.org/>

- Facial expression: there are several methods based on image processing to correlate movement and facial expression to emotions. Further research has contributed by creating a data base of facial expressions (Wang, Ko, Huang, Liu, & Lin, 2014). The most widely used technologies are cameras and tracking systems like Kinect.
- Posture and body language: these methods focus on identifying gestures and positions of the body that correlate with emotions. In this area the most widely used technologies are tracking systems, accelerometers and gyroscopes (Kleinsmith & Bianchi-Berthouze, 2013).
- Emotional voice expression: the recognition of the emotional features of speech are a key research area in speech analysis (Matsumoto & Ren, 2011). The affect is transmitted through the content of the conversation and also through nonverbal para-linguistic features (speech ratio, how the sentence is structured, volume of voice, vocalisation etc.).
- Physiological signals: several types of non-invasive measurements have been explored over the years: brain signals through electromyogram, electro dermal activity, electrocardiogram, electrooculogram, eye tracking (Lanata, Greco, Valenza, & Scilingo, 2015) and electroencephalography, as well other recently discovered techniques based on neuroimaging (fmRI) (Calvo & D'Mello, 2010).
- Text features: this method assesses hidden data in human conversations via voice and using digital content of the user (mails, SMS) . The result of this analysis is the emotional intensity of the text and the connotation of the words (if they have a positive and negative connotation) (Calvo & D'Mello, 2010).

Nowadays the trend is to combine these methods: some studies about audio and video analysis have been done: For example, AVEC research attempts to predict the affective valence of User Interactions and depression. (Valstar et al., 2013). Some ready market technologies are: EmoSPARK (MPV), a home console that interacts with the user for conversations, music and multimedia content. It is accessible through PCs, televisions and mobile phones using a videoconferencing system⁵². In 2001 Rosalind W. Picard had already envisioned affective medicine with special emphasis on the negative influence of emotional states like stress, depression and anger (Picard, 2001). Several research projects related to health have attempted to assess the emotions of people with mental disorders, with a special focus on predicting mood swings. Relevant contributions has been made in Europe through PSYCHE (Valenza, Gentili, Lanatà, & Scilingo, 2013) and MONARCA (Faurholt-Jepsen et al., 2013): these systems provide bipolar patients with a mobile phone that gathers data from sensors (from wearable sensors, accelerometers, GPS and voice (Guidi et al., 2015)) and from the users (mood scales, clinical questionnaires, diaries) to assess the current mood status and infer a prediction about the evolution of said mood status. MONARCA results have been exploited and nowadays there is a commercial solution in the market: Monsenso⁵³.

⁵² <http://emospark.com/>

⁵³ <http://monsensio.com/>

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Figure 28: Monsenso: a mHealth solution for mental illness

Nowadays it is still hard to objectively quantify the level of stress (Butler, 1993): a new research paper focuses on this topic and tries to measure the physiological and emotional responses to stress. For example a Spanish project called COINCIDENCE⁵⁴ developed a system to assess the mental fitness and level of stress caused by human tasks. The proposed system uses textrodes (electrodes built with a textile structure) to measure the ECG and the TEB signal (thoracic electrical impedance), a vest, an electronic recorder that processes the analogic signal and a Smartphone that receives the information. The system aimed to build an algorithm to classify user tasks as neutral, emotional, mental and physical. These experiments have been used to create an algorithm to detect a person's stress levels (Mohino-Herranz, Gil-Pita, Ferreira, Rosa-Zurera, & Seoane, 2015). Another interesting project in is ES3 that uses a more extended physiological monitoring platform (ECG, Respiration, body temperature, EDR, blood pressure, PPG, EMG, Biochemical analysis and Phychometric Tests) and applies a specific protocol in different target users: healthy people (university student), hospitalised people with depression, parents with a child undergoing critical surgery and their childs, (Aguilo et al., 2015, p. 3). Another interesting approach is the one taken by Ceja et al. that proposes using the accelerometers in Smartphones to assess the level of stress in the working environment (Ceja, Osmani, & Mayora, 2015). Seoyeon et al. proposed a cortisol-based approach by providing a Smartphone and a salivary kit to extract the level of cortisol (Choi et al., 2014). There is an on-going study that uses electrovestibulography, a method that collects vestibular signals and identifies fluctuations in the neurotransmitters, which is having promising results for a broad range of conditions like Parkinson's, bipolar disorders, depression, Meniere and schizophrenia (Lithgow & Moussavi, 2013).

⁵⁴ Cooperation in Scientific Research and Development in Strategic Technologies program (DGAM DNR 1003211003500).

Figure 29: EvestG™: electrovestibulography to diagnose mood disorders.⁵⁵

1.3.5.1 Mobile interventions improve the emotional state

SuperBetter⁵⁶ is a gamefied app that promotes adapting to new habits, in order to cope with emotional distress, which can be caused by anxiety, depression, chronic illness or pain and while recovering from Post Traumatic Stress Disorder (PTSD), and allows patients to connect with relatives and specialists.

Figure 30: Superbetter, the concept and a phone screenshot⁵⁷

The program was used for 10 minutes/day for 1 month during a clinical study with 283 iPhone users. Some improvements to depression levels were measured but the results did not have statistical significance (Roepke et al., 2015).

⁵⁵ <http://www.neuraldiagnosics.com/EvestG.html> , Source from a Web Video

⁵⁶ <https://www.superbetter.com>

⁵⁷ <https://www.superbetter.com/>

1.3.5.2 Interventions to reduce stress anxiety and depression.

In general the interventions using technology can be based on education and counselling (Patnaik, Joshi, & Sahu, 2015) or using more specific therapies, which aside from medication and electroconvulsive methods (ECT), encompass other techniques like Cognitive Behavioural Therapy (CBT). Some ICT research has been carried out to provide mobile-based CBT therapies solutions. In this field already there are mobile solutions like Deprexis⁵⁸ or more complex environment based on Virtual Reality to create an immersive exposure to situations. A pertinent new technique is Mindfulness Based Cognitive Therapy, which nowadays can be performed through expert consultancy or by using a wellness app (as spire.io). In 2015 the American Psychological Association published an article (Volume 46 N 6) about Mindfulness being a promising new technique in the treatment of depression⁵⁹. A revision of the 2014⁶⁰ created an evidence Map of the different techniques that were effective in different target populations using three kinds of therapies:

- Mindfulness based stress reduction (MBSR)
- Mindfulness based cognitive therapy (MBCT)
- And other mindfulness interventions

The following map shows various mindfulness interventions in green, MBCT therapies in purple, MBST therapies in pink and MBCT+MBSt therapies in blue:

⁵⁸ <http://www.deprexis.com/>

⁵⁹ <http://www.apa.org/monitor/2015/03/cover-mindfulness.aspx>

⁶⁰

http://www.hsrp.research.va.gov/publications/management_briefs/default.cfm?ManagementBriefsMenu=eBrief-no88

Figure 31: Bubble plot of the evidence of the Mindfulness⁶¹

he use of mobile solution to control and treat mood disorder is a promising market. For example joyable⁶² is an app that offers a CBT service to overcome social anxiety. The

⁶¹ http://www.hsrd.research.va.gov/publications/management_briefs/images/no88-bubblelg.gif

⁶² <https://joyable.com/>

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company sells a three-month programme for \$239, which includes a personal coach to support online users. The company joined a financial round in the 2014 of 8 Million dollar⁶³. An article was published in 2015 about the positive effects of mindfulness meditation for people with chronic pain (lower anxiety and depression index, better QoL, level of pain)(la Cour & Petersen, 2015).

Big technological advances have been done to assess the emotional state of a person. Affective technology has been proved as medium to provide intervention for emotion regulation and control. For this reason affective and empathic technologies combined with specific intervention are a promising solution mental well being of the persons.

1.3.6 Personal integrated data

ICT technologies provide a wide range of solutions for human life and on a daily basis more data are being gathered from different domains (e.g health, social network, media information etc.). Thanks to cloud computing and the API. it is easy to integrate this information into one unique tool. The potential of this platform is to make data available to other service providers to provide further services. In this sense the TicTrac app has been built to collect data from different sources (social networks, mails, wellness and fitness app, sensors) in order to show to show an integrate view and management of the data. It is interesting that in May 2014 Novartic decided to partner up with this tracking and analytic platform to exploit personal data.

⁶³ <http://en.sunningview.com/article/109647>

Figure 32: Personal identity ecology⁶⁴

Another interesting initiative is track.me⁶⁵, a service that monitors the localization of persons, vehicles health status, objects and documents, animals) The web “quantified self” provides a guide for selecting self-tracking tools. They also provide a meet up community for people to share their own digital-tracking experiences. But this trend has also become controversial because the idea of integrating personal individual is jeopardised by the lack of legal policy relating to data sharing; a recent study by the School of Computer Science resulted in an article called “Who’s peeking at your personal data?”⁶⁶. Another interesting initiative is PrivacyGrade⁶⁷ which analyses the level of privacy of every installed app.

⁶⁴ (Institute for the Future, 2010)

⁶⁵ <http://track.me/>

⁶⁶ <http://www.cs.cmu.edu/link/whos-peeking-your-personal-data>

⁶⁷ <http://privacygrade.org/>

BACKGROUND

Biogram is an app that provides photo sharing with biometric measures. There is an ongoing clinical study to understand how the public sharing of health data influences relationships and interactions on social networks⁶⁸.

Figure 33: Biogram app screenshot

The daily use of the mobile phone generates a big amount of information about user's daily task. Health information is just one dimension of the user's data. Data can be merged using tools that aggregate data from different domain, generating two benefits:

- **Users can monitor habits having an integrated view.**
- **This data can be used to extract behavioral pattern that could be correlated with the health status.**

The information generated by the mobile phones represents an opportunity to further study human behaviours and habits and its impact on health.

⁶⁸ <http://www.imedicalapps.com/2015/11/biogram-2-researchkit-medical-app/>

1.3.7 Persuasive technology

Persuasion can change human behaviours. A persuasive person encourages people to make decisions daily, such as to buy new clothes, take a trip, change job as well as perform healthy behaviours. Brian J. Fogg was one of the first researchers to study the influence of technology in human behaviour in Stanford University. In 1998 he published his PHD thesis entitled *“Charismatic computers: creating more likable and persuasive interactive technologies by leveraging principles from social psychology”* (Brian J. Fogg, 1998). He later founded a specific department called “captology”⁶⁹ that studies computers as a force of persuasion.

Fogg founded in the Stanford University the department of Captology:

- Captology studies how technology change attitude and /or behaviour
- Captology focuses on the endogenous force of the technologies, in the persuasive intent of the technologies to change human behaviour and intentions, without coercion or deception. Persuasive technologies exclude Computer Mediated Interaction between humans.

It was in 2002 that Fogg released the book called “Persuasive technology: using computers to change what we think and do” (B. J. Fogg, 2002) in which he described the “Funcional Triad” of the persuasive technologies:

- **Technology as a tool:** technology helps to make tasks easier and quicker for humans. In the context of persuasion, the technology could be used to make a certain behaviour easier to perform, guiding the user through a process to prepare him or her for the behaviour change or by performing estimation and assessment of what really motivates the user.
- **Technology as a medium:** technologies can provide users with media information to better understand the cause-effect relationships, with motivation by providing other representative stories of behaviour performance and by giving them counselling to perform the behaviour. Fogg identified two categories of media: the symbolic and the sensory. The first refers to the use of symbols (texts, icon, graphics etc) and the other refers to a more sensorial media based on video, audio, sensation and smells.
- **Technology as social actor.** The computer plays the role of a social actor or even as a living entity. One example is the Tamagotchi, a portable video game embedded with a digital life that users had to take care of by cleaning it, giving it meals and putting it to sleep.

The persuasive technology can persuade on two levels:

- Macro persuasion: the overall persuasive intent of the technology.
- Micro intent: represents the persuasive intent through a specific technological component (e.g. feedback, avatar).

⁶⁹ <http://captology.stanford.edu/>

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Nowadays the penetration of mobile technologies opens up a new opportunity to design persuasive technologies for changing human behaviours. This potential was already envisioned by Fogg in 2007 (B. J. Fogg, 2007).

1.3.7.1 Characteristics of the tools

The tools defined by Fogg have the following characteristics:

- Reduction: technology can simplify the performance of a behaviour; this feature could improve self-efficacy.
- Tunnelling: the technology can provide a step-to-step approach to perform a specific behaviour (an example could be the procedure of installing something using a “wizard”, commonly used nowadays in operating systems to install new programs)
- Tailoring: it represents the personalisation of the contents; it provides relevant information to change individual attitude or behaviours or both.
- Suggestion: technology should suggest the behaviour at the right time.
- Self-monitoring: users that monitor their own behaviours are more likely to achieve specific behaviours or goals. The self-monitoring feeds the self-understandings that could be used to drive behaviour change.
- Surveillance: peoples’ behaviours could change if an external agent is monitoring their behaviours. In this sense all the surveillance system installed across the world act following this principle. Surveillance should manage privacy and ethical concerns.
- Conditioning: the technology provides reinforcements or rewards to promote behaviours. Conditioning is used to promote complex behaviours. This principle leverages on the intrinsic motivation of the individual, unlike surveillance that acts as an extrinsic motivator.

1.3.7.2 Characteristics of the media

The media is a functionality of the technology that provides a simulation of concepts that will be useful when promoting and performing target behaviour. Fogg considered that a medium could be persuasive by:

- Providing a “safe experiment”: Unlike tools that are used to perform a behaviour, the media provides another space in which the users are not performing the behaviour. Through the media users can understand, simulate the behaviour and increase willingness and self-efficacy. Relevant usages in healthcare are the CBT therapies that use Virtual Reality technologies to treat anxieties and phobias (Scozzari & Gamberini, 2011).
- Understanding the link between cause and effect. Media provide simulations and understanding of concepts related to the behaviour. Relevant examples are the Coronary Heart Disease risk calculators, a tool that calculates the risk of suffering a MI⁷⁰.

⁷⁰ <http://cvdrisk.nhlbi.nih.gov/>

- Persuading in subtle ways. Users do not know the bias that could be presented in the simulation, and generally the attention is focused on the experience and they do not tend to judge the biases. The designer could insert a bias to reinforce the link and the effect, making a different simulation of the reality. Users should be aware that simulations are not real experiences.

1.3.7.3 Characteristics of the Social actor

Technology could operate as a social actor in the following ways:

- Rewarding with positive feedback
- Modelling a target behaviour
- Providing social support

These ways are characterized at five levels (primary types of social cues), which are:

- Physical: the social role is represented in technology (e.g. an avatar). Physical attractiveness has a very high potential of persuasion.
- Psychological: the technology uses psychological models as the cue (the use of feelings, empathy, humour). One interesting approach is the principle of similarity; in with individuals are more influenced by similar other individuals. Fogg studied how also this is valid in technology, for example users use to more like feedback system with their own similar personality. (Fogg tested creating two conversational systems, one dominant and other submissive).
- Language of interaction: the technology communicates using natural language (interactive, spoken, speech dialogue etc). Even technology has its own language that nowadays influences human behaviours: a relevant example are emoticons, in 2015 the Oxford English Dictionary defined the word emoji as a “A small digital image or icon used to express an idea or emotion in electronic communication”⁷¹
- Social dynamics: building interactive relationships promoting cooperation, praise for achievements, answering of questions etc.
- Social roles: having a social representation (e.g. doctor, teacher etc.)

The credibility of the social actor aspect of the technology depends on the perceived trustworthiness and expertise that users believe the machine possesses.

Four types of credibility are defined: presumed (depends only on the user on the first use), surface (after a initial usage of the technology), reputed (the technology was endorsed by a third party), earned (the user has sufficient experience with the technology). In his 2002 book, Fogg envisioned the huge potential of mobile phones for further study. In a preliminary analysis of 72 applications related to health he found that many potential persuasive technologies have not yet been explored. (page 186). His book also states the need for persuasive technologies to be well designed, also from a Human Computer Interaction point of view. (B. J. Fogg, 2002). The paradigms of technology design are reported later in the sections.

Fogg envisioned the Kairos Factor principle, which is the capacity of the mobile to trigger the user interaction (e.g. prompting a message) at the opportune moment. In

⁷¹ <http://www.oxforddictionaries.com/definition/english/emoji>

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fact mobile phones can provide physical locations, typical routines, time of the day, the person's goals and the current task.

In 2009 Fogg published the behaviour model for persuasive design (B.J. Fogg, 2009): in this model three elements play a key roles for the performance of a specific behaviour: user should be sufficiently motivates, should have the ability to perform the behaviour and need triggers to perform the behaviour.

Figure 34: The Fogg's Behaviour Model⁷²

Another relevant contribution of Fogg is the behaviour grid⁷³ in which defined how the behaviour is performed in the time (one time, for a certain period of time or from now) to the type of behaviour (new behaviour, familiar behaviour, increased behaviour, decreases behavior or stop behavior). The following diagram shows the behavior grid:

⁷² (B.J. Fogg, 2009):

⁷³ <http://www.behaviorwizard.org/>

	GREEN Do new behavior	BLUE Do familiar behavior	PURPLE Increase behavior intensity	GRAY Decrease behavior intensity	BLACK Stop existing behavior
DOT One time	GREEN DOT Do a new behavior one time	BLUE DOT Do familiar behavior one time	PURPLE DOT Increase behavior one time	GRAY DOT Decrease behavior one time	BLACK DOT Stop behavior one time
SPAN Period of time	GREEN SPAN Do behavior for a period of time	BLUE SPAN Maintain behavior for a period of time	PURPLE SPAN Increase behavior for a period of time	GRAY SPAN Decrease behavior for a period of time	BLACK SPAN Stop behavior for a period of time
PATH From now on	GREEN PATH Do new behavior from now on	BLUE PATH Maintain behavior from now on	PURPLE PATH Increase behavior from now on	GRAY PATH Decrease behavior from now on	BLACK PATH Stop behavior from now on

Figure 35: The behaviour grid of Fogg⁷³

Fogg defined strategies to achieve the behavior, based on the proposed behavior model. It is notable that in 2013 Nike + involved J.B Fogg in the design process of the Nike+ system.

In the context of this research some limitations of the model have been found:

- The persuasive technologies focus on the achievement of a behavior not improved well being of the person. A single specific behavior could be achieved using persuasive technologies but the general well being represent a more complex construct of the user that are out from the scope of the persuasive technologies field.
- The health status and emotions has not been further investigated. Health and emotions have impact on the user daily life and on the attitude toward the adaptation to healthy behaviors.

1.3.7.4 Behaviour change support system

In 2010 Oinas-Kukkonen introduced the concept of Behavior Change Support System, which is persuasive technology aimed at fostering improved health and lifestyle. He proposed this as a key construct for further research in the area of persuasive

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technologies. He defined it as “*A behavior change support system (BCSS) is an information system designed to form, alter or reinforce attitudes, behaviors or an act of complying without using deception, coercion or inducements.*” (Oinas-Kukkonen, 2010a). This technology should address 3 types of changes: a complying behavior, a behavior change and an attitude change. The use of the BCSS should reinforce the following outcomes:

- Behavior that was not present before
- The alteration of a existent behavior (e.g. increasing the level of exercise)
- A reinforcement of current attitudes and behaviors.

Kukkonen identified three different outcomes that are required to change the attitude or the behaviour of the person (Oinas-Kukkonen & Harjumaa, 2008):

- A shaping outcome: technology has formed new behaviour or attitude in a person.
- A changing outcome: technology helped to change the attitude and the behaviour change
- A reinforcing outcome: technology makes the attitude more persistent

For the case of the BCSS there must exist some stakeholder to have the intention to influence behaviour or attitude.

The theoretical construct of the BCSS has many open research topics that have been identified by Oinas-Kukkonen in the 2013 (Oinas-Kukkonen, 2013a):. The topics are about :

- Theoretical basis of BCSS (7 topics). There is the need to translate the knowledge of psychology into computer model.
- Understand the intended outcome: deeply understand the differences of A-B-C change .
- Analysis of the persuasive potential: the HCI should investigate what are the more principles on what make a technology more persuasive than other.
- Impact of the BCSS in the society: ethical, cultural and business research should be done to better understand the role of these system in the society.

Behaviour change support system is the most closed definition of technologies to promote a general wellbeing of a person. Nevertheless a lot of research questions are still open; in the list there are two topics that are relevant for the context of this research: the role that emotions play in the persuasive technology.

1.3.7.5 State of the persuasive technologies:

Specific research on persuasive technology demonstrated to have been used to improve healthier lifestyles in healthcare (Kraft, Drodz, & Oisen, 2009), in the management of diseases and risk factors (Strecher, 2007), exercise habits (Harjumaa, Segerståhl, & Oinas-Kukkonen, 2009) as well as green behaviors in the working environment (Obermair, Reitberger, Meschtscherjakov, Lankes, & Tscheligi, 2008).

In cardio rehabilitation no specific system has been published with the keyword persuasive technology, in the 2015 it was discussed presented the idea to develop application for people with CAD using persuasive technology. The paper just presents the idea and include in the design pattern of the system principles of persuasive technology (Sankaran, Supraja, Luyten, & Coninx, 2015).

Out from the specific definition of persuasive technologies the Institute for the Future released a special issue about the future of persuasion in 2010 (Institute for the Future, 2010). They identified emerging technologies that could convey persuasion and named the persuasive forces, which are as follows:

- Digital mirrors: they are artifacts that create a digital representation of the individual. These digital mirrors collect all the information about an individual from other services and thereby get a better understanding of the user. An example of this could be the Personal Performance Coach that is able to measure speech interruption during a phone conversation. A more classical view is the digital mirror proposed by Philips: a mirror with LED display capabilities that can provide augmented information about health status, agenda of healthy habits⁷⁴.
- The Network: this is a wide concept of connection. Nowadays ICT enhance the growth of social communities and provides different modalities of Human-Human interaction via technology (sms, voice all, videos, podcasts etc).
- Telepathic technologies: they use Brain Machine Interface to provide control of the graphical User Interfaces of games and apps. They also can be used for generating biofeedbacks (like Muse⁷⁵) and emotions recognition.
- Catalysing human actions: technology that helps users made decisions or systems that reduce barriers to action. Another interesting aspect is catalysing human action by using the environment to stimulate engagement.
- Social: these technologies use social interaction to stimulate engagement. A very interesting commercial product is the Intuitive Automata, a socially interactive robot that has also been used with patients receiving standard tele-medicine services. The research demonstrated that tele-monitored patients with chronic diseases are more engaged with a technology that is based on conversational interfaces rather than digital questionnaires.
- Games: competition is a big motivator for people; as such the potential of persuasion has been explored. A very famous example of this is the Game "Screen Zombies", which has been used to motivate obese children to perform physical activities. In New Zealand the AIMFIT study used these games in a randomised and controlled clinical study of teenagers, but it was not found to have any significant effects on fitness (Direito, Jiang, Whittaker, & Maddison, 2015). Another interesting component of gamification, which is used by Fitocracy, is to set goals that earn badges and open up new functionalities within the app.

⁷⁴ <http://www.gizmag.com/go/3773/>

⁷⁵ <http://www.choosemuse.com/>

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Figure 36: Gamified app of Marshfield Clinic's Heart Health⁷⁶

- Amplified imagination: there are tools that provide an extended self-view and of the environment. This technology includes avatars, virtual and augmented realities and data representation. Nowadays there are the virtual reality solutions that are very affordable for the end user. A very interesting and affordable virtual reality product is the Google CardBoard, for which special glasses have to be purchased in order to use the mobile phone for watching 360° videos⁷⁷. Samsung released Game VR headset⁷⁸ to be used (\$99) to play 360° videos and games.

⁷⁶ <https://itunes.apple.com/us/app/heart-health-mobile/id581978737?mt=8>

⁷⁷ <https://www.google.com/get/cardboard/>

⁷⁸ <https://www.oculus.com/en-us/gear-vr/>

GOOGLE CARDBOARD

Experience virtual reality in a simple,
fun, and affordable way.

Figure 37: Example of affordable virtual reality device:Google CardBoard⁷⁹

- Awe-gmented reality: this is an extension on the concepts of virtual reality and emphatic technologies. This technology understands human emotions and awareness and offers a positive and reinforced augmented user experience.

⁷⁹ <https://www.google.com/get/cardboard/>

1.4 Design of the Human Computer Interaction

The discipline that encompasses all the methods of computer interfaces design is the Human Computer Interaction, which includes ergonomics, information technology system, psychology, cognitive science and engineering (Grudin, 2005). The concept of HCI appeared for the first time in the mid 1970s in a Carlisle James H. paper with the working title "*Why Human-Computer Interaction Doesn't Work Like Human Dialogue*" (Carlisle, 1975). The fundamental goal of HCI is to ensure the required functionalities and usability in order to provide an effective and pleasant user experience. To reach this goal the designers, managers and developers of a technology need to understand and model the users, the environment, the tasks, the contexts and choose the appropriate technology (Carey, Galletta, Kim, & Wildemuth, 2004). The association of Computing Machinery and the IEEE Computer society pushed to define HMI as a specific branch within Computer Science. From these initiatives a first workshop on HCI was held in 1985. Through the commencement of these initiatives the ACM created a specific research cluster called "Group in Computer-Human interaction" to define pathways for education and dissemination of the HCI concept. Through this initiative the component of HCI has been defined. Five interconnected facets of HCI have been defined (Hewett et al., 1992):

- The nature of human computer interaction it has been defined characteristics of the system (communication, agent paradigm, tool paradigm, task organization and supervision).
- The use and context of the computer: it is the contextualization of the system from the human perspective and is based on three pillars: models on how humans and society function, the application areas (the types of system that can be developed), and how the applications of technology meet the objectives.
- Human characteristics: this models the way humans process information, how the actions are structured, the nature of communication, as well as physical and psychological requirements. This dimension encompasses cognitive models, and theories about memory, perceptions, motor skills, concentration, problem solving, learning, motivation and diversities (including physical disabilities). It also defines the communication between humans and computers and the system's ergonomic characteristics.
- The system and interface architecture: this defines the main features that enhance HCI, which are: input and output devices, dialogue techniques and genres, computer graphics and dialogue architecture.
- The development process describes the design process. It focuses on approaches to design, the implementations and how it is validated in terms of productivity and usability.

This revision focuses on the following topics:

- User Centred Design (UCD): it is a consolidated approach of design technology based on user's real needs and characteristics. It is founded on a standard that defines the design process to be followed for the development of a product.
- Methods based on User Centred Design: from UCD new methods of design have been proposed in the last years, that depend on the focus and the paradigm of design.

- The design of technology to foster the change: it focuses on the design of technologies that promote the behavior change.
- The design of technologies for patients: it focuses on the approaches to be followed to design technologies for the health.
- The methods to validate the user's experience with the technology: it focuses on the methods to measure the level of acceptance of the technology.

1.4.1 User Centred Design

User Centred Design is a methodology that focuses on understanding the design needs and characteristics. The process includes the participation of end users in order to iteratively validate the designer's assumptions. The methodology was proposed by Donald Norman in 1986 it started to be consolidated in the 1990s until a specific standard was defined in 1999 to design Human Centred Processes for Interactive Systems: the standard ISO 13407⁸⁰.

User Centre Interaction encompasses several basic and applied research areas (Ritter, Baxter, & Churchill, 2014): human factors and ergonomics, psychology, computer science, engineering, design, mathematic, anthropology, sociology, ethnography and other field related to humans and technologies.

Norman's definition provided four recommendations on how Interactive Systems should be designed:

- Provide user functionalities that are easy to determine at any moment during the use.
- Provide visibility of possible actions, alternative actions and the results of those requested.
- Make it easy to assess the current state of the system
- Map user's intentions with required actions, of the system

The aforementioned ISO 13407 provides a system design process using an iterative and incremental methodology as the following figure shows:

⁸⁰ http://www.iso.org/iso/catalogue_detail.htm?csnumber=21197

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Figure 38: ISO 13407 ⁸¹

User Centred Design from the 1990s started to be accepted as best practice and had an impact on the whole cycle of software development. In the fourth edition of his book 'About Face' Alan Cooper identified the progressive adaptation of the development process within the software industry:

- The early phase of the software industry in which a new software was developed using the knowledge of a skilled computer programmer who programmed and tested the system.
- The managers have been included in the software in order to translate the market opportunities into system requirements.
- The industry matures and increases the quality of the product introducing quality control and design improvements (the look and feel).
- The design comes prior to development, as a strategic choice because decisions on system capabilities are made before the development gets underway.

⁸¹ <http://www.wqusability.com/handouts/personas-team-uf2008.pdf>

Figure 39: The evolution of the software design process

User Centred Design has a key role in the process of development of a product or service.

1.4.2 Methods based on UCD

This section shows relevant methodologies and recommendations that follow the current trends to design the Human Computer Interaction.

The selected methods for design are the following:

- Strategies for effective interaction, defined by Shneiderman. Which contain 8 basic rules and principles to design a system.
- Goal Directed Design, a methodology proposed by Alan Cooper; it is based on the definitions of user's goals.
- Emphatic design a novel approach to improve the user's understanding of needs and behaviours.
- Design thinking: a method that combines a creative process with the user centred method of design.
- Game design a new emerging and specific methods to design games.

1.4.2.1 Strategies for effective interaction

In his 1987 book Shneiderman proposed “Designing the User Interface: Strategies for Effective Human-Computer Interaction” eight golden rules of system design (Shneiderman, 2010):

- Strive for consistency: system should provide a consistent interface in the sense that every prompt, menu, action and response should be coherent (not changing names and functionalities) in every part of the system.
- Enable shortcuts: User’s desires to reduce the number of interactions. Abbreviations, shortcut buttons, function keys, macro are very helpful for expert users that need to increase efficiency while using the system.
- Offer feedback: in order to be aware of the status of the system, feedback is required.
- Design dialog: sequence of actions should be organised as a workflow and dialogs should be designed to provide the status of the system and the options available as well as to prepare the next groups of actions.
- Simple error handling: system must be designed in a way that users cannot make critical errors. If an error is detected, the system should provide a comprehensive mechanism to cope with it.
- Easy revert of action: user needs to feel that every mistake can be undone; this encourages the exploration of the system’s unfamiliar options.
- Support feel of control: design the system in a way that the user feels in control of the system
- Reduce short-term memory load: the system should interact with the adequate the speed, and the presented information must be adapted to the cognitive capacities of the user. Promote training and mnemonics for complex actions.

1.4.2.2 Goal Directed Design

Goal Directed Design (GDD) was proposed by Alan Cooper and reviewed over the last year (Cooper, 2014). It applies interviews with stakeholders, ethnographic techniques to models the user and the scenarios of use. One of the main objectives of GDD is to translate the knowledge gathered through to the stakeholders into a fully detailed design specification. This methodology aims at fulfilling user’s needs and goals while satisfying business requirements. This process can be divided into six phases: Research, Modelling, Requirements, Framework, Refinement and Support. (Cooper, 2014)

Figure 40: The Goal Directed Design Process⁸²

Research

The Research phase applies ethnographic techniques (observation and contextual interviews) to provide qualitative data about the users. It also includes one-on-one interviews with stakeholders, developers, subject matter experts (SMEs), and technology experts of the particular domain. One of the principal outcomes is the definition of a set of behavior patterns that help to define the use of a potential or existing product. These patterns suggest motivations and goals of the users.

Modelling

During the Modeling phase, the behavior patterns discovered in the research phase are synthesized into domain and user models. Domain models includes information flow and work flow diagrams. Two main construct are defined :

- **Personas:** it is a representation of the type of users that uses a specific product. They function as archetype and encapsulates a distinct of behavior patterns regarding the use of the system to be designed. These patterns along with specific motivations and goals define the persona.
- **Goals:** represent who the users wants to be (life goals), what the user wants to do (behavioral) and how the user wants to feel (experience goals).

Requirements

This phase employs scenario-based that do not focus on the specific task of the user but on to meet the user's goals and needs of the specific persona. In this process the persona is analyzed and the functional needs (expressed in term of context, actions and objects) The analysis is accomplished defining scenarios that describe 'a day in the life' of the user.

Framework

At this phase the input methods (keyboard, mouse, tactile) are specified and the first views of the system are defined according to the defined scenarios. The functional and data elements required to the users to interact with the technology are defined. From this functional list the information is structured in functional groups and hierarchies. A preliminary interface is sketched to represent functionalities, descriptions and relationships between the functionalities.

⁸² (Cooper, 2014).

Refinement

This phase is similar to the previous but with an increased focus on the details of the implementation. The designer should focus on coherence, key path scenarios . Visual designers define the style, icons, sizes and all the required visual elements.

Support

At this phase the designer support the development of the systems. In this phase the designer should be available to answer the programmer's questions, otherwise they are forces to adjust the design.

1.4.2.3 Emphatic design

Emphatic design is an emerging design-oriented technique that provides a more intensive and engaging experience by taking the user's emotional response into account. This design theory begins with the notion that for products and services to be accepted they first have to satisfy functional and emotional needs. Emphatic design provides techniques to gain deep insight and understanding of users' needs. Sinek (Sinek, 2011) introduced the golden circle concept that models the user's goals on three dimensions:

- Why: the reasons that motivate the user to achieve the goal
- How: how the person achieves the goal
- What: is the outcome of the process

Figure 41: Golden Circle Concept⁸³

A solid construction of these user goals allows users to not only focus on the operational perspective, but also on their own emotional needs. In this regard, the

⁸³ (Sinek, 2011)

design strategy attempts to model of thoughts and feelings, motivation, emotions, mental models, values, preferences and inner conflicts (Fulton, 2003). Empathic design recommends to the designer to change the attitude during the design: empathic research strategies incorporate collaboration, shared language, ethnography and empathy which in some cases could lead the designer outside of the comfort zone. The designer perceives the users needs and integrates this insight with the awareness of a life expert user (Thomas, 2013). One crucial aspect of this theory is the empathic model, which is a strategy to stretch a person's empathic horizon. The process is based on the following:

- Gaining on a surface: the designer should gain the interest of the interviewer to discuss about his needs
- Understanding the user's point of view
- Develop a deep understanding of the users
- Gain empathy with other humans
- Develop an emotional connection with another humans

These methods have been applied to design technology for people with physical and cognitive disabilities. The strength of this approach is its ability to generate a strong insight of the user model; it also requires a closeness between researcher and user, as collaborators work together gathering knowledge that will be used to generate solid resolutions of user's needs.

The designer's studies focus on three activities:

- Ethnography, interviews, as common practice of the UCD methods.
- Participate in the lives of the users. When possible the designer should enter in the daily life of the user. They can also use less intrusive methods such as camera observations.
- If possible designs should be immersed in the user context.

It is also interesting that this research is not focusing on quantitative data to understand the key of design, but instead looks at qualitative experience data with an empathic perspective. (Koskinen, 2003)

Figure 42: New perspective of designer applying empathic design ⁸⁴

1.4.2.4 Design thinking

This approach was proposed by Brown as a way to create innovative products by exploring iteratively with the users, a set of possibilities that have been created using a divergent outlook on the solution. It is used to solve difficult problems. Through this process the relevant options are taken into account and validated with the users. The last phase of the process is convergent thinking in which the collected experience from the different types of solutions converge into the design of the final solution. The process of design can be summarized as follows⁸⁵:

- Empathy: again, the first step is to gain the empathy with the end users. Designers had to observe, interact and immerse themselves in the user experience.
- Define: Process and model the findings from the previous phase of research (empathy) with the users.
- Ideate: create a variety of solutions exploring innovative ways of solving the problem.
- Prototype: create a prototype to test the design's assumptions.
- Test/Feedback: test the solution with the end user.

⁸⁴ (Koskinen, 2003)

⁸⁵ <http://dschool.stanford.edu/redesigningtheater/the-design-thinking-process/>

Figure 43: Design Thinking process ⁸⁶Game design

Computer games are a growing market and recognized as a relevant cultural medium. These Games have a very high complexity of design and nowadays there are no specific methodologies, but instead mostly combinations of UCD methodologies are used. The interactive modalities and the game dynamics require a specialized team (see diagram below).

86 (Brown, 2008)

Figure 44: Role for design a game ⁸⁷

- Game designers: responsible for designing the dynamic of the game. Their vision drives the process of development for the game.
- Subject Matter Experts: provide the functional and instructional contents of the game. They have to identify the learning objectives of the game, the metrics to assess, and help to define the strategy of the game.
- Instructional designers: identify the content of the SME and build a effective set of instructions for the player.
- Programmers: write the code of the game. There are normally different specialties of programming: rendering, networks, input / output interfaces, connection to Internet services etc.
- Artists: create all the graphical components, e.g., 2D/3D modeling, video production, motion graphics, illustrations.
- Technical directors: manage creative input from artists, and technical results from the programmers. They coordinate the team and envision the final product.

⁸⁷ http://www.e-games.tech.purdue.edu/images/GD1_B.png

Figure 45: Phases of development of a game ⁸⁸

1.4.3 Design of technology to foster habits

The design of this research context is centered on the Human Computer Interaction Field. In this area Benbasat (Bensabat, 2010) identifies two types of systems: one 'neutral' that is used to perform a specific task (e.g. filling a symptoms questionnaire), and the other is used to persuade users to perform a specific action, which has to be designed with the specific intent in mind. This section focuses on the design methods that are done with a specific intentions to persuade users to perform specific behaviours. Two revisions has been done: one about the design of the persuasive technologies that have been presented in the section 1.3.7 and another more specific of the design of serious game. A serious game is designed from other specific purpose other than the user's entertainment: in this research is presented a relevant proposed methodology to design game based on the Cognitive Behavioural approach..

1.4.4 Persuasive Design

In the 2009 J.B Fogg presented a paper in the conference, Persuasive 2009 (Claremont, California, USA), about persuasive design, titled: "Creating persuasive technology: an eight step design process" (B. Fogg, 2009). The aim of the work is to show the process of designing technologies that facilitate behaviour change "increasing the odds of success". The paper presented the following design process diagram:

⁸⁸ http://www.e-games.tech.purdue.edu/images/Design_2_Big.png

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Figure 46: Fogg's methodology to design persuasive technology⁸⁹

The process can be summarized as follows:

- Choose a simple behaviour target: the designer team must define a simple behaviour target. This behaviour target has been called desired behaviour.
- Choose a receptive audience: the success of a persuasive technology is to propose the technology to people that are really interested in the desired behaviour.

⁸⁹ (B. Fogg, 2009)

- Find out what prevents the target behaviour: this step analyses the barriers that prevent the user to perform the desired behaviour. J.B Fogg, identifies 3 possible categories of barriers:
 - Lack of motivation: it refers to the intrinsic motivation of the user to perform the behaviour.
 - Lack of ability: there are external causes that jeopardise the possibility of performing the behaviour.
 - Lack of triggers forcing the person to perform the behaviour.
- Choose a familiar technology channel: the users need to interact with a familiar and accepted technology..
- Find relevant examples of persuasive technologies: Fogg suggests an analysis of the existing solutions in the market, in order to understand the best methods, the best devices, and solution.
- Imitate successful examples: by analysing the relevant examples, the team of designers must understand the characteristics and features that make the solution effective , in order to achieve the desired behaviour.
- Test and iterate quickly: Fogg proposes using the model of iterative design, with many reiterations as a way to refine the solution quickly.
- Expand on success: This is the last step that consolidates the previous results of the process and expands the validation of the controlled experiment.

Another aspect that Fogg discussed about the design of the persuasive technology is the simplicity that if applied it will have a greater opportunity to persuade the user. (B.J. Fogg, 2009). The model is based on 6 dimensions:

- Time: time is a scarce resource and technology should reduce the time needed.
- Money: it is a critical resource.
- Physical effort: it is difficult to demand physical effort from the users.
- Brain Circles: technology must be functionally simple and require low cognitive processing.
- Social deviance: the solution should not be to break the society's rules. If it causes the user discomfort, it should be avoided.
- No routine: breaking human routine is difficult.

The design of persuasive technologies requires iterative design in which the strategy is validated with the end users.

A more detailed method to design persuasive technologies has been provided by Oinas Kukkonens that proposed the Persuasive System Design (PSD), a 3 step process to build a persuasive system (Oinas-Kukkonen, Harri and Harjumaa, Marja, 2009) that is based on:

- Understanding the aim of the persuasive technology
- Analyze the persuasion context
- Design system qualities

The following figure shows the element of the design.

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Figure 47: Persuasive system design process ⁹⁰

The first step is an analysis process that focuses on the understanding of the consequences of a persuasive method in HCI. Seven principles have been stated:

1. The technology “it’s always on” that means that the persuasive technologies are effective in a process rather than with a single use. Furthermore it’s important to understand the influence that the system can have to the users.
2. People like their views about the world to be organized and consistent. The persuasive system should facilitate users’ commitment and be consistent with them to avoid attitude change.
3. Direct and indirect routes: Direct persuasion provides argumentation, consistency, and credibility, indirect persuasion applies simple stereotypes, as force of persuasion like “expensive=good” or “rare=valuable”, in order to influence to classify the message based upon few key features. Indirect persuasion requires little cognitive functions.
4. Persuasion is often incremental. This statements suggest that the persuasive system facilitates the achievement of the target behavior step by step,
5. The persuasion must be open, in the sense that it’s important to reveal the goal of the system, the addressed target behavior to the user.
6. Persuasive system should aim to unobtrusiveness: the system must avoid disturbing the primary user tasks, in order to fulfil the user expectation.

The second step is the analysis of the persuasion context and the understanding how the information will be processed by the user and includes 3 facets of the persuasion:

1. The intent: the intent defines who the persuader is: the persuader can be the technology designer (endogenous), who gives access to the technology

⁹⁰ (Oinas-Kukkonen, Harri and Harjumaa, Marja, 2009)

(exogenous) or the same user (autogenous). Another feature of the intent is the change in the type of attitude of the users, which could change over time.

2. The Event: the event represents the “shape” of the persuasive system, by defining the scope (or use context), the user needs, goals and characteristics (user context) and the technology which interact with the users.
3. The strategy: the key facet of the strategies are the messages to the user.

Figure 48: Components of the persuasive context ⁹¹

The last step is the design of system features, which come up with the requirement definition of the persuasive system. The system specification of a persuasive system essentially refers to information content, description, and software functionalities.

The proposed design patterns are the following:

- Primary task support: the main goal of the application. The suggested design principles to foster persuasion are: tunnelling, reduction, tailoring, personalization, self-monitoring, simulation and rehearsal.
- Dialog support: it is the feedback system that will be used to achieve goals and target behaviours. The design principles suggested are: praise, rewards, reminders, suggestion, similarity, liking and social role.
- Credibility support: this feature has to be taken into account in order to provide a more credible persuasive system. The proposed patterns are: expertise, surface credibility, real-world feel, authority, third-party endorsement and verifiability.
- Social support: persuasion can leverage the social support; the design principles are social facilitation, social comparison, normative influence, cooperation, competition and recognition.

These characteristics can be summarized by the following image:

⁹¹ (Oinas-Kukkonen, Harri and Harjumaa, Marja, 2009)

BACKGROUND

Figure 49: Key design features of the PSD ⁹²

A theoretical model of perceived persuasiveness of the used has been proposed: from the 4 PSD elements (primary task, dialogue, credibility and social support) he proposed a model that adds these elements: design aesthetics, unobtrusiveness, intention to use, the Completeness of the program. The authors designed used a Web Based intervention system for diet, weight and mental wellbeing, management, (Lehto, Oinas-Kukkonen, & Drozd, 2012). This model has been used to improve the Persuasive System Design and better adapt to the design of Behaviour Change Support System.

⁹² (Oinas-Kukkonen, Harri and Harjumaa, Marja, 2009)

Figure 50: The Persuasive System Design⁹³

The Persuasive System Design method maps the persuasive features to functional element of design.

Furthermore Kukkonen considers that the implementation of theories of health psychology is still an open issues for the persuasive technology. In the Open agenda of the Behaviour change support system (Oinas-Kukkonen, 2013a) questioned:

How can we map psychological and behavioral theories within computer and information science frameworks?

⁹³ (Oinas-Kukkonen, 2013b)

The modeling of the psychological and behavioral theories is still a open question in the design of the persuasive systems

The design of persuasive technologies to promote health is a relevant research topic. Marja Harjumaa and Salla Muurauskangas in line with the paradigm of BCSS of Oinas-Kukkonen (Oinas-Kukkonen, 2010a) studied how PDS design could improve the definitions of the system features. They designed 2 systems: one for fall risk assessment and another for mental wellbeing. They identified for both session a number of system features. For the second iteration they co-design the system with people involved in the area of mental wellbeing and elderly fragilities. They registered and incremented of the features of the systems; 160% for the app to prevent fall risk, and 60% for the mental wellbeing app (Harjumaa & Muurauskengas, 2013).

Davis (J. Davis, 2010) applied PSD to introduce new persuasive features in the system design. He creates a inspirational card workshops, to inspire participants to think about possible persuasion features.

In the Conference Mobile HCI in the 2015 Luca Chittaro presented a workshop called "Mobile Persuasion for Health and Safety Promotion" (Chittaro, 2015). In this workshop Luca focused on three aspects of the persuasive design: The theories of persuasive design, how to design and evaluate, and presenting relevant examples that link technologies to the theories. During the last few years Luca has been very active in the field of technology design; he was the program chair at the persuasive 2014 conference about persuasive technology, and participated on the editorial board of Personal and Ubiquitous computing.

1.4.5 Cognitive Behavioral Game Design

A recent publication of an interesting approach based on psychology's models of changes proposed the Cognitive Behavioral Game Design as a unified method to design serious games (Starks, 2014).

Figure 51: Cognitive Behavioural Game Design⁹⁴

The framework is based on three pillars:

- The use of social cognitive theories in technologies, as a media to influence behaviour change (Bandura, 2001). The *knowledge* refers to the awareness of health risks, goals include game and personal (e.g. behaviour change) *goals* refers that the game should help achieve by using a step to step approach (Goal Settings), *personal expectations* refers to the idea that the game should cover the personal expectation of the users, *encouragement* means that the game should provide supportive feedback and *barriers* that represent the impediments to attain the goal. These components if well designed could improve the user's self-efficiency.
- Multiple intelligence: this theory is based on Gardner's research (Gardner, 1999). This approach is based on the principle that individuals have 8 types of intelligence: spatial, bodily-kinesthetic, Musical, Linguistic, Logical-mathematical, Interpersonal, Intrapersonal, and Naturalistic. These qualities have been mapped into components of a game and are:
 - Graphics: the fundamental aesthetic characteristics of a game.
 - Space / positioning: how players are able to move within the game.

⁹⁴ (Starks, 2014)

BACKGROUND

- Relationships / model: represents the interpersonal intelligence with characters of the game, or personas involved in the game (e.g. in healthcare: educators, psychologist, physicians).
 - Music and sound: musicians, or other professionals, that are able to recognize note, and pitch variations. It also can be a strong learning facilitator.
 - Narrative: the verbal intelligence of the game, that guides the user through the game experience.
 - Math / Numbers: the math/logic intelligence of the user.
 - Physical movement: represents the body/kinesthetic intelligence. Games involving these components include dance, exercise, sport simulation, and also gesture.
 - Words / elements: the words, and language of the game.
 - Humor: positive emotions, especially humor, could strengthen the relationship with the user.
 - Nature: the game provide references to the external world
 - Personal reflection: the game should provide a reflection of the users (e.g. using avatar)
- The enjoyment process: this process describes the process of engagement and behaviour change. Four components have to be defined in the game mechanic:
 - Engagement: it is crucial to grab the attention of the user. Some techniques include high resolution graphics, immersive scenarios, and first person perspective.
 - Challenge: this is the motivation to play the game. The challenge should be regulated through a mechanism of reward and feedback. Games should support the achievement of complex goals (behavioural and intrinsic) by using a goal settings strategy.
 - Flow: flow represent the mental state of the users while they're performing an action in which they are fully immersed and involved.(Nakamura & Csikszentmihalyi, 2009). Flow is an ideal situation in which users are fully engaged in the dynamic of the game.
 - Persistence: it is fostered by player mistakes and how the game respond to them.
 - Mastery: the win experience is an essential part of the game. Mastery contributes to self efficacy (Bandura & Schunk, 1981).

In the July 2015 Ludden et al. published work on how to design effective intervention using Web Technology. He proposed a framework based on 4 pillars; positive emotions, positive relationship, meaning, and accomplishment (PERMA). As a serious game provokes a the double effect of the intervention: on the usage of the Web, and in following the required intervention (e.g. cardiac rehabilitation, diet etc.) (Ludden, van Rompay, Kelders, & van Gemert-Pijnen, 2015).

Games design based on cognitive and behavioural approach opens new opportunities to the industry of the games to deliver new engaging tools to foster healthy habits

1.4.6 Design of technologies for the health care

The first discussion about interaction design in the area of health care appears in the 90s where Pathel et al posed the key role of the cognitive science to design technology in health care (Patel & Kushniruk, 1998). The last trend is to advocate User Centred Design (van der Linden, Waights, Rogers, & Taylor, 2012) for the design process, and interact with technology experts to explore persuasive computing. A relevant research has been done by Elena Villalba that defined a specific HCI model for chronic users using personal devices and wearable technology. The model has been proven with HF patients and a UCD method has been used to design the system (Villalba Mora, 2008).

There is not a specific method to design health technologies. The literature advocates User Centred Design methodologies. One specific contribution has been found and it defined the user interaction model to design a guided tele-monitoring system for people with chronic disease.

1.4.7 Model of technology acceptance

The Technology Acceptance Model (TAM) is a theory that models how user's accept and use a technology. The model is based on the theory of the reason action is founded on two key elements that define the acceptance and the adoption of a technology: the perceived usefulness and the perceived ease of use.

Figure 52: Technology Acceptance Model⁹⁵

These theories have also been used in the Unified Theory of Use and Acceptance Model (Venkatesh, Morris, Davis, & Davis, 2003) and include more extended dimensions that influence the user's decision to use a technology.

⁹⁵ (F. Davis, 1989)

BACKGROUND

The Health Information Technology Information merge the dimensions of the TAM with other dimensions of model user to promote health: Health Belief Model and the Theory of Planned Behavior(Kim & Park, 2012).

The following table summarizes the scales relevant s for the context of this research.

Technological acceptance	
Technology Acceptance Model (F. Davis, 1989)	It explains how users accept technology and define the dimensions of acceptance, perceive usefulness, perceive ease of use,
Unified theory of acceptance and use of technology (Venkatesh, Morris, Davis, & Davis, 2003)	This revised version combines the TAM model with another 7 models of behaviour. The new model is based on 4 constructs: expectation of performances and effort, social influence and facilitating conditions

Table 7: Models of technology acceptance

1.5 Summary

From the revision of the literature of the four proposed domains (cardiology, health psychology, technology and design of the human computer interaction) the following conclusions key concepts has been drawn:

Key concepts of the cardio rehabilitation:

- Cardio rehabilitation is an individualized program that follows a multidisciplinary approach to support the user to recover from the myocardial Infarction. manage the cardio vascular disease and the comorbidities.
 - Adopt healthy habits.
 - Cope any emotional distress.
- Cardiac rehabilitation requires user participation and willingness to perform behavioral modifications and change the attitude toward the management and prevention on the disease.
- Participation in the Cardio Rehabilitation program is not high, home based rehabilitation program is a promising solution to increase participation.

Key concepts from health psychology:

- There are consolidated theories to design specific health intervention to promote behavior change.
- There is evidence of the negative effects of mood disorders like stress, anxiety and depression on the health status of a person.
- The mental health does not represent only the absence of any mental disease, it represent an attitude and skills of a user to maintain the well-being.

Key concepts from technology

- The existing tele-monitoring technologies provide physical and educational content for the tele-rehabilitation process, but they do not leverage on the persistence of healthy habits and mental wellbeing. Furthermore the published works are not describing specific methods of the health behaviour intervention
- Users have access to programs that can be installed directly to their personal devices to provide information about the diseases, to control and manage health data (BP, Weight etc) and also promote healthy lifestyle.
- Behaviour change support system is the most closed definition of technologies to promote a general wellbeing of a person.
- The role that emotions plays in the persuasive technology is an issue to be further investigated.

Key concepts from design

- User Centred Design has a key role in the process of development of a product or service. The Persuasive System Design method maps the persuasive features to functional element of design.
- The modeling of the psychological and behavioral theories is still a open question in the design of the persuasive systems.
- There is not a specific method to design health technologies . The literature advocates User Centred Design methodologies. One specific contribution has been found and it defined the user interaction model to design a guided telemonitoring system for people with chronic disease. No literature has been found

02.

HYPOTHESES AND OBJECTIVES

The next page states the hypotheses and objectives of this research.

2 Hypotheses and Objectives

After the revision of four domains (Cardiology, Health Psychology, Technology and Design) the following hypotheses and objectives are stated:

H1: It is possible to define methods to design technologies that maintain and promote the wellbeing (physical and emotional) of a person.

Persuasive technologies and behaviour change support systems define the features, the strategies and the design method of the technology.. Limitations have been found in this constructs: further research must still be done to define the role of emotions and how the psychological health intervention can be translated into computer methods. Furthermore, a methodology to design technologies for users in the context of health care has not been found, and the role of persuasive technologies in health care needs to be further researched.

H2: It is possible to apply the defined design methods and develop the technology to deliver a cardio-rehabilitation program of patients that suffered an myocardial infarction.

Cardiac rehabilitation requires user participation and willingness to perform behavioural modifications and change the attitude toward the management of the condition and the recovery process. Participation in the Cardio Rehabilitation program is not high; a home-based rehabilitation program is a promising solution to increase participation. The existing tele-monitoring technologies provide physical and educational content for the tele-rehabilitation process, but they do not leverage on the persistence of healthy habits and mental wellbeing. Furthermore, the published works do not describe specific methods of health behaviour intervention.

H3: Technology that promotes wellbeing needs to provide reinforcement to negative emotions because they can impact on the health status and on the acceptance of the technology.

There is evidence of the negative effects of mood disorders like stress, anxiety and depression on the health status of a person. From a design point of view, the role of emotions needs to be further investigated in terms of the impact they can have on the health status and how they impact the use and acceptance of the technology.

The validation of the research hypotheses will be done addressing the following objectives:

01: Define a theoretical framework to design systems to promote wellbeing and health status.

02: Contextualize the persuasive technologies in the domain of wellbeing in healthcare.

03: Define a method to design and develop technologies to promote wellbeing.

04: Apply the proposed design methods to design and develop a cardio rehabilitation system.

05: Verify that users accept the technology and its intentions.

06: Verify the effectiveness of the health intervention on the user.

07: Verify the persistence of the habits over time.

08: Demonstrate the impact of emotions in the health status of patients with a more severe CVD.

09: Verify the impact of technology in people suffering from a mood disorder.

A man with glasses and a woman are looking at a large architectural model on a table. The man is wearing a light-colored button-down shirt and a watch. The woman is wearing a light-colored jacket. The model appears to be a large-scale architectural drawing or a physical model of a building. The background is a solid green color.

03.

MATERIALS AND METHODS

The chapter describes the approach of this research and the materials and methods that have been used.

3 Materials and methods

This research focuses on three elements that could foster the behavior change in individuals: the physical status and the emotional status of the person and the technology. Every component can influence the users attitude and behavior in the following ways:

- Physical status: bad physical status could change human attitude toward the necessity to adopt health behaviors, good health status at the same time reduce the need to adopt healthy habits.
- Emotional status: the attitude has an affective component, negative emotional state can reduce the ability of a person to adopt new behaviors and mental well being is the ideal situation in which individual have predisposition to adopt healthy behaviors.
- Technology: it can help user to adopt new behaviors and can be also support to promote physical and emotional status.

The approach can be represented in the following way:

Figure 53: Approach of this research

Following this approach the idea driven in this research is that a **technology that is designed to improve the physical status and the emotional status of the individual could better foster behavior change**

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The following materials and methods have been used in this research:

- **Methods to foster behavior change using technologies:** these methods are taken from health psychology and from the Human Computer Interaction field; they are used to define specific methods to design technologies to foster healthy habits and deliver health services to individuals.
- **Materials to apply the proposed methods:** the methods of this research have been applied to projects in which it was possible access to key resources to apply the proposed methods: end users, the expertise of the health professionals and the technology that have been used to develop the proposed design.
- **Validation methods:** this research has been validated using quantitative methods to verify the objectives of the work: a specific strategy of validation it has been defined; specific materials have been used to test the design solutions and the effects on the users.

3.1 Models from health psychology

Two psychological models have been used to define the methods of design of technologies to foster healthy habits: The Health Belief Model and the Trans Theoretical Model.

3.1.1 Health Belief Model

The Health Belief Model (HBM) is a widely used conceptual framework to understand and predict health behaviours. It was proposed in the 50s by social scientists of the U.S Public Health Service and it has been used largely to promote the adaptation of healthy behaviours (condom usage, seta belt use, therapy adherence, screening etc). It proposes six dimensions the influence the change of attitude and behaviour of the persons (Janz & Becker, 1984):

- Perceived severity: it represents the subjective assessment of the health condition. The dimension makes a person feeling more vulnerable or not to develop a disease.
- Perceived susceptibility: it represents the subjective assessment of the risk of developing a disease.
- Perceived benefits: it refers on how individuals perceive the benefits of specific actions to threat, reduce or prevent a disease.
- Perceived barriers: this represents if an individual perceive obstacles in performing a specific health actions.
- Cues to action: it is a stimulus that trigger the decision making process: they can be internal (e.g. symptoms) or externals (a medical advice to adopt healthy behaviour).
- Self-efficacy: it referrers on how the person feel confident to perform a specific health behaviour. This construct was not original in the model, it was added in the 80s'.

Figure 54: The Health Belief Model⁹⁶

The health belief model has been used to create a model of the individual intrinsic factors that motivate to a change of attitude or behavior.

3.1.2 Trans Theoretical Model

The model posits that behavior change is a process of six stages: precontemplation, contemplation, preparation, action, maintenance, and termination (Prochaska & Velicer, 1997). These can be described as follow:

- Pre-Contemplation is the stage in which there is no intention to change behavior. The individuals are unaware or under- aware of their problems. Their families and friends are often well aware that the pre- contemplator has problems. The pre-contemplators can be described as resistant or unmotivated, because they tend to avoid information and discussion regarding the behaviour change.
- Contemplation is the stage in which the individual is aware that a problem exists and is seriously thinking about overcoming it but has not yet made a commitment to take action. It is common that people remain stuck in the contemplation stage for long periods.
- Preparation is a stage in which the patient has both intention and some behaviour towards the change. Typically, the patients in this stage are intending to take action in the next month and have unsuccessfully taken action in the past year. They often report some small behavioural changes, but have not yet reached effective action (e.g., abstinence of smoking).

⁹⁶ (Glanz, Rimer, & Viswanath, 2008)

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- Action is the stage in which the patients modify their behaviour, experiences and environment in order to overcome their problems. Action involves obvious behavioural changes and requires considerable commitment of time and energy.
- Maintenance is the stage in which the patients work to prevent relapse and consolidate the gains attained during action.
- Termination is the stage in which people have completed the change process and no longer have to work to prevent relapse. Termination is defined as total confidence or self-efficacy across all high-risk situations and zero temptation to relapse (e.g., skipping exercise results frustration rather than pleasure).

The Trans Theoretical Model has been used to design a computerized strategy to adopt healthy behavior.

3.2 Methods from the Human Computer Interaction

From the Human Computer Interaction three methods have been used in this research:

- **User Center Design methods:** the work is based on the UCD standard design process. Specifically the Cooper's Goal Directed Design (Cooper, 2014) method will be used and adapted for the context of this research.
- **The Persuasive System Design** the method is used to analyze and define the persuasive features of the system.
- **A specific interaction framework to design technologies for patients:** the research work carried out by Elena Villalba in her PhD dissertation (Villalba Mora, 2008), in which present a Holistic Interaction Model to design tele-monitoring system for elderly people with Heart Failure.

3.2.1 Goal Directed Design

Alan Cooper proposed this methodology to design the Human Computer Interaction; it is based on six steps (Cooper, 2014):

- **Research:** focusing on the users and the domain (that for this research is cardiology, health psychology and technology). It involves interviewing stakeholders and end users, revising literature and similar healthcare solutions. At this step the users goals are defined.
- **Modelling:** in this phase the user has been modeled by defining the personas that represent the user's archetype. Personas are defined from a set of patterns that have been identified during the research phase.
- **Requirement:** it employs scenario based design methodology: the context of use is described using scenarios as ideal situations for use. Scenarios are defined from the user's goals, needs and expectations and use to be defined in storytelling format.
- **Framework:** in this phase data and functional needs are identified and mapped to the design of functional elements. The process includes the definition of I/O methods, system views, functional and data elements,

hierarchy of the functionalities, a sketch of the interaction framework and the identification of the key-path.

- Refinement phase: in the refinement phase the solution become more consistent through a more coherent user interaction, secondarily the look and feel be defined and graphic designed.
- Support: in this phase the designer assist with the developers' analysis of the requirement phase. Designer helps to address the solution from the technical point of view, resolving issues to minimize the impact on the design requirement.

Goal Directed Design has been used to design the Graphical User Interface of a system to deliver a cardio-rehabilitation program.

3.2.2 Persuasive System Design

This research is based on the construct of the Behaviour Change Support System (Oinas-Kukkonen, 2010b):

"A behavior change support system (BCSS) is a socio- technical information system with psychological and behavioral outcomes designed to form, alter or reinforce attitudes, behaviors or an act of complying without using coercion or deception".

Persuasive System Design (PSD) represents the current State of the Art of the method to design these technologies (it has been described in the section 1.4.4). The following figure summarizes the software features that are defined using the PDS approach.

Figure 55: Persuasive software features categories in BCSS⁹⁷

In the context of this research the theoretical construct of Behaviour Change Support System has been extended and contextualized to design systems to promote physical and mental health. The Persuasive System Design methods have been used and extended with an original theoretical construct of this research work.

⁹⁷ (Oinas-Kukkonen, 2010b)

3.2.3 User interaction model

Villalba proposed a Holistic Patient Interaction Model (hPIM) to model patient's using tele-monitoring technology at home. The model supposes three contexts (Villalba Mora, 2008):

- The context of patients: this represents the technology that users have in their surrounding environments, which includes personal devices, sensors, actuators and other devices. This context is based on the user's routine, mental models, and cognitive factors.
- The medical context refers to the tele-monitoring services provided to users. This context includes the medical professionals who interact directly with the patients or through a specific technical platform.
- The Social and Business context: this context defines the social and clinical rules that the service should consider.

Figure 56: Holistic Patient Interaction Model ⁹⁸

The holistic Patient Interaction Model has been used and the patient and medical context have been extended.

⁹⁸ (Villalba Mora, 2008), figure 36

3.3 Materials

Two research projects made possible this research: HeartCycle⁹⁹ and Psyche¹⁰⁰ project. They are EU founded project of the 7th Framework programme¹⁰¹. In the context of this research the two projects gave:

- Opportunity to apply the design framework: thank to the HeartCycle project it has been possible to test the design methods to develop a system to deliver Cardio Rehabilitation at home.
- Access to patient population: it has been possible to perform user's interview and perform usability round with CAD users that suffered a MI, HF users and bipolar patients.
- Expert support: cardiologists and electro physiologists, nurses, psychologists, educators have been contributing to define the requirement of the theoretical framework.
- Test of emerging technologies: Both projects are based on the concept of Personalized Health System and provide users a UI device and a wearable sensor. DSS system has been used to monitor or predict the health status of the user.
- Final clinical studies: it has been possible to test the devices in a real scenario and measure the effects and consequences of the proposed design methods.

The next sections detail the projects scope, approach and materials used from this research.

3.3.1 HeartCycle

This research has been carried within the European funded project HeartCycle (Grant agreement number FP7-216695), a 66-month-long project (from 1st March 2008 to 31st August 2013). The main aim of the project was to provide a closed loop disease management system for Heart Failure Management and Coronary Heart Disease. The project developed a multi-parametric system to monitor vital signs in order to assess the patient's condition and deliver therapy recommendations.

HeartCycle envisioned a "double closed loop" approach, which indicates two main loops in the system:

- A patient loop: the system interacts directly with the patient provide information about health status, support the treatment, keep the user motivated, improve adherence and self management.
- A professional loop: the system supports the professional to manage the care of the patient, by providing messages, alerts and tools for monitoring the patient's health status remotely.

The project focuses on defining the home loop, the professional loop and develop specific sensors. The home loop is a home-based system that monitors the patient's

⁹⁹ <http://www.heartcycle.eu/>

¹⁰⁰ <http://www.psyche-project.org/>

¹⁰¹ http://cordis.europa.eu/fp7/home_en.html

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vital signs through wearable and fixed sensors, stores the patient's home measurements, provides the patient with feedback on the measured data and empowers the patient by educating and motivating them to adhere with recommendations and care plan. The professional loop transfers data to the clinical professional, facilitates the professional in decision-making and provides personalised care plans.

Figure 57: The HeartCycle concept ¹⁰²

The project focused on two target populations: Heart Failure patients, and CAD people that suffered a MI.

HeartCycle gave the opportunity to design a cardio rehabilitation system for patients who have suffered a Myocardial Infarction.

The requirements were defined with the support of cardiologists, psychologists, and nurses; along with other engineers the systems that have been used in clinical studies have been developed.

The following people gave support to the execution of the project:

- Cecilia Vera: she was the manager of the work package responsible to deliver the user devices. She monitored that the design was in line with the requirement of the project.
- Dario Salvi: Responsible for the development of the user's device platform. He also coordinates all the technical integration activities in other parts of the system like the clinical server, the sensors and algorithms. His contribution made possible to realize the designed system.

¹⁰² <http://heartcycle.med.auth.gr/resources/WP4andWP5closed%20loop.jpg>

- Ignacio Peinado: User Interaction Expert who helped in the design the Graphical User Interface.
- Camilla Diaz: she supported the development of the look and feel and designed the application's graphical components.

Other Technical partners contributed to this research

- Salla Muuraiskangas: expert in human computer interaction. She contributed on the system revision and the definition of the system's messages. (VTT Technical Research Centre, Espoo, Finland)

Four clinical partners contributed to this research:

- The NHS Lothian's Heart Manual Team (Edinburgh, UK). They provided support for the CR intervention design. The overall strategy was designed with their help.
- The RWTH Aachen University's Department of Cardiology: designed the cardiac rehabilitation exercise protocol and provided patients for the clinical study. (Key person: Christian Knacksted).
- Castle Hill Hospital (Kingston upon Hull, UK) provided access to patients for usability study and the final study (Key persons: John Cleland, Paul Atkin).
- Hospital Clínico San Carlos (Madrid, Spain) provided access to users for the usability tests, interviews and the final validation.

Thanks to HeartCycle project has been possible to apply the methods of design that have been developed in this research. It has also be possible to have contact with cardiologists and experts of Cardio Rehabilitation and interview patients who suffered a Myocardial Infarction and other patients with a chronic cardiovascular disease (Heart Failure patients).

3.3.1.1 Heart Manual

The Heart Manual refers to very well established methods for promoting Health Behaviour that has been backed up with over 23 years of clinical trials. The Heart Manual team, based in the NHS Lothian clinic in Edinburgh leads the cardio rehabilitation practice in the UK. Their method has been exported abroad to Canada, Italy, Australia, New Zealand, Holland, Ireland and Singapore. The benefits of the methods have been measured in three randomised clinical studies (Jolly et al., 2009). They provide a six-week self-help manual supported by a nurse that has been compared to an 8-10 weeklong hospital-based rehabilitation course (Dalal et al., 2010). The Heart Manual programme aims to address the issue of cardiac misconceptions (cardiac beliefs and attributions) in the very early stages of the programme. This involves assessing the patient's beliefs and understanding and guiding the patient to recognise their misconceptions and test their validity using a cognitive behavioural approach. Patients are also encouraged to set goals and pace themselves in order to obtain a healthier lifestyle. The principles of the heart manual can be summarised as follow:

- Provide an intervention in the early stages of the rehabilitation process.

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- Provide the support of a nurse and a self-help manual.
- Heart Manual provide individualized advice.
- Include support to family and relatives.
- Teach patients to self monitor (symptoms, habits etc.).
- Step by step approach.
- Follow up on patient's progress.

The manual teaches users how to identify symptoms, the consequences of having a MI, the duration of the recovery process, the causes and the cure as well as how to identify modifiable and non-modifiable factors. The Heart Manual approach also provides tools for nurses. The recommended strategy is:

- Build a rapport: the facilitator should build a relationship with the patient.
- Think about the CHD, the second step is to make the patient think about the condition, in order to understand reasons and causes that led to him/her suffering the MI.
- Reflect on the risk factors for a deep understanding of how the disease could be controlled.
- Set goals and time frames: at this moment starts the intervention to change behaviours, the goal setting strategy is proposed (e.g. weight reduction, increased physical activity), users follows a diary to write down the activities.
- Sum it up. Provide feedback on progress, summarize activities and reward the users.

The methods also include quiz to prevent the common misconceptions about cardiology: The book also focuses on the emotions, with special attention on phobias, depression, low moods and stress. They provide strategies to deal with fears, anxiety, depression and stress by proposing an audio (using a DVD or Audio CD) relaxation session. Together with the nurse, the heart manual helps to implement a goal-settings strategy for behaviour change based on the SMART principles (Specific, Measurable Achievable, Realistic, Timely).

Figure 58: Heart Manual: phases of the cardio-rehabilitation ¹⁰³

The Heart Manual approach not only focuses on short-term recovery but also assists the user to adopt long-term self-management habits.

The NHS Lothian was involved in the design of the cardio rehabilitation programme. They co-designed and revised the specification of the design, giving to this research foundations of the proposed approach.

3.3.1.2 Technologies implied in this research

Three platforms have been used for the development of the Cardio Rehabilitaiton system: two platform for the user's devices (the pHPP platform and the MyHeart Devices) and a software for the clinical service (Nohmad platform).

The pHealth Patient Platform (pHPP)

The development of this research work has been made possible thanks to the previous PHD research carried out by Dario Salvi (Salvi, 2014); within his research a development platform for the pHealth domain was generated called pHealth Patient Platform (pHPP). This platform includes a set of library, programming and deployment tools, a tutorial and a documented example application. The system has four modules:

- **Data Collection Engine:** it integrates abstract sources of information as sensors or external services, it maps data to databases and ontologies, and allows for event-based interactions and filtering.

¹⁰³ <http://www.theheartmanual.com/>

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- GUI Engine: it abstracts the user interface in a message-like interaction model.
- Workflow Engine: it allows the development of the application's user interaction flows with graphical workflows
- Rule Engine, it gives developers a simple means for programming the logic of the application in the form of "if-then" rules.

The Rule Engine provides high-level rules in the form of "when-then" conditions. Thanks to this high-level message it is possible to define very easy persuasive rules as:

When
Patient has performed a specific behaviour
Then
Sends a message as a reward

The system has been designed under the principles of Context Aware systems; the data collection engine provided capabilities so it can be easily integrated to services and sensors and access to this information from the rule code.

Figure 59: Architecture of the pHPP framework¹⁰⁴

This research defined the specifications of the graphical User Interface, the messages and content that is shown to the user. The feedbacks rules have been developed using the rule engine library.

¹⁰⁴ (Salvi, 2014)

MyHeart user device

HeartCycle has been founded on another EU project called MyHeart of the 6th project in which was performed a controlled clinical study of a tele-monitoring system for patient suffering of Heart Failure Disease. The devices have given to the consortium to be used to develop part of the Heart Cycle system. The device was the Qtek S200 based on Windows Mobile version 5. This device has been programmed by other partner to deliver the designed system.

This research defined the specification of the Graphical User Interface and the messages and feedback to the user.

Nohmad Platform

The professional platform is based on NOMHAD platform, provided by TSB technological (Spain), that was selected as provider for the development of the system of cardio rehabilitation. This platform was integrated with the pPHP framework and used in the clinical study.

The Nohmad platform was not used in the context of this research but the Nohmad services make feasible the HeartCycle tele-monitoring system and the final clinical study.

3.3.2 Psyche

Psyche is the acronym for “Personalized monitoring System for Care in mental HEalth”: it developed a personal and multi-parametric monitoring platform to assess and predict mood fluctuations in bipolar patients. It is a 7th programme framework EU-funded project: this tele-psychiatry research applied affective computing methods to analyze human emotions and provide extensive information about patients’ emotional statuses to clinicians. Studies have also been carried out on tools that promote self-control and improve the therapeutic alliance with the health professional. PSYCHE provides users with a mobile Android-based app and a sensor that is worn on some days of the week, while sleeping and during restful activities. The mobile collects two types of data:

- Objective data: the data produced by the wearable sensor (ECG, respiration, movements, Heart Rate, body positions), by the voice (to measure pitch and speech ratio, tone, volume), and by the accelerometers.
- Subjective data: patients can report emotions using scales, questionnaires as well as in a diary.

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Figure 60: PSYCHE: final system architecture ¹⁰⁵

This system was not designed to provide a specific intervention; it was designed with the aim of providing tools for controlling and monitoring emotions. A clinical study was carried out at the end of the project, some of the results of which will be shared to demonstrate how emotions can influence the acceptance.

The user device has been developed using GDD approach (for patient and health professional) and it was validated iteratively with the users and at the end of the clinical study

The following institutions collaborated with the research presented in this document:

- Universidad Politecnica de Madrid: provided the mobile app to the users and a web portal for the psychiatrists.
- Università di Pisa: they provided the algorithms for the analysis and mood status predictions (key persons: Enzo Pasquale Scilingo, Nicola Vianello, Gateano Valenza) as well as the patients for the usability and clinical validations.
- Smartex: the company provided the wearable sensor (Rita Paradiso)
- CSEM: the Swiss company designed and provided the electronic to process the physiological data of the wearable sensor. It also provided Bluetooth

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communication libraries to integrate the sensor into the Android app (Mattia Bertschi)

- University Hospital of Geneva: they provided clinical expertise and patients to validate the system (Markus Kosel)
- University of Strasbourg, INSERM U114 Fédération de Médecine Translationnelle University of Strasbourg, INSERM U114 Fédération de Médecine Translationnelle (Gilles Bertschy: he provided clinical expertise and patients to validate the system)

Psyche system was conceived as a 'neutral' system, in which no behavioral intervention to foster healthy habits was provided. System has been designed using GDD methods and persuasive design principles have not been applied. In this context of research it has been used to demonstrate the effects of severe mood disorder on the acceptance of the technology.

3.4 Validation methods

Three elements have been identified to play key roles in the human decisions and attitude toward the adaptation a healthy lifestyle: the physical status, the emotional status and the support that can provide the technology. On top of this approach specific design methods are defined in this research and validated designing a system to provide cardio-rehabilitation at home within the HeartCycle project.

But in the project it was decided to not focus on the emotional status of the patients. Two main reasons justify this decision: the focus on the project that was to deliver cardio-rehabilitation and focus on physical recovery of the users and behavior change but excluding in the system any kind of assisted and monitored emotional support. Those cases (depression, anxiety etc) have been treated with standard practice. **Since it was not possible to apply the whole approach of this research another validations have been defined to study the implications of the inclusion of the emotional state in the design of systems to promote health and behavior change.**

The final case studies are:

- **Case study 1:** this is the main case study to test the design methods that have been defined in the context of this research. In this case the design methods are be fully applied for the specific domain of the cardio-rehabilitation. In this case the design will focus on the deliver of the cardio-rehabilitation program and a delivery of a specific intervention to foster behavior change.
- **Case study 2:** in this case the role between health status and emotions has been explored. None technology has been designed. A population suffering from a more severe disease has been selected: users with HF. This study was performed with an interview with users.
- **Case study 3:** in this case people with mood disorder have been selected to study the impact of emotions in technology. A specific analysis of the Psyche system has been performed to study how severe depression levels change the acceptance and usability level of a system.

The figure summarize the case studies of this research:

Figure 61: Case studies of the presented research

Two types of validation are performed to achieve the goals of this research:

- Interim validation of the design solution: the design solution has been validated through interview and usability tests.
- Final validation: of the research hypothesis specific scales have been used to assess the metric required to validate this research.

3.4.1 Validation of the design solutions

Goal-oriented design provides guidelines for designing UCD solutions combining different ethnography techniques, interviews with stakeholders, market research, user models, scenario-based design and a set of design principles for Human Computer Interaction. The methods intrinsically address a solution based on the user's needs; nevertheless, periodic inspections of usability principles and user needs are performed during the iterations. Two methods had been applied: Heuristic Validations and Usability tests.

3.4.1.1 Heuristic validation

User Interaction solution of the system to deliver cardio rehabilitation (case study 1) has been iteratively revised with experts using the principles of the heuristic validations (Nielsen & Molich, 1990). These principles are the following:

- Visibility of system status: the system should keep informed user about what is going on and provide appropriate feedback within reasonable time.
- Match between system and real world: system should speak the user's language and use words, phrases and concepts familiar to the users. System oriented terms must be avoid. Follow real world conventions, making information appear in natural and logical way.
- User control and freedom: user often chose system functionality by mistake and it needs to leave and cancel the unwanted state without having to go to an extended dialogue.
- Consistency and standards: user should not have to wonder whether different words, situations or actions mean the same thing.
- Error preventing: even that design good error messaging is better to make a careful design, which prevents a problem from occurring. Eliminate error prone conditions or identify and prompt the risk of an error before it happen.
- Recognition rather than recall: minimize the user's memory load by making objects, actions, functionality and options visible. User should not have to remember information to execute the tasks.
- Flexibility and efficiency of use: system should provide accelerators to speed up the interaction of an expert user.
- Aesthetic and minimalist design: avoid no relevant information in the dialog.
- Help user to recognize, diagnose and recover from errors: error messages should be expressed in plain message (not code) and should precisely indicate the problem.

Heuristic validation has been performed during the design process and it has been used to refine the solutions. Heuristic validation has not been quantified but used to refine the user interaction solutions.

3.4.1.2 Usability Tests

The usability test in an empirical measurement that aims to achieve the following goals:

- Improve the usability of the system
- Involve real users in the testing
- Give to the real users specific task to execute with the system
- Enable the tester to observe and record the actions of the users
- Perform an analysis of the data and changed the design according to the results.

This test has been performed during the process of design of the cardio rehabilitation system.

3.4.2 Methods for the validation of the research hypothesis

This research has been validated following these steps:

Define the design methods: the methods will be defined and described. This task has been described in the chapter 4 (Design methods).

Apply the design methods to a cardio rehabilitation system: at this step the presented methods are applied to design a system to deliver cardio rehabilitation at home based on mobile devices and wearable sensors. Health professional participate in the definitions of the requirement. This step is described in the chapter 5 (Program of cardio-rehabilitation).

Interim validation of user acceptance and system intentions: end user: the system has been validated in usability tests: it has been used specific questionnaire for the usability, and questionnaire based on the Technology Acceptance Model (F. D. Davis, Bagozzi, & Warshaw, 1989). The step is described in 5.1.3 (Validation of the neutral design) and 5.2.3 (Validation of the persuasive design).

Development of the system and setup of the clinical study: at this step the system has been developed, in this research the rules of the messages and the educational content have been developed. This task has been described in the section 5.3 (Development).

Verification of effectiveness of the health intervention: the system has been used in a randomized clinical trial and the effectiveness has been compared to a control group that received standard rehabilitation practice. The comparison between the two groups has been done measuring the user's perception toward the disease (Broadbent, Petrie, Main, & Weinman, 2006), the knowledge about the exercise and cardio vascular disease using the Cardiac Knowledge questionnaire (Maeland & Havik, 1987) and measuring the exercise habits using the iPAQ (International Physical Activity Questionnaire) (Craig et al., 2003). Also the Final system acceptance has been measured. The details of the study and the results can be found in the section 5.4 (Final results).

Analyze the role of emotions and health in the design: an interview of people with Heart Failure disease has been performed and the results are discussed. The results can be found in 6.1 (Case 1: relationship between symptoms and emotions).

Analyze the impact of emotions in technology: the Psyche study is presented and the result discussed to focus on the negative impact can have depression on the technology compared with other groups. The result can be found in 6.2 (Case 2: mood status and technology).

Revision of the hypothesis: finally the result are merged and discussed to conclude and revise the proposed hypothesis. This content can be found in chapter 7 (Conclusions).

The following table summarizes the steps to be achieved in this research

Steps of the research work	Target	Metric	Chapter
Define the design methods	01 02 03	N/A	4
Apply the design methods to a cardio rehabilitation system	04	N/A	5
Interim validation of user acceptance and system intentions	05 06	User interview, User acceptance, specific questionnaire	5.1.3 5.2.3
Development of the system and setup of the clinical study	04	N/A	5.3
Verification of effectiveness of the health intervention	05 06 07	User acceptance, specific questionnaire, perception of the user, exercise habits, knowledge	5.4.2 5.4.3 5.4.4
Analyse the role of emotions and health in the design	08	User's interview, Specific questionnaire	6.1
Analyse the impact of emotions in technology	09	User acceptance, usability questionnaire	6.27
Revision of the hypothesis	H1 H2 H3	Combination of previous results	7

Table 8: Summary of the validation process of this research work

04.

DESIGN METHODS

The section presents the methods to design technologies that maintain and promote the wellbeing (physical and emotional) of a person.

4 Design methods

The chapter presents the methods to design technologies to promote wellbeing in people suffering from a physical disease. The proposed work addresses the following issues:

- Define a theoretical framework to design technologies that promote physical and wellbeing in the context of health care.
- Define the role of the persuasive technologies in health care. Design technologies that promote health maintenance and improvement applying clinical guidelines and best practice and provide technologies that foster behaviour change and wellbeing.
- Propose a process of design. Describe how these presented methods should be implemented.

The proposed **Well.Be.Sign** is the contraction of the expression Well Being Design. It is a framework to design technologies for patients to deliver care and promote. The framework is based on three views:

- **The theoretical framework:** it represents the patterns that have to be defined to design the technologies to promote the wellbeing.
- **The influence diagram:** it shows the persuasive forces in the context of health care. The role of the persuasive technologies is contextualized in a wider universe where other factors and persuasive forces influence a patient.
- **The design process:** it shows the process of design using an iterative, incremental methodology that applies a combination of existing methodologies (GDD, PSD) and others that are originals of this research.

4.1 Theoretical framework

The theoretical framework is based on 8 elements:

- **A cue:** it is an external stimulus that provokes a response from the user. The stimulus can be of a different nature: face-to-face, computer mediated interaction, human computer interaction.
- **The intrapersonal context:** it has one input from the cue to the perceived cue (PeC) that represents how the user interprets the cue. PeC is controlled by the user's attitude (A) that has control on the execution of specific behaviour (B). Attitude can be changed by the physical, emotional and cognitive factors (PECF). Over time the cue has effect on PECF at least at cognitive level considering two relevant factors that are intrinsic in the problem domain:
 - The past experience that user has to perform a specific behavior. If a behavior has been never performed, then users need to build the skills to be able to perform a behavior. The repetition of a behavior over time can modify user's attitude.
 - The knowledge represents the understanding of facts related to the execution of the behavior, the reason of the behavior (why is recommended) and the effect.

- **Technology context:** represents the technologies of user: end-user consumer electronics devices (mobiles phones, tablets, smart TV etc), specific medical devices (Blood pressure cuffs, Wearable sensors etc) and Smart Objects. These devices gather data from the user and environment through explicit *input* systems (e.g. keyboards, speech and gesture recognitions) or implicit inputs using *sensors*. The information is processed in the *digital context (DC)*, which processes and models the current users situation. This information is used by the *UX strategy (UXS)* to define the type of *cue* to the user. The system provides this response through the *Graphical User Interfaces (GUI)* or other actuators (Act).
- **User context:** represents the user in a specific environment (e.g. at home) interacting with the technology context and / or other humans. The cues occur inside this context.
- **Clinical Context:** it represents the hospital settings, in which doctors visit patients and use *clinical tools* to assess and prescribe specific interventions. These tools are integrated with the extended persuasive context in health care, leaving the control to the health professionals to set for instance the therapy goals and the required lifestyle modifications.
- **Extended persuasive context in healthcare.** In this context the information is processed and managed in three steps: the data of the technology context is used to make the assessment of the clinical, behavioral and intrapersonal status of the users. The information is used to generate a care plan (defined in the clinical context or automatized). The care plan synthetizes and harmonizes the specific therapies and recommendations that user should follow. The last process identifies the required *wellbeing strategy*. The strategy defines the empowerment strategies (to assist user to follow the care plan) and a general well being strategy to promote physical and mental health. This intervention defines the specific *target behaviors and habits*. The target behavior are then used to design a *UX strategy*, that is this context of research will be based on the principles of UCD and persuasive design. Wellbeing strategy can also implement strategies that involve relatives and other stakeholders. These strategies are required when the target behaviors and habits involves the social context (e.g. food habits).
- **Social context:** relatives, families and other stakeholders can collaborate to the execution of the wellbeing strategy. They can support the achievement of the target behavior in the user's daily life.
- **Life trigger:** they represent situations, event conditions that interfere in the human life.
- **Other existing cues:** they represent other external stimuli (media communication, advice from educational institutions, campaigns to promote healthy behavior etc) that could influence on the *interpersonal context*.

Figure 62: The Well.Be.Sign Theoretical Framework

The theoretical framework defines patterns for the design of systems to enhance behavior change in health care.

4.2 The influence diagram

The influence diagram shows the mechanisms of human decision to adopt a healthy behavior. The diagram is based on four elements:

- **Intrapersonal factors:** they are the *factors* of the theoretical model. They include physical and emotional status, the knowledge and the past experience (the two cognitive presented in this research).
- **Clinical influence:** in the context of healthcare, the health care team plays a key role. This influence is intrinsic of the nature of the health professionals that provide care and guidance for the health and wellbeing of the people. All types of therapy (medical and psychological), prescriptions, recommendations, and motivational interviews are examples of situations in which health care team operated as exogenous intent of persuasion.
- **Technology influence:** this influence is provided by the persuasive technologies as Fogg and Kukkonen proposed. If this technology is connected to the clinical context there is an implicit clinical influence that generate two perceived benefits: the system credibility and the perceived care.

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- **Social Influence:** this is another force of persuasion in society; it includes relatives (family, friends, colleagues, etc) that can contribute to achieve target behaviours or habits.

The influence diagrams contains a closed loop between intrapersonal Factors, Attitude and Perceived cue that are the proposed basic element to foster the behavior change. This mechanism is based on four principles:

- Cue regulation: attitude modifies how the user perceives the cue.
- Cue effect: the perceived cue can modify the interpersonal factors (e.g. knowledge, emotional state).
- PECF regulation: physical, emotional and cognitive factors modify the attitude that a user can have toward a specific behavior. User's cognitive factors (previous experience of the behavior, knowledge and understanding of the behavior) and current physical and mental status have direct affect on increasing intrinsic motivation and attitude.
- If performed, the behavior can be consolidated and became habit. The lifestyle modification has impact on the PECF of the users and reinforce the attitude.

Figure 63: Influence diagrams of the Well.Be.Sign framework

The influence diagram describes the interpersonal mechanism of behavior change and the possible types of external influence (clinical, social and technological) to adopt healthy habits.

4.3 Design process

The process involves 4 main stakeholders:

- **The target users** are the end users (e.g. the patients suffering a disease) that need a technological tool capable of motivating them to manage and improve their health status and physical and mental wellbeing.
- **The medical team** is a group of health professionals that guide and certify the design process in order to deliver a system that is compliant with the clinical guidelines and the best practice. In this research the clinical needs refer to the medical viewpoint, and the practice of patient's counseling and health behaviour change. This group includes cardiologists, nurses, psychologists, health educators and GPs.
- **The persuasive designer team** is a team of engineers and user interaction experts that work on the design of the system. They have the role of designing the system, and provide the system specifications for its development. They co-design the system with patients and clinicians and the result is validated iteratively.
- **The software developer** is responsible of delivering the software that is used during the tests. The final development follow a maturation process in order to deliver a system that can be used in a real clinical scenario.

The proposed design is achieved in four steps:

- **Neutral design:** the goal of this phase is to define a prototype according to the user's needs. GDD methods are applied to define goals, personas, scenarios from which the initial user interaction solution is proposed. A user prototype is developed and validated with the users. This phase is called 'neutral' design because no intention of persuasion is used has to be used for the definition of the concept.
- **Persuasive design:** at this step the theoretical framework is used. The extended persuasive context in health care (assessment, intervention, model of change and target behaviors) is defined and revised with the clinical experts. The prototype is then updated and for every target behavior new specific Persuasive Feature are defined using PSD (Oinas-Kukkonen & Harjumaa, 2009). From the new requirements a new prototype is released. Users validate the acceptance of the system and the intentions of the systems (target behaviors).
- **Development** of the solution: the system is developed according the specifications defined in the previous steps.
- **Validation:** system then is deployed in a production environment, it is installed in the in the healthcare centers. Then the system is used in a clinical study to measure the effectiveness of the solution.

The flow of design is iterative; the system is built in increments that are validated with the end users in order to verify the design solution. The theoretical framework is applied during the second iteration as the following diagram shows:

Figure 64: Iterations of the proposed methodology

Initial planning: at this stage the managers plan for the human and technological resources that will be used in the project. The following resources are required:

- **End users and stakeholder:** since the design is based on UCD it is required to involve the users in the process of design, and at the testing of the final solution. The Health professionals and other stakeholders are required to co-design the system in the step two of the proposed design process in order to define the clinical pathways of the users and tailor the design according to the clinical requirements. Furthermore the intervention is designed with a team of psychologists and nursing experts in the fields of patient support, and health behaviour change. The other stakeholders that support the users in the daily life (relatives, patients communities, friends) are also taken into account in order to provide the social support.
- **Managers:** they are responsible of managing the whole process of development and delivery of the solution. They are also responsible for to give a clinical meaning and a business orientation of the new developed system. Managers include: project coordinators, technical managers, clinical experts, and researchers.
- **User Interaction Designers:** they are responsible for designing the user interaction solution and setting the requirements for the technical

development. They apply the proposed persuasive context framework for health care to specify the solution.

- Designers: work alongside the User Interaction Experts to provide graphical elements to the User Interaction.
- Programmers: they are responsible for developing and testing the solution. Programmers use specific software development methodologies (e.g. Agile programming) that include iterative and incremental processing for development.

It is also best practice to plan also the required technological resources such user devices, servers, access to internet, libraries and programs, tools for the development of hardware and software artefacts.

Figure 65: Proposed flow to design persuasive technology in healthcare

4.3.1 Neutral design

The methodology proposes to begin the design of a neutral system by using the Goal Directed Methodology of Alan Cooper. The design process focuses on the definition of the user solution with a deep understanding of the user needs, implementing a ‘neutral’ (with no persuasive intent) approach. During this process the system concept is defined, discussed and validated with end users.

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The requirement phase starts reviewing medical guidelines, best practice in nursing, and health behaviour plans. Secondly it requires a preliminary interview of clinical experts and end users. The goal of these interviews is to understand the unmet needs and find if there are potential concepts to build on. From this feedback, Goal Directed Design is applied in the analysis and design phase to specify the User Interaction Solution and the system requirements. From this preliminary output a rough list of the user's task is defined and the user interaction workflow refined (key paths). During implementation the first prototype proposes:

- User Goals, personas and scenarios
- A preliminary user interaction solution, by defining the devices the input and output modalities that best fit on the user's needs.
- A preliminary look and feel of the system.
- A preliminary mock up of the system.

The design had to be done following consistent methods and principles such as Heuristic Validation (Nielsen & Molich, 1990) and the Simplicity psychological framework (B.J. Fogg, 2009). The system is then validated through in a usability test and interviews to:

- Approve the overall concept, and consolidate the identified user needs.
- Identify user preferences and preferred functionalities.
- Test the usability of the prototype.

4.3.2 Persuasive Design

At this step the theoretical framework is applied to design the persuasive feature of the system. Two context of the theoretical framework need to be defined:

- The *extended clinical context*: it is a process that defines the specific strategy that will be adopted to design technology to foster the behavior change. From an initial analysis it specifies the required target behaviors that should be achieved by the user. These specifications need to be defined together with a multi disciplinary team of clinical experts formed by specialists and health psychologists.
- The (persuasive) *technology context*: the prototype is designed to achieve the target behaviors that have been defined in the *extended clinical context*. The 'neutral prototype' is upgraded using the principles of the functional triad of Fogg (B. J. Fogg, 2002) and specified using PSD (Oinas-Kukkonen, Harri and Harjumaa, Marja, 2009). Then the new functionalities are designed and integrated into the prototype.

4.3.2.1 Design of the extended clinical context

The design consists in defining the three element of the extended clinical context: the care plan, the well being strategy and the assessment.

- Care plan: at these steps the medical team defines the required intervention of the specific population (e.g. medication, program of rehabilitation, monitoring of physiological data etc.).
- Physical and mental wellbeing strategy: the strategy is designed with health psychologists and nurses. The goal of this strategy is to provide tools to empower the patient to adhere to the care plan (specific strategy) and a global strategy to promote physical and mental wellbeing. The defined strategies are then applied to a **model of change** based on TTM and adopted for the context of technologies.
- Assessment process: at this step is discussed how the future system can evaluate the user's status and situations. The proposed system manages different data types as health related data (physiological data, symptoms questionnaires), behavioral data (reported activities, activities performed using the technology), cognitive data (knowledge about a specific health topic, attitude, belief etc). The assessment also leverage of the diagnostic processes, and follow-ups that have been performed in the clinical context. (e.g. diagnostic during a visit).

Model of change

The theoretical framework provides a model of change that defines the strategy to promote the change using technology. The model is based on the TTM Stages of Changes and defines the goals of the persuasive system to achieve the next step of the stage.

Stages of change	Goal of the persuasive system
Pre-contemplation	Build a simple personalized and credible relationship.
Contemplation	Reinforce belief and knowledge
Preparation	Provide tools to perform behaviours. Introduce the tools to the users; provide behaviour simulation for complex behaviours.
Action	Build confidence using Goal Settings approach.
Maintenance	Promote the change as a habit. Reinforce patient's attitude and increase ability to perform the behaviour.
Termination	The technology operates as a tool, reinforcement is given in case of relapse.

Table 9: proposed model of change based on TTM

According to the table the goals a list of corresponding target behavior of the users can be defined. This list and addressed in the persuasive design In case that a target behavior is considered complex it can be further divided into smaller target behavior in line with the Goal Settings theory (Locke & Latham, 2002).

4.3.2.2 Design of the technology context

The technology context is achieved by completing three types of design:

- Cue design: at this step the target behavior are used to specify the functionalities of the system. Persuasive System Design methods are applied (Oinas-Kukkonen & Harjumaa, 2009)
- Interaction design: from the cue design new functionalities are identified and the user interaction need to be updated. At this step GDD is used from the requirement step and the new functionalities are added in the prototype.
- Strategy configuration: this step set up the logic to trigger functionalities and messages according to the specific cues that have been defined. The strategy is specified over time and depending of the user situations. At this step rules to trigger functionalities and messages to the user are defined.

When all these dimensions have been distinguished a new version of the prototype is developed and test with end users. The goal of this confirmation is the following:

- Quantify the acceptance of the intentions of persuasion in the system, while target behaviours are revised and discussed with the users.
- Approve the global concept, measuring overall acceptance and user's opinions.
- Assess the usability of the prototype, through observation and quantification of the users' while they're using the system. (e.g. unobtrusive task).

4.3.3 Development

At this stage the concept is fully specified and developed. The validation at the second iteration is used to refine the functionalities and the user interaction solution. The design is fully revised and transformed into system requirements. The specifications are defined in the following manner:

- Revision of the medical protocols that will be developed: the revision includes the whole intervention program and encompasses form protocols and guidelines that have been designed into the system of "models of change" that has been developed to promote behavioural modifications.
- The strategy and the user interaction solution will be refined according to the result of the validation at the end of the previous iteration. Furthermore the strategy will be revised under different dimensions available on the digital context: time (how the strategy is implemented over the time of use), performance (how the strategy responds to the behaviour of the users).
- Specification of the functionality of each tool: thanks to the PDS design the software will be described in terms of software qualities and the GDD will provides the design solution to develop the GUI and the specification of the user interaction.

4.3.4 Validation

Three types of validations are required to validate the system designed with the Well.Be.Sign method:

- Acceptability and easiness of the technology: this dimensions need to be assessed during all interim validations of the design process and at the end of the study. Two types of data need to be gathered: the user's data (using questionnaire based on the Unified Model of Technology Acceptance) and the logs of the developed device, in which it will be possible to explore in details how users use the system and perform specific analysis of usability to measure the system learnability, the technical failures and how the use the technology in his daily life.
- Health outcome: system has been designed to deliver health services to improve the health status of the user and the quality of the life. The proposed method needs to be compared with existing practice.
- Measure the changes provoked by the use of the technology: behaviours (eating habits, physical activities etc), knowledge on the specific disease. These dimensions need to be periodically over time to validate the long term effects of behavioral modifications.

05.

PROGRAM OF CARDIO-REHABILITATION

The section describes how the proposed methods have been applied to design, develop and validate a tele-rehabilitation program for patients that suffered a myocardial infarction.

5 Program of cardio-rehabilitation

The chapter shows the second result of this research work: the design, of a system to deliver the cardio rehabilitation program at home to patients that suffered a MI. The design of the system followed the proposed methods of the Well.Be.Sign framework; the three iterations of the proposed design methods and the results are presented in the next sections. The work has been done in the context of the HearCycle project in which it was possible to define the intervention with clinical experts and validate the design solution with real patients in every phase of the process. The final validation has been done in a randomized controlled study, their result are presented at the end of the chapter.

5.1 Neutral Design

The goal of this iteration is to design a “neutral” system: system has been designed focusing on the user needs following the GDD approach. In the context of the HearCycle project the preliminary requirement have been defined during a workshop with clinical experts, designer that previously interviewed the patients and expert in design and development of technologies for the health care. This requirement has been used as starting point to apply the Goal Directed Design and develop a preliminary concept. The concept has then validated with 3 CAD users.

5.1.1 Initial workshop

A patient workshop has been performed within the HearCycle project in order to identify the needs of patients. The workshop took place in Eindhoven (NL) on 28- 30 July of 2008. Previously the team interviewed 11 people with coronary heart disease and they presented the results in the workshop from these interviews; the results were discussed and enriched over a round table together with health and technology experts. The following topics have been discussed (Cleland & Naujokat, 2008):

- **Stages of the cardio-rehabilitation.** The discussion focused on the clinical treatment throughout the clinical settings of the United Kingdom, Spain, and Germany. Typically, according to the clinical guidelines the patients are treated with antyplatet and antytrombothyc therapy and in some cases a percutaneous coronary intervention is required. The period of hospitalization differs from country to country: up to 4-5 days in UK; and only 1-2 weeks in Germany. In this period the pharmacological treatment starts and re-mobilization of the patient begin. At this stage the patient's have a high level of motivation and attention on the clinical instruction given by the medical team because the memory of the event is fresh in their mind. After the discharge the availability of cardio-rehabilitation services differ largely within the three countries: in Spain just 10% of patients have access to services and the rehabilitation is done in specialized units of hospitals, in Germany the health care system offer every patient 3-4 weeks of service. In the UK the rehabilitation programme takes anywhere from 6 to 12 weeks with a bi-weekly follow up from a nurse. In general after the discharge, the patient's motivation is still high because he / she has usually discovered new limitations within their daily lives (fatigue,

chest pains) which make them feel vulnerable. After weeks (or months in the most critical cases) a stable phase is reached, patient's should continue with the medication regime and adopt a healthy lifestyle;

- **Patient attitudes:** in the long term the patients under 70 years of age without comorbidity did not perceive the illness. Usually they would adhere to the medication regimen, while reporting difficulties to change lifestyle routines. Many of the patient's reported psychological effects such as, losing confidence in themselves, feeling useless, and suffered from low self esteem. Regarding their attitude with the technologies related to healthcare the majority of adult people (over 70 years old) were sceptical but in every case there was an interest if the technology produced a direct benefit for them.
- **Proactive attitude in front of the disease:** There is an urgent need for people to adopt a proactive attitude in light of their disease, and commit themselves to adopting a healthier lifestyle. Lifestyle intervention could comprise the promotion of physical activity; weight reduction, healthy dietary habits (salt and fat reduction), and smoking cessation. Eating habits also require a more complex intervention, in many cases the patient's are not cooking directly for themselves and the dietary choices should focus not only on the type of food consumed, but also on how it is prepared.
- **Education:** there is a clear need to receive information about the risk factors and treatments. Education requires a large amount of tailoring because of the varying education levels of the subjects, but also because different individual needs should be addressed according to their habits.
- **Motivation:** it is a key step for long lasting lifestyle changes. It will vary depending on clinical status (chronic/ acute status, symptoms or not) and the individual, every new person could require intrinsic or external motivation cues.
- **Being informed:** patients want to be in control of their health status but don't want that the information that could cause them panic. There are situations in which the information could frustrate the patient because it cannot be controlled in the clinical outcome. They are interested in being informed of their weight, and blood pressure. They would like to perform safe exercise, and have accepted the idea of using technology to be trained safely in order to use a heart rate monitor in hospital settings during the phase 2 of their CR.
- **Management of medication:** this is not urgent as the medication usually is not complex, as it can be with chronic patients (e.g. heart failure). Furthermore the monitoring of the medication is considered strictly private and not shared with the clinician.
- **Personalized treatment plan:** the treatment plan should be personalized according to the patients lifestyle, and user's preferences. The clinicians also understand that the patient's attitude is one dimension that should be taken into account. Comorbidities should also be included in the treatment; this need is in line with current research activities about integrated health care.
- **Technology needs:** patients use medical technology at home (e.g. weight scales, blood pressure cuffs) and they are interested in new technology that can help them to manage their coronary heart disease. They need unobtrusive tools that do not remind them of their disease. There are many differences in device preference depending on age, and social status. The most preferred devices are

mobile phones, computers and televisions. Users want a system that doesn't require a lot of time to use, and is simple and easily integrated into their daily life.

- **Social support:** family support is appreciated; in many cases the lifestyle changes depend on family and cultural habits (active lifestyle and dietary options).

5.1.2 Goal Directed Design

The system has been defined applying the Cooper Methodology presented in the books called *"About Face: the essential of the interaction design"* (Cooper, 2014). In this iteration the design focus only on the user's perspective.

5.1.2.1 Goals, Personas and Scenarios

After the research produced with the revision of literature and the results of the workshop the user goals have been identified. According to GDD there are three categories of goals: the life goal (what user wants to be), the experience (what the patient wants to feel), the end goal (what user wants to do with the system).

Type of goal	Description
Life Goal	To be in control of their own health
Experience	To feel connected with the doctor
Experience	To feel that technology can help to manage their health status
Experience	Technology that is quick and easy to use
Experience	To enjoy the ubiquity and portability of the technology
Experience	To feel safe while exercising
Experience	Receive practical information and tips
End goal	Receive personalized information
End goal	To take part in 'safe' training exercise sessions

Table 10: User's goals

The next step has been the definition of two *personas*, the user's archetype.

Mr. Michael Mills is a 60-year old engineer that lives in Liverpool. For the last few years, Michael has run his own engineering company, which he shares with a partner. During a camping trip, Michael started feeling chest pain and, after a few hours, his wife convinced him to go to the nearest hospital. The doctors confirmed that Michael had suffered a MI, due to a two-vessel coronary artery disease. He was scheduled to a coronary angiography at a hospital near his home, where he was treated with balloon angioplasty and coronary stenting. Although the diagnosis scared him at first, Michael did not quit his job. He focused on what he had to do, and tried to be compliant with medication, and follow his doctor's recommendations

about a change in his diet and lifestyle. At times Michael has doubts about what he is and is not able to consume, and sometimes while he is at work he eats food his doctor explicitly told him to avoid. He's quit smoking, but still has the occasional cigar at special events. Regarding his physical activity, two or three times a week he exercises on the stationary bicycle he bought a few years back. On weekends and holidays, Michael and his wife take their recreational vehicle and travel the countryside, where they go hiking. Although he still considers himself in good shape, and has not changed his lifestyle too much, Michael is afraid that someday his heart may fail again, this time fatally.

The secondary persona is described in the following:

Mr. Thomas Muller is a 76-year old male patient; living in Aachen (Germany), he had his first MI during the 1960s, and a second event more recently. He did not notice the latter; it was detected accidentally during a medical check-up. A stent has been inserted into his coronary arteries, and doctors were considering whether or not he needs a pacemaker. He refused to join a rehabilitation programme after his first MI, but now after the second scare he would like to participate in a programme. Besides his heart problems, the patient also suffers from diabetes and orthopaedic problems. The patient lives alone in his apartment, but has a good network of informal care: his nephew is a trained paramedic and can help him with any medical questions, while his daughter cooks for him, and his daughter-in-law cleans his apartment.

The patient checks his blood pressure twice daily, and his blood sugar level three times a day at home. He said that he misses physical activity but that it causes him too much pain due to his dyspnoea and orthopaedic problems. He sees his GP regularly every three months for a check-up (which includes blood tests).

Thomas and Michael's personas represent the archetype model of the user. Under the behavioural point of view, they may be interested on using a technological solution to manage the health. A first pre-condition scenario has been defined to describe how the user will get the system and start using it. The pre-condition scenario is the following:

Scenario 0 (pre-condition): Set up in the hospital

During the follow-up visit the cardiologist proposed that Michael Mills join a tele-rehabilitation programme which utilises a wearable sensor and a mobile app. The rehabilitation programme will last for six months, during which the system will help the user to perform monitored exercise, and use a set of interacting tools to understand the health condition and improve the lifestyle choices. Michael Mills agreed to take part in the tele-rehabilitation programme. In light of Michaels decision the cardiologist recommended a cardiac stress test to assess his cardiovascular capacity. An ergo-spirometry is performed while the patient is walking quickly on a treadmill. The cardiologist records the results and gives Michael his consent to begin the programme, a bag is then given to the patient containing the HeartCycle information and devices.

System has been described defining two specific scenarios in which user use the system. The following scenarios define the needs that Michael and Thomas will require from the system. Three of them have been identified below:

- **Exercise programme:** the user performs a personalised exercise training that is “guided” through a live feedback provided by signals and voice commands.
- **Improving knowledge and fostering healthy habits:** in this scenario the systems offers support to improve the patients education of their disease, while promoting lifestyle change in order to reduce modifiable risk factors.

The defined scenarios are the following:

Exercise Programme

Michael started using the HeartCycle system

Michael receives a message on his Smartphone in the morning, reading “Michael it’s time to exercise”. He has time, so he puts on the sensored shirt, his jogging pants, and shoes and goes out to fulfil his exercise session. He decides to go to the park near his flat. Before he starts the smartphone triggers a symptoms questionnaire and ask Michael how is feeling today and if he took his morning medication. After completing it, Michael starts the exercise session and puts the Smartphone in his harm band. First, he warmed up for 5 minutes, then he walked moderately to raise his heart rate to 90 BPM. He felt great and had a lot of energy and no problems to sustaining his BPM at this level. After 5 minutes the mobile advised Michael that the warm up is finished and the training session should start. Now the heart rate goal is 125 BPM and it should be maintained for 15 minutes. Michael starts running slowly and as soon the mobile asks him to increase his pace he increases his speed. Today is a beautiful day in the park, Michael is feeling good and he has a lot of energy. The mobile alerts him with a sound to not run too fast, his heart rate is at 140 BPM and rising above the ‘safe zone’. Michael understands the alert and slows down to a more comfortable pace. In the middle of the training he starts to sweat a bit. The mobile phone alerts the end of the exercise and notifies Michael to decrease his speed and start walking until his heart rate returns to 90 BPM. After a while the mobile phone asks for feedback regarding todays exercise, and in a scale from 1 to 10 Michael selected 6, today was a good day of training!

Improving knowledge and fostering healthy habits:

Michael is at home and wants to check the progress of the morning exercise session. He takes the HeartCycle device and notices he has two messages in the inbox: the first message is about the mornings exercise session: the system reminds him the importance of following the alerts during their exercise, and avoid running faster than the system requires. Michael presses the next button and reads the second message: this one is a suggestion for the user, and provides information on controlling hypertension: Try to reduce salt intake, and avoid processed foods. Michael presses a button to know more about the tip and reads an excerpt on the importance of reduced salt intake in the diet. The educational contents provide him with practical tips; such as recommending other spices for food, and to avoid bringing salt to the table while eating in order to reduce the temptation to add more salt to the food. Michael will start considering his salt intake, he’s planned on having a Cesar Salad with his wife this evening and has already thought of a healthy alternative for dressing it.

5.1.2.2 Interaction qualities

The following table describes the characteristics of the interaction qualities.

Device characteristics	Mobile system and wearable device to perform the exercise sessions. Mobile system / tablet to use the system at home to improve knowledge and foster healthy habits.
Interaction requirements	Home page with menu of functionalities, User controls the interactions System triggered messages Easy to use Tailored for different user profiles
Input methods	Explicit: Touch screen
Output messages	Tests, Videos, sounds, and speech

Table 11: user interaction requirement

5.1.2.3 Preliminary functionalities

The following functionalities have been proposed and further developed.

Functional areas	Functionality
Messages	Generation of motivational, reinforcement messages
Exercise	Exercise support
Medication	Medication support, reminders, advise effective information
Education	Educational content, tests, personalisation of the content
Health	Care plan visualisation, charts, evolution of the disease

Table 12: Preliminary functionalities

Preliminary key paths have been defined according to the scenarios. The following figure shows the preliminary functionality map of the patient system:

Figure 66: Key path of the patient system

The following key-path has been defined for the exercise scenario:

Figure 67: Key path of the exercise system

A prototype, and two mock-ups have been developed: the exercise system on a mobile phone, and the patient system on a tablet.

Figure 68 Example screen shot of patient recommendations

Figure 69: First mock up of the exercise system

5.1.2.4 Preliminary global concept

The preliminary concept called Guided Exercise System (GEx) is based of three elements:

- **The Patient Station:** it is a user device to be used during entire process of rehabilitation. It provides educational support, and feedback about the progress of the rehabilitation.
- **The Portable Station:** it is a specific tool to provide a monitored and guided exercise training session. This element has two devices: a wearable sensor that will be used to monitor physiological variables (ECG, respiration) and a PDA that will receive this biomedical signal, process, and provide feedback to the patients according to their specific exercise goals.
- **The clinical system:** the health professionals use this system to tailor the rehabilitation process for each patient. They configure the exercise training sessions according to the result of the cardiac stress test. The system stores the cardio rehabilitation program of every patient and the results of their training sessions.

Figure 70: Preliminary system architecture

5.1.3 Validation of the neutral design

The preliminary concept of the Patient Station and Portable Station has been validated interviewing with the patients. The interviews had the following scheduling agenda:

Section	Subject	Time
Introduction	Informed consent Aim of the interview System introduction	5 min
General questions	Demographic questions Technology level Health status	5 min
Rehabilitation assessment	Physical exercise and rehabilitation Learning preferences	15 min
Introduction to the system	Introduction to the system concepts	5 min
Validation of the usage scenarios	Presenting the two scenarios and the devices that will be used.	
Conclusion	System acceptability User's preferences	3 min
Closure		2 min
	Total time	50 min

Table 13: Scheduling of the usability round (Neutral Design)

3 CAD users have been interviewed in the Castle Hill Hospital of Hull. Two were 60 years old and one 70, all of them were males. One was included in the Heart Manual rehabilitation program. The system was well accepted by 2 of the three interviewed patients. One of three patients was sceptical towards the system, and stated 'neutral' when asked if he liked the system, and went on to say that he would not use the system frequently. From the results of the questions about education preference, it is interesting to see how the users negatively scored the content related with changes in lifestyle. The three users negatively scored the educational content about smoking cessation (they did not smoke).

The following table shows the details of the interview, (-) indicates a negative attitude and (+) a positive attitude toward the presented system.

	User 1(-)	User 2 (+)	User 3 (+)
Do you consider this solution for controlling your health is...?			
Not interesting at all / Very interesting	4	5	5
Scary / Not Scary	4	5	5
Very unpleasant / Very pleasant	4	5	5
Dull / Stimulating	4	5	5
No useful at all/ very useful	2	5	5
Very difficult to fit into my life / very easy to fit into my life	4	5	5
Please score the following aspects of the system (1 not interesting, 5 very interesting)			

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The system records my vital signs during exercise	5	5	5
The system reminds me when I have to exercise	4	3	5
The system sends my vital signs to my nurse / doctor / physiotherapist	5	5	5
The system warns me when one of my measurements is out of range during the exercise	5	5	5
The system proposes an exercise plan	5	5	5
The system provides me with educational content	5	5	5
Do you like to know more about how to reduce your risk factors? Yes/ No	No	Yes	Yes
Suppose the system can also provide you with education on different aspects of your health, which aspects would you like to know more about? (1 Strongly disagree / 5 strongly agree)			
1.Weight reduction	1	5	5
2.Controlling your blood pressure	1	5	5
3.Know more about your disease	4	5	5
4.Understanding the symptoms of your disease	3	5	5
5.Diet recommendations	1	5	5
6.Recommended physical activity	1	5	5
7.Stress reduction	1	5	5
8.Relaxation techniques	1	5	5
9.Quitting smoking	1	1	1

Table 14: User answers for the first usability round

5.2 Persuasive design

According to the proposed methods of Well.Be.Sign in this step two contexts need to be defined: the extended clinical context and the technology context as defined in The methodology proposes to begin the design of a neutral system by using the Goal Directed Methodology of Alan Cooper. The design process focuses on the definition of the user solution with a deep understanding of the user needs, implementing a 'neutral' (with no persuasive intent) approach. During this process the system concept is defined, discussed and validated with end users.

The requirement phase starts reviewing medical guidelines, best practice in nursing, and health behaviour plans. Secondly it requires a preliminary interview of clinical experts and end users. The goal of these interviews is to understand the unmet needs and find if there are potential concepts to build on. From this feedback, Goal Directed Design is applied in the analysis and design phase to specify the User Interaction Solution and the system requirements. From this preliminary output a rough list of the user's task is defined and the user interaction workflow refined (key paths). During implementation the first prototype proposes:

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- User Goals, personas and scenarios
- A preliminary user interaction solution, by defining the devices the input and output modalities that best fit on the user's needs.
- A preliminary look and feel of the system.
- A preliminary mock up of the system.

The design had to be done following consistent methods and principles such as Heuristic Validation (Nielsen & Molich, 1990) and the Simplicity psychological framework (B.J. Fogg, 2009). The system is then validated through in a usability test and interviews to:

- Approve the overall concept, and consolidate the identified user needs.
- Identify user preferences and preferred functionalities.
- Test the usability of the prototype.

Persuasive Design section (section 0). In this context the clinical goals of the system have been defined and used as basis to design the system.

Improve cardio vascular functionality	Determine the improvement obtained in long-term adherence to home-based rehabilitation programs (cardiac rehabilitation phase III) when following a guided exercise training prescription supervised by a system specifically designed to optimize the training effects and maximize the patient's security.
Foster adherence to the programme	Provide a system that foster
Improve knowledge	Understand the conditions and convey a proactive approach on health management and control
Secondary prevention	Reduce modifiable risk factors

Table 15: Clinical goals

5.2.1 Design of the extended clinical context

At this step the care plan and the global intervention is designed with the team of clinical experts. The main clinical goal is to determine the improvement obtained in long-term adherence to home-based rehabilitation programs (cardiac rehabilitation phase III) when following a guided exercise training prescription supervised by the system. This goal has been defined in the care plan. The secondary goal is to provide a plan of secondary prevention to reduce the progress of the CAD and reduce the occurrence of the MI. This goal will be defined in the Global Intervention Strategy.

5.2.1.1 Care plan

The required intervention has been defined with cardiologists and experts in sport medicine: they defined the exercise protocol and the requirements that grant patients

a safe and personalized exercise session. Two types of exercise have been defined: endurance, and resistance exercise. The endurance exercise is monitored using the Portable Station and the Wearable sensor, the system includes instant feedback (e.g. alerts to speed up or slowdown); the resistance exercise is done without any techniques of supervision.

Endurance Exercise protocol

The following diagram shows the structure of the exercise session, in line with the clinical guidelines of exercise training that have been described presented in the section 1.1.3.10. The phases of the exercise has been specified:

- Warm-up phase: which consists of a walking exercise, running or cycling exercises which should increase the Heart Rate from a basal HR to the 80% of the HR_{min} . After 5 minutes patient is instructed to perform 5 minutes of stretching exercises.
- Core phase (or conditioning): at this phase of the training the user should maintain the heart rate at a specified level for a fixed period of time.
- Cool down phase: this is the recovery phase in which the user should decrease the exercise level and perform a final stretching exercise.

Figure 71: Structure of the exercise session.

This type of structured exercise can be executed by setting the variables of the heart rate: HR_{Min} and HR_{Max} , the duration of the core phase, the goal of the perceived effort of the users and the weekly frequency of the exercise. In this research project the department in charge of this estimation was the institute of Cardiology and Sport medicine of the German University of Cologne.

Resistance training support

The cardiologists and medicine experts of the Heart Cycle project also defined the training model of endurance exercise. A resistance exercise session consists of the following steps:

- Warm-up phase: that consists of 30-60 step or walk, and arm movements ('as marching soldier parade') as well as a set of mobilization and stretching exercises.
- A core phase: which patients perform a subset of resistance exercises (shrug, front raise, hip flexion, hip extension, seated forward bending, seated diagonal stretch, elbow flexion, lateral raise etc. (see Annexes)
- The cool down phase: which consists of stretching exercises.

The patient will start with 2 exercises, and will add another exercise when the current plan has become easy to perform. The patient should not add more than 2 exercises per week. Adding exercises can be done at the patient's initiative. When all above exercises have been added to the program, the patient may increase the number of sets (per exercise) from 1 to 2. When it has become too easy to perform 2 sets of all above exercises, the patient may increase the number of sets from 2 to 3.

The patient should rest 30-60s between two consecutive sets of the same exercise. The rest time between two consecutive exercises is at least one minute.

To have the right level of resistance, the patient uses a rubber latex band (or Thera-Band). Resistance bands are available in different colours with progressive resistance as the following schema shows:

THERABAND® Color Progression

Thera-Band® Band/Tubing Color	Increase from Preceding Color at 100% Elongation	Resistance in Pounds at:	
		100% Elongation	
THERA-BAND Tan	-	2.4	BEGINNER ↓ ADVANCED
THERA-BAND Yellow	25%	3.0	
THERA-BAND Red	25%	3.7	
THERA-BAND Green	25%	4.6	
THERA-BAND Blue	25%	5.8	
THERA-BAND Black	25%	7.3	
THERA-BAND Silver	40%	10.2	
THERA-BAND Gold	40%	14.2	

Represents typical values. All products not available in all colors.

Figure 72: Specifications of the Thera-Band¹⁰⁶

The medical team of the HeartCycle project has defined the following specifications described in the clinical protocol of the exercise program (Schauerte, Bover, & Cleland, 2011):

The patient should choose the resistance band according to his or her current exercise status: the patient should choose the band that enables him or her to complete 20 repetitions with mild fatigue (Borg Scale 12-13) and without holding his or her breath. The number of 20 has been chosen since this number promotes muscle endurance (rather than muscle strength), and is on the safe side. The patient may need different band colours for different exercises. If someone is not able to repeat the exercise in the prescribed manner (20 times), the load is too high and must be reduced to decrease the intensity of the exercise. This reduction can be managed by positioning the grip at the resistance band a little bit higher (near to the end) and by this reduce the stretching level of the resistance band. If after these changes the intensity is still too high, the resistance band must be changed and a resistance band with lower resistance level used. The patient can progress to the next colour band (higher resistance level) if he or she feels that they are easily able to complete the 3 sets of 20 repetitions.

¹⁰⁶ http://www.thera-bandacademy.com/elements/clients/images/TheraBand-Progression__635437153146560991.jpg

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The cardiologists designed the exercise program using an incremental approach. The patients will start to perform endurance sessions with a stretching exercise before and at the end of each session. The intensity will increase over time and throughout in the following stages of the rehabilitation new resistance exercises will be introduced. This approach was based on the principles of the FITT (frequency, intensity, time and type).

Figure 73: Intensification strategy of the exercise¹⁰⁷

The exercise scenarios have been discussed and approved by cardiologists (of the Aachen Hospital and San Carlos of Madrid). According to the clinical guidelines they suggested 5 phases of the rehabilitation in which the intensity and the frequency and duration of the exercise increase:

¹⁰⁷ (Schauerte, Bover, & Cleland, 2011)

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Phase	Length	Type/ Frequency	Duration	Intensity
Initial	3 weeks	Endurance (2/week)	3X10 - 30 min	11 of Borg scale
Improvement A	2 weeks	Endurance (2/week) Resistance (2/week)	3X10 - 30 min	12 -13 of Borg scale
Improvement B	2 weeks	Endurance (2/week) Resistance (2/week)	3X15 - 45 min	12 -13 of Borg scale
Improvement C	2 weeks	Endurance (3/week) Resistance (3/week)	3X15 - 45 min	12 -13 of Borg scale
Maintenance	12+ weeks	Endurance (3/week) Resistance (3/week)	3X20 – 60 min	12 -13 of Borg scale

Table 16: Exercise program for cardio-rehabilitation

5.2.1.2 The Intervention Strategies

Two strategies have been defined this the Heart Manual Team: a global strategy of cardio rehabilitation and another to specific for the exercise program defined in the care plan.

Global strategy for the rehabilitation

The General intervention strategy is based on the principles of the multifactorial rehabilitation program that have been implemented in the Heart Manual programme. In the context of the HeartCycle project the strategy is based on the following points:

- Improve general knowledge about the disease; remove common disease misconceptions, to improve the patient's attitude toward a proactive self-management and overall understanding of the condition. The strategy is based on tools to identify the user's misconceptions and tailor specific reinforce educational material to change the attitude and belief of the person.
- Support behaviour change: providing practical information on how to reduce modifiable risk factors. Empower the patient to adopt a healthier lifestyle and

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give subtle psychological support, providing information on how to manage stress, anxiety, and depression.

According to the Heart Manual approach the first step of the strategy is to make the patient aware of the conditions he / she suffered. Individuals are not likely to change behaviours if they don't believe it is necessary, or when they do not feel in control of the situation. For these reasons the cardiac misconceptions will be addressed in the early phase of the intervention. The patient's attitude is assessed using a cognitive behaviour approach. This process is used to prepare the user to review the modifiable risk factors and how they can be controlled. The next step is to ask the users what they would like to change in their lifestyle. This strategy will support the following areas by providing the following educational content:

- Practical tips on exercises, managing setbacks, tips to exercise in daily life.
- Negative effects of smoking, and tips on how to cut back and stop smoking.
- Understand blood pressure values, the effects of the disease, and how to monitor blood pressure.
- User's learn how to reduce their weight by understanding the concept of calorie balance, the need to reduce calorie intake, and increase physical activity.
- Alcohol consumption: user learns about the risks of excessive daily alcohol consumptions. User learns the maximal daily intake.
- Healthy eating: users learn what healthy and unhealthy foods are and how to apply healthy alimentary choices in their daily lives.
- Psychological support: users learn how to understand negative emotional response related to their disease conditions and daily life. Anxiety, worry, stress, and depression are explained, and practical tips are given to control these emotions. The program also proposes 20 minutes of an audiotape relaxing session.

Figure 74: Global strategy of the cardio rehabilitation process

Strategy for the intensification of the exercise

The system provides a specific strategy for the user to stick to the exercise plan and integrate physical activity into their daily life. First, users need to be supported and prepared for the exercise, in this case it is important to investigate the user's beliefs and address any misconceptions they may have. Secondly, the exercise activities are tailored according to the individual capacity and user preferences. The user exercises with a system that provides the proper feedback during the monitored exercise session and afterwards, according to their exercise performance and their perceived effort.

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Figure 75: Strategy for the promotion of the exercise habits

5.2.1.3 Models of change

Models of change characterise the approach that the technology uses to execute the intervention. The Well.Be.Sign framework proposes the TTM model adapted to define the goal of the persuasive system for each stage of change of the user. The interventions that have been explained in the previous steps are merged in a unique strategy of change that is delivered progressively depending on the user's progresses and behaviours. The following diagram shows the process that has been designed for the Guided Exercise system.

Figure 76: Configuration of the strategy using the state of change

5.2.1.4 Target behaviours

The following target behaviours have been proposed:

- TB1: User starts using the system.
- TB2: User exercises using the system.
- TB3: User intensifies the exercise programme.
- TB4: User understands the benefits of exercising.

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- TB5: User has general knowledge about cardiovascular diseases, heart attacks, and risk factors.
- TB6: User knows about how to reduce and control risk factors.
- TB7: User continues exercising and engages in healthy behaviours outside of the system.

The target behaviour is incremental and the advancement to the next behavior level depends on the results /performance of the current behaviour. The target behaviour will be used to design the technological context with the principles of the persuasive technology.

5.2.1.5 Assessment

In this phase all the required assessment processes have been identified. This analysis is necessary to have a clear vision of what can be managed by the system, and identify what other required tools could be used in a clinical context. For each desired behaviour a list of apprehension assessments have been outlined.

Target Behaviour	Assessment
TB1: User starts using the system.	Use of the system, successful tasks
TB2: User exercises using the system.	Cardiovascular capacity, health status, exercise performances,
TB3: User intensifies the exercise programme.	Quiz result , data of the exercise session
TB4: User understands the benefits of exercising.	Use of the system, Cardiovascular capacity, health status, exercise performances,
TB5: User has general knowledge about cardiovascular diseases, heart attacks, and risk factors.	Quiz results, use of the system
TB6: User knows about how to reduce and control risk factors.	Quiz results, use of the system, diary
TB7: User continues exercising and engages in healthy behaviours outside of the system.	Health status, exercise report, perceived usefulness

Table 17: Analysis of assessments of the target behaviour

From the preliminary list the types of assessment are then derived and mapped to specific tools that should provide this information.

Type of assessment	Reason	Tools
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Global assessment of the user	Establish whether or not the patient could join the rehabilitation program	Hospital tools (HIS), Diagnostic tools (ECG, angiography, eco2d)
Assess the exercise capacity	Tailor the exercise program according to user's physiological status	Hospital tools (HIS) and cardiac stress test
Assess the level of knowledge	To tailor the educational content	The Patient Station
Assess the modifiable risk factors	To tailor the recommendations	The Patient Station
Assess the behaviours of the users.	To tailor the feedback given to the user depending on the performed behaviour	The Patient Station
Assess the adherence to the instructions of the exercise	To train the user in the optimal and safe HR zones	The Portable Station
Assess the risk of performing exercise	Minimize the risk of adverse events during the exercise session	The Portable Station
Assess the evolution of the cardio-rehabilitation program	Monitor the patient's progress	The Web Portal of the health professional

Table 18: Global assessment specification

5.2.2 Design of the technology context

At this stage, the Persuasive System Design is applied (Oinas-Kukkonen & Harjumaa, 2009). The persuasion context has been construed by explaining the intent, the event and the strategy. The idea for the specific application is a mix of the following three styles of intention:

- Exogenous because the health care team recommends this system to patients who have suffered a MI, urging them to join a tele-rehabilitation program. For the physicians, it's an opportunity to provide tele-rehabilitation where it is not normally possible (e.g. in Spain) or an opportunity to extend and improve on the service as in Germany. The participation of the tele-rehabilitation will depend on the patient's willingness.

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- Autogenous: because the users use tools to improve their knowledge about the disease, and about healthy habits. The program will run automatically, and takes into account the patient's progress.
- Endogenous: because the system has been designed with the intent to promote physical activity, an understanding of the disease, and the ability to control of risk factors.

The second element is to define the type of change that is addressed: a-change (attitude change), b-change (system selects a more enduring behaviour), c-change (user performs at the request of the system).

The following table maps the changes to the target behaviours:

Target behaviours	Required Change type
TB1: User starts using the system.	C-change
TB2: User exercises using the system.	C-change
TB3: User intensifies the exercise programme.	B-change
TB4: User understands the benefits of exercising.	A-change, B-change
TB5: User has general knowledge about cardiovascular diseases, heart attacks, and risk factors.	A-change, C-change
TB6: User knows about how to reduce and control risk factors.	A-change, C-change
TB7: User continues exercising and engages in healthy behaviours outside of the system.	A-change, B-change

Table 19: Target behaviours and required change according to the BCSS.

According to the Six Principles of Simplicity (B.J. Fogg, 2009) the technology need to cover the following simplicity factors:

Dimension	Feature
Time	The user's tasks must be shorter. The exercise session will be the longer task should optimize the interaction (during preparation, in between the exercise phases at the end).
Money	The system will be free. The hospital will provide it to the patient's
Physical effort	The required physical effort is be gradual, according to the real exercise capacities of the user. A feedback strategy will keep informed and motivated the users.
Brain cycles	The user's task should be simpler. A usable graphical interface is required
Social deviance	The system should be less intrusive as possible. The exercise system should be very similar as the fitness application present in the market.

Non routine	The system should fit in the daily life
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Table 20 Technology context using the Six principles of simplicity¹⁰⁸

According to this preliminary analysis the design of the technology context is done following three steps:

- Design the Cue, using the PSD to specify new features of the system
- Design of the interaction: the prototype is upgraded according to the new identified features.
- The configuration of the strategy, by defining the rules of the messages.

The next sections details these results.

5.2.2.1 Cue design

The cues have been designed following the design of the system qualities of PDS. For each desired behaviour the persuasive context is analysed according with PDS (Oinas-Kukkonen & Harjuma, 2009) by defining the primary task, the dialogue support and the system credibility and the social support. The credibility has been built with the idea that the system is a medical system for tele-rehabilitation, designed and monitored by the health professionals. The social influence also is based on the health professional support that supervised the rehabilitation process and it in contact with the user, by a periodic follow up visit and also using an internal message system. Other care givers (familiar, informal care givers) have been not included in this solution.

¹⁰⁸ (B.J. Fogg, 2009)

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Target Behaviour	Primary task	Dialog support	Credibility	Clinical support
TB1	Introduction to the system	A message system introduces to the system, an Avatar gives instruction to the patients	Exercise designed by doctors, well formed messages.	Instructions and first introduction given by doctors.
TB2	Perform exercise	Instruction to speed up / down according to exercise plan. Check symptoms, reminders	Guidelines to perform the exercise, symptoms check	No real time support.
TB3	Perform exercise, exercise result, educational content about exercise	Instruction to speed up / down according to exercise plan. Check symptoms. Quiz about exercise, feedback on exercise, exercise personalization, reminders	Guidelines to perform the exercise, symptoms check, recommendations from health professionals, instant feedback on quiz	Patient can receive message from health professional regarding suggested educational content and in relation with the training plan
TB4	Perform exercise, changes in the exercise table	Messages to inform about the exercise plan changes, follow up messages, exercise personalization, reminders, previous compliance to the exercise plan	Intensification strategy according to the clinical guidelines	Health provides support for any doubt and clarification. Periodic visits of follow up
TB5	Perform quiz	Provide direct feedback to misconceptions, scheduled educational message to improve the knowledge, reminders, automatic messages with educational reinforce	System have been designed by health professionals	Health professional feedback via messages
TB6	Perform quiz	Provide direct feedback to misconceptions, scheduled educational message to improve the knowledge, reminders, automatic messages with educational reinforce	System have been designed by health professionals	Health professional feedback via messages
TB7	Perform extra exercises	Diary to report the exercise, messages to promote extra exercise (e.g. resistance exercise), reminders, feedbacks on progress	Guidelines to perform the exercise,	Health professional feedback via messages

Table 21: Design of system qualities using PSD

From the previous table the task are derived and described with the principles of the Persuasive System Design.

Task: Introduction to the system	
Features	Requirement
Reduction	The system will provide a gradual introduction to the system
Tunnelling	System will guide patients through the use of the system
Tailoring	The content must be tailored according user preferences (e.g. language)
Personalisation	None
Self-monitoring	None
Simulation	None
Rehearsal	It is possible to perform a test exercise

Table 22: Analysis of the first use

Task: perform the exercise	
Features	Requirement
Reduction	The exercise plan will be incremental according to the beginning fitness level of the user and the progress made.
Tunnelling	The exercise session will be guided and monitored through a wearable device. The user will be trained to recognise and stay within a safe zone of heart rate.
Tailoring	Time, day preferences, type of exercise (running, walking and cycling)
Personalisation	The exercise is personalised according to the exercise capacity of the user.
Self-monitoring	Sessions are stored and can be visualized in their tablet, or pc.
Simulation	None
Rehearsal	It is possible to perform a test exercise

Table 23: Analysis of the exercise session

Task: exercise result	
Features	Requirement
Reduction	The result will show the progress of the user
Tunnelling	Not supported because the task is simple
Tailoring	The results will be tailored according to the goal of the exercise sessions
Personalisation	None
Self-monitoring	User will see the progress of the exercise
Simulation	None
Rehearsal	It is possible to perform a test exercise

Table 24: Analysis of the task of the user's result

Task: educational content about exercise	
Features	Requirement
Reduction	Progressive educational content
Tunnelling	Simple guided tutorials
Tailoring	Tailoring of the content depending on user preferences
Personalisation	None
Self-monitoring	User will see the progress of the exercise
Simulation	None
Rehearsal	Quiz available to test the knowledge

Table 25: Analysis of the task educational content

Task: quiz	
Features	Requirement
Reduction	Progressive questions
Tunnelling	Not available
Tailoring	Language
Personalisation	depending on prior patient knowledge.
Self-monitoring	Instant feedback on quiz result
Simulation	Instant feedback on quiz result
Rehearsal	Reinforcement messages for incorrect answers.

Table 26: Analysis of the task to answer a quiz

Dialogue support: message system	
Features	Requirement
Praise	The system generates messages about the status of the tele-rehabilitation program. It provides feedbacks based on the exercise performance of the user.
Reward	When a goal is achieved a reward message is provided.
Reminder	Reminder alerts about exercises, reminder messages to urge the user to read up on educational content.
Suggestion	Suggested content for specific user
Similarity	Not supported
Aesthetic	Graphical look and feel
Social role	Messages received by the physicians

Table 27: Features of the dialog support for the message system

Dialogue support: Avatar	
Features	Requirement
Praise	It appears in the home screen and gives instant feedback depending on the use of the application. In case of low adherence it generate messages on how to use the system.
Reward	Reward texts appear when new goals are achieved
Reminder	Reminders to perform the exercise sessions
Suggestion	Not supported

Similarity	Not supported
Aesthetic	Avatar rendered in 3d,
Social role	Avatar is a digital assistant

Table 28: Features of the dialog support for the Avatar

Dialogue support: Feedback during exercise	
Features	Requirement
Praise	Instant feedback to the user in order to increase or decrease the workload of the exercise.
Reward	None, no rewards supported in instant feedback
Reminder	None supported, the feedback is for a current situation
Suggestion	Instruction to speed up using voice, sounds, and texts. Support in case of symptoms
Similarity	None,
Aesthetic	Graphical representation of speed up
Social role	None

Table 29: Features of the dialog support of the exercise feedbacks

System credibility support: guidelines	
Features	Requirement
Trustworthiness	System provides information based on medical evidence.
Expertise	System provides educational content based on the best practices in rehabilitation. The health professionals selected content.
Aesthetic	Acceptable look and feel.
Reach	Patient must feel connected with the health care system.
Authority	Messages will refer to doctor's advice.
Third party endorsement	Not available
Verifiability	All information is verifiable because it is based on clinical guidelines.

Table 30: Features of the system credibility 1

System credibility support: health professional support (via messages)	
Features	Requirement
Trustworthiness	Health professionals are responsible of the tele-rehabilitation program.
Expertise	Granted
Aesthetic	Message system and periodic visits
Reach	Yes
Authority	Not applicable
Third party endorsement	Not applicable

Verifiability	Not applicable
---------------	----------------

Table 31: Features within the system credibility 2

The specification of the cues generate new functional requirements of the Guided Exercise Concept that have been revised and modeled to be included in the system. The result of the cue design generated a more detailed system description.

From these features a more detailed system description have been defined. Three elements have been defined in the system: the clinical server, the patient station, and the portable station, as a specific sub system for the user to perform their outdoors exercise.

The professional system is responsible to provide to the health professional with the required tools to design and tailor a specific care plan for patients that have suffered a myocardial infarct. Health professionals will have secure Web access to the application that will provide the following functionalities in the graphical user interface (GUI):

- Configuration of the tele-rehabilitation program for every specific subject. The results of the cardiac exercise tests are entered and used to define the training plan. According to each patients personal characteristics and health status, the health professionals will identify the modifiable risk factors that will be used to build the required educational content for each subject.
- Monitor and assess the tele-rehabilitation plan: this module will provide the clinical team with all the information about performed exercises; the patient's questionnaire, and quiz. It provides analytics and an alert system to notify the patients of symptoms, low exercise performance, adherence to the training plan, or poor use of the application.

The server will run the services thanks to a care plan manger, a service that manages the specific clinical process and provides the required clinical workflows to support the information exchange among the different roles from within the hospital (nurses, doctors, educators). The system also provides a storage system to manage all the patient information and maintain by synchronising it with the HIS (Hospital Information System). The clinical server has a secure communication module layer that connects with the patient system to provide the care plan, and receive the performed activities from the user's device (exercise session, learning tasks, quiz, questionnaire).

The Patient Station is based on a tablet PC that will be used by the patient at home to manage the rehabilitation plan that clinicians have tailored specifically for him or her. The user can interact with the device thanks to a graphical user interface that provides the following functionalities:

- Avatar: it is a digital assistant that helps the users navigate the system. It will guide them through the system functionalities, while provideding high-level information, and feedback about their tele-rehabilitation.
- Message Inbox: the messaging system provides different types of messages for the users:
 - Reminders: the system reminds the user of activities that should be performed.
 - Propose an activity: depending on the progress the system can propose extra activities.

- Feedback about a performed activity including reward feedback, praise, and suggestions to achieve the goals of the cardio rehabilitation.
- Suggested educational material.
- Exercise: this module comprises three sections:
 - An overview of the exercise plan, as well the exercise personalisation option.
 - The weekly progress provides a visualization of the evolution of the performed activities on a weekly basis.
 - The global progress provides a graphic representation of the results of the exercises performed during the whole rehabilitation plan. A podium will help represent the global performance of the patient.
- Calendar: the module helps visualize the performed and tested activities of the rehabilitation plan.
- Learning: this module is comprised of tools for counselling and educating the patient: specific educational content has been developed by health professionals. The module supports different types of media with hypertexts, sounds, animations, and videos. Patients can score the preferred content. It also contains quizzes, and questionnaires to verify the knowledge of the user.

The internal services of the patient system make it feasible for the execution of the tele-rehabilitation process. The communication module has a bidirectional communication with the clinical server and the exercise system. The clinical server receives the care plan configuration, doctor messages, and the required educational content to be proposed to the user. The exercise configuration (duration, frequency, heart rate safety zones) is sent to the exercise system in order to correctly personalise the session for the specific user. It server receives all of the data from the exercise session: the bio-signals coming from the wearable sensor, the questionnaire results, and other information related to the exercise session performance. This information together with the information generated by the patient system is sent to the clinical server, where it's stored, analysed, and provided to the clinical team. The care plan executor it is in charge of configuring the user's devices (both, the patient system, and exercise system) according to the tele-rehabilitation program that has been defined by the clinical team. The care plan executor personalises the educational content, the questionnaires, and the exercise sessions. The assessment module provides the behavioural analysis and the analytics of the status during the rehabilitation process. It comprises implicit and explicit methods to keep track of users preferences, status of their rehabilitation, and the levels of their exercise performances. According to their assessment results the feedback system implements all the logistics to trigger the proper feedback message to the user. In this scenario the feedback system acts as the messaging system and the avatar. The patient system implements the data persistence thanks to the storage module.

The **Portable Station** is a sub system that patients will use to perform guided exercise sessions. It includes a wearable sensor based within a t-shirt which is built with 2 lead ECG, used to monitor the heart and the respiration rates. once it's collected this information is sent to the mobile phone. The mobile phone then provides all the instructions and protocols the user needs to carry out a safe exercise session. It sends a questionnaire module to evaluate the user before and after the exercise. The branch logic then provides proper feedback to the user. The exercise engine is the module that provides the user with guidance throughout their exercise. It provides different kind

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of instant feedback that gives instructions to the patient, urging them to stick to the training plan that the cardiologist set up. The exercise analysis system is a repository of algorithms which analyse the physiological data that is received by the wearable sensor. It is used to provide feedback during (instant) and after (processed) the exercise session. All the data is then stored in the mobile phone (Storage). The communication module makes the devices sync with the patient system: the bidirectional communication allows users to send data to it and to receive new exercise configurations.

The following image shows the element of the system.

Figure 77: Modules of the system.

5.2.2.2 Patient Station

A new graphical user interface has been designed according with the new detailed specifications. The system has been conceived using a messaging system to provide instructional tips and feedback to the user.

Avatar

An Avatar called “Hearty” has been defined. The reason to integrate these Graphical Components is to provide relevant information to the users, as well as providing specific feedback after their exercises sessions. It has been included in the following part of the system:

- In the Patient Station, in the home screen and in the exercise sections to provide feedback on the global cardio rehabilitation program.
- In the Portable Station, to provide specific feedback after an exercise session.

An algorithm has been assigned to design the Hearty messages, based on the specific situations and conditions.

- When the user first starts the system. Hearty introduces itself as an assistant that will be there to help the user during the rehabilitation program.
- When the user receives a new message: The avatar advises them when the new message has been received.
- When the cardio rehabilitation plan changes: Hearty informs the user when when a health professional adjusts the plan, or the exercise is incremented as explained in the intensification strategy of the exercise.

When system requires that user's synchronize the Portable Station. The Portable Station has been designed for outdoor exercise, the user will have to maintain the devices synchronisation in order to execute the proper exercise session on the Portable Station.

- Hearty also proposes certain exercise activities to the user, according to the scheduled exercise session.

Figure 78: Home screen of the Patient Station.

An algorithm has been designed to select the best user feedback. The following diagram shows the rule that have been defined:

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Figure 79: Feedback algorithms of the avatar

Messages

The system provides an automatic message system to guide and support users throughout the cardio rehabilitation program. The following types of messages are utilised:

- **Notifications:** these messages deal with the rehabilitation program and inform patients about changes within the exercise plan. for example in the intensification strategy the exercise level will be increased, and patient will be notified.
- **Proposed task:** messages that remind to the user to perform a specific (previously scheduled) behaviour or propose a new specific activity (e.g. answer a questionnaire, read educational content, watch a video, etc.) -
- **Feedback on progress:** the message system provides the overall progress of the cardio rehabilitation.
- **Instructions:** the system provides support to execute the operational tasks of the devices (e.g. charge sensors, or synchronize the Portable Station).
- **Tailored tips:** they are short messages that include suggestions and recommendations to promote healthy habits. Depending on the users level of knowledge and beliefs, a specific content is triggered.

Figure 80: Message inbox system

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Figure 81: Message that prompts the user to fill out a questionnaire.

Calendar

A calendar has been designed to show to the user the performed activities (in green) and the scheduled one (in orange). By selecting one of them it is possible to visualize the results of the performed exercise session or the type of exercises that have been scheduled.

Figure 82: Home screens of the calendar module

Figure 83: Reported resistance activity

Exercise

The system initially proposes the endurance exercise by offering a specialized device, the Portable Station to perform outdoor and indoor exercise. The exercise options are running, walking, and cycling. The execution of the intensification strategy will increment the number of exercises and then the resistance exercise will be proposed. The Patient Station coordinates the endurance exercise session by synchronizing the Portable Station to the current exercise plan, depending on the stage of the cardiac rehabilitation and of the progress of the patients. During this process the device must provide to the user feedbacks to:

- Give instructions on how to perform the exercise session
- Provide reminders to perform the exercise
- Inform about the importance of exercise
- Provide proper reinforce / reward feedback depending on the progress of the exercise session
- Increment the exercise session according to user's training plan

Figure 84: Exercise menu

My plan

The Portable Station provides options to personalise the exercise plan by choosing the preferred days and time. The system then triggers a message 30 min before the scheduled exercise. At the moment of the exercise the Portable Station user chooses the preferred types of exercise (running, walking or cycling).

Figure 85: Exercise personalization

Exercise results and progress

The second option of the exercise menu is to visualize the performed exercise sessions: by default the page shows the exercise that have been performed in the day.

Figure 86: Exercise endurance agenda

Users can also select a weekly of global view of the results. In this page 3 graphical components have been defined: two widgets to represents the progress of the endurance and resistance exercise and a global result widget based on the Avatar.

- The endurance exercise progress widget: it provides information about how user follows the rehabilitation plan in terms of number of exercise prescribed (compliance) and how the user follows the instructions of the Portable Station during the exercise sessions.
- The resistance exercise progress widget: it provides information about how the user follows the plan of the prescribed resistance exercise. Since this exercise are not monitored with a sensor it has not been possible to develop the performance monitor.
- An Avatar with a podium: it represents the global performances of the endurance and resistance exercise.

Figure 87: Global progress example.

Support to resistance exercise

The Patient station provides specific content with instructions to perform resistance exercise session. Resistance exercises are integrated in the exercise plan of the user and the Portable Station reminds to the user to perform it. A specific page to report the exercise has been defined:

Figure 88: Exercise report table.

Learning

The Patient Station system includes educational content addressing the whole rehabilitation process and more specifically the importance of the exercises. The content is organized in courses or topics that patients can check by clicking on the

“Education” section of their PC Patient Station. The Guided Exercise system includes the following:

- Practical tips to exercise: the chapter introduces the system and provides instructions about to prepare for the exercise session.
- Exercising: practical tips that explain the importance of exercise, the types of exercise (stretching, endurance, and resistance instructions) manage setbacks, understand the level of effort, and how to correctly breathe during the exercises. The section also contains a quiz to assess the patient’s knowledge and commitment to the exercise sessions.
- My Heart Condition: in this section the user can find information pertaining to their Cardio Vascular Disease. and the reason that lead to a MI.
- Recovering form heart attack: the section provides educational content to support the user’s belief about the possibility to recover to the condition and have an active role in the management of the health.
- Managing my condition: in this section user can found content related to diet, weight control, stop smoking, control of blood pressure and a section that introduces to breathing based relaxation.

Figure 89: Learning page example

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Figure 90: Subsection of the learning menu

Figure 91: Example of educational content about the heart attack.

Quiz

The Heart Manual team proposed during the definition of the global strategy (described in the Section 5.2.1.2) to use a questionnaire to remove the false belief about the disease, the exercise and the general wellbeing. The questionnaire will be triggered at certain time and the Patient Station will prompt the task to the user via messages. If the user accepts to perform the task the questionnaire is displayed in the device screen. The true or false question will be viewed; the patient will answer by stating if the statement it is true or not for him or her. The system then triggers the corrective feedback in case of a user mistake. The Patient station will trigger another message in

the following days and provide related educational content to remove any false beliefs of the user.

Navigation	Questionnaire, page 2
Home	4. The heart gets worn out with hard work ☐ True ☐ False
Messages (1)	5. The heart works better with exercise ☐ True ☐ False
Calendar	6. It is good to exercise everyday ☐ True ☐ False
Exercise	
Learning	
<div>Previous</div> <div>Check</div>	

Table 32: Example questions

Navigation	Questionnaire, page 2
Home	4. The heart gets worn out with hard work ☐ True ☒ False Correct You are right!
Messages (1)	5. The heart works better with exercise ☒ True ☐ False Correct You are right!
Calendar	6. It is good to exercise everyday ☐ True ☒ False Incorrect It is important to exercise to keep your circulation active, to give your muscles, including your heart, some exercise and to make you feel better.
Exercise	
Learning	
<div>Previous</div> <div>Next</div>	

Table 33: Questionnaire feedback

5.2.2.3 Portable Station

The portable station has been designed to guide the user before, during and after the endurance exercise sessions. In order to perform the protocol of exercise a user interaction solution based on the tunneling principles has been specified (B.J. Fogg,

2009). The user is be guided during all the stages of the exercise. The home screen of the Portable device can be seen below:

Figure 92: The home screen of the Portable Station.

The two main functions are shown: the user has the option of starting the exercise, or configuring the exercise. The configuration menu allows user to activate secondary input feedbacks (sounds and vibrate), deactivate the proposed stretching session (in the case that user doesn't want to perform it) and/or to change the language.

Figure 93: Configuration Menu

Pre exercise check

In order to grant the safety of the exercise a detailed pre-exercise algorithms assessment has been designed by cardiologists. Two controls have been set: depending on the patients symptoms and blood pressure. The details of these controls can be found in the Annexes. The first control is the blood pressure check, the patient has to take their blood pressure using a provided cuff and insert the values manually in the portable station. The following figure shows the blood pressure check in progress:

Figure 94: Blood pressure input screen

The system begins by checking the coherency of the inserted data, if the data was entered correctly it is processed to see if it lies within the safe zones ($160/90 < \text{Blood pressure} < 180/90$). In the case that it is too high or too low a another message to further investigate the situation is triggered.

Figure 95: Medication check procedure

In the case that a patient has not taken their medication, the system recommends the user do so and then wait 1 hour before measuring their blood pressure again. After an hour if the patient's blood pressure is still not in the safe zones, the system recommends that the patient avoid any exercise by prompting another message.

Figure 96: Messages to cancel the exercise session

Another step of clinical safety within the exercise system is shown below; if a patient shows any signs of symptoms or problems exercising, a simple question is triggered (e.g. "Do you feel well today?") should the patient answer suspiciously their symptoms are further investigated.

Figure 97: Symptom questionnaire

The investigated symptoms are: chest infection, flu-like symptoms, dizziness or heart palpitations, breathlessness or chest pain, blackouts, sore joints, sore muscles, or other symptoms.

Starting the exercise

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After the pre-exercise check the options of exercise are presented. Three types of endurance exercises are supported, cycling, running, and walking. The exercises are performed using a wearable sensor that provides instant feedback to train the patients in the safe ranges of heart rate. According to these requirements an exercise session is then composed.

Figure 98: Options of exercise

After selecting an exercise the system asks the user to wear the t-shirt, plug-in the sensors, and press a button to continue. A connection with the wearable sensor is established and a signal quality check is performed. In the Portable station three algorithms (Runti, Honka, & Chovarda, 2012) have been developed to monitor the exercise session :

- Before exercise: the quality of the signal is checked, morphology of the signal is evaluated.
- During the exercise: a live analysis is done to provide guidance by using the activity level, which is measured through reading the HR with the accelerometer of the wearable sensor. The HR is used to give instructions to the user during the exercise: maintain the intensity of the workload, speed up, slow down, or stop.
- The recovery algorithm is used to assess the cardio vascular risk of the patient. In fact the time from recovery to a basal situation is a good indicator of their cardiovascular fitness. The algorithm estimates the risk by monitoring the decrease of the heart rate over time.

From the results of this algorithm, different types of real time feedback are prompted to the user. The following instructions are given:

- Maintain the level of the workout
- Slow down the workload
- Increase intensity of the activity
- Stop the exercise, in case that over activity is detected (heart rate surpasses the safe zones put in place by the cardiologists).

The mobile screens of the Portable System have been designed for easy reading, in order to avoid the patient from ever over exercising. One of three stages are clearly illustrated on the screen:

- The user is exercising from within the safety zones or below, in this case the screen will be green and instructions will be given at the bottom of the screen.
- If the user surpasses the training HR zones, a yellow screen is displayed.
- The HR is very high (over the max HR allowed by cardiologists) a red screen is shown.

Figure 99: Exercise level within the desired thresholds

Figure 100: Exercise level below the lower threshold

Figure 101: Exercise level over the upper threshold

Figure 102: Exercise level alert to stop

Apart from a fully guided interaction the feedback can be set to prompt the users with sounds and vibrations on their mobile phone. The audio and haptic alerts are put to work when a user changes the phase of the exercise, or when the level of exercise is not optimal. They can be disabled in the configuration menu of the home screen.

When the exercise is finished the user reports the level of effort they exerted by using the Borg Scale, designed in a digital format: the solution provides a description of every possible value of the scale (from 6 to 20) (Borg, 1982). The scale maps the perceived effort to a scale that analyses the common heart rate response (60 bpm represents no effort, while 200 bpm represents very heavy activity).

Figure 103: Borg scale questionnaire

Final feedback

This index provides outputs from each of the analysis components. A team from VTT designed the algorithms that estimated the exercise performances depending on the global adherence to the instruction of the proposed exercise. It provides a score from 1 to 100 depending on the time in which the patient has been followed the Portable Station Instruction (Runti et al., 2012).

The score has been used to design the proper feedback when the exercise finalizes. The score is calculated as a weighted score of the 3 phases of the exercise. The final feedback provides the final scoring, and a feedback about the performance of every phase.

Figure 104: Final feedback screenshots from the Portable Station

The details of the messages and feedback are defined in the next section, where the strategy is configured in the designed technology.

5.2.2.4 Configuration of the strategy

At this step the strategy is configured for the seven target behaviours that have been identified.

The following types of messages have been defined:

- Messages about the exercise routine, progress and changes to the plan.

Assessment questionnaires: the two questionnaires about misconceptions and health behaviour change will be proposed to the users.

- The recommended educational content: depending on the identified misconceptions and knowledge, the system suggests related educational content in the next days.

To configure the strategy it has been defined the concept of use that represents the use of the system on an average day. Depending on the use the system will trigger a specific set of messages. The following chronogram represents the configuration of the target behaviours that will be promoted by the system during the rehabilitation process.

Table 34: scheduling of the target behavior intervention

The target behaviour messages related with the number TB2 (the user exercises with

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INITIAL	The patient starts using the system.	The patient exercises using the system (TB1).
IMPROVEMENT A	The patient understands the benefits of exercising. The patient intensifies the exercise programme (resistance exercise).	Maintenance of TB1 The patient intensifies the exercise programme.
IMPROVEMENT B	The patient intensifies the exercise programme. The patient has general knowledge about cardiovascular diseases, heart attacks and risk factors.	Maintenance of TB1 The patient intensifies the exercise programme.
IMPROVEMENT C	The patient intensifies the exercise programme. The patient has general knowledge about cardiovascular diseases, heart attacks and risk factors.	Maintenance of TB1 The patient intensifies the exercise programme.
MAINTENANCE	The patient intensifies the exercise programme. The patient has knowledge about how to reduce and control risk factors. The patient continues exercising and engages in healthy behaviours even without using the system.	Maintenance of TB1

Table 35: Promotion of the target behaviors in the cardio-rehabilitation

The scheduling of the messages has been defined by estimating a minimum number of system uses. In this manner the incremental strategy will be possible over time. Depending on the duration of the phase in every session a specific set of messages will be triggered over time.

Phase	Length	Required number of use of the system
Initial	3 weeks	6
Improvement A	2 weeks	4

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Improvement B	2 weeks	4
Improvement C	2 weeks	6
Maintenance	12+ weeks	24

Table 36 Trigger criteria

After the estimation the entire scheduling of the messages for all the different phases of the rehabilitation are defined. The scheduling was designed in collaboration with the people from the NHS and VTT who provided expertise in patient counselling, behaviour change strategies (NHS), and feedback design (VTT).

					Exercise			
Stage	Use	Educational Content	Misconception questionnaire	Tips	Resistance	Endurance	Summary	Training plan
Initial	1	Introduction to the system					Yes	Introduction to the exercise plan
Initial	2		Exercise	Tips about the identified misconceptions			Yes	
Initial	3					Yes	Yes	
Initial	4	Things to remember about exercise					Yes	
Initial	5						Yes	
Initial	6	Practical tips to exercise				Yes	Yes	Summary of progress
Improvement A	1		Cardiac diseases	Tips about the identified misconceptions	Yes (introduction)		Yes	Start improvement
Improvement A	2	Checking with the Borg scale					Yes	
Improvement A	3					Yes	Yes	
Improvement A	4	Correct Breathing					Yes	Summary of progress

Table 37: Scheduling of the messages to of the initial and improvement A phase.

Stage	Use	Educational Content	Resistance	Endurance	Summary	Training plan
Improvement B	1		Yes		Yes	Intensification of exercise
Improvement B	2	Introduction to coronary heart disease		Yes	Yes	
Improvement B	3				Yes	
Improvement B	4				Yes	Summary of progress
Improvement C	1		Yes	Yes	Yes	Intensification of exercise
Improvement C	2	What is a heart attack?			Yes	
Improvement C	3				Yes	
Improvement C	4	How I can manage C.A.D?		Yes	Yes	
Improvement C	5				Yes	
Improvement C	6				Yes	Summary of progress

Table 38: Scheduling of the messages to of the improvement B and C phase.

Stage	Use	Educational Content	Resistance	Endurance	Summary	Training plan
Maintenance	1		Yes	Yes	Yes	
Maintenance	2				Yes	
Maintenance	3				Yes	
Maintenance	4	Selected content 1		Yes	Yes	
Maintenance	5				Yes	
Maintenance	6				Yes	Summary of progress
Maintenance	7			Yes	Yes	
Maintenance	8	Selected content 2			Yes	
Maintenance	9				Yes	
Maintenance	10			Yes	Yes	
Maintenance	11	Selected content 3			Yes	
Maintenance	12				Yes	Summary of progress

Table 39: Scheduling of the messages to of the maintenance phase (1/2)

Stage	Use	Educational Content	Resistance	Endurance	Summary	Training plan
Maintenance	13			Yes	Yes	
Maintenance	14	Importance to keep the level			Yes	

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Maintenance	15				Yes	
Maintenance	16			Yes	Yes	
Maintenance	17	External rewards			Yes	Summary of progress
Maintenance	18				Yes	
Maintenance	19			Yes	Yes	
Maintenance	20	Exercising without the system			Yes	
Maintenance	21				Yes	Summary of progress
Maintenance	22	Wrap up content 1		Yes	Yes	
Maintenance	23				Yes	
Maintenance	24	Wrap up content 2			Yes	Global result

Table 40: Scheduling of the messages to of the maintenance phase (2/2)

Tips in the Guided Exercises appear as short messages that include recommendations and suggestions to teach patients about how to use the system and comply with the exercise plan. As such, they are closely related to the educational material and motivational aspects. The system mainly sends these tips to the patients through messages in the Patient Station that provide links to the corresponding extended educational content.

Feedback configuration

Feedback will be provided to the users at different points of their experience both in the Portable Station as well as in the Patient Station. The following scenarios have been defined:

Exercise feedback

- **Reminder to exercise:** according to the exercise plan and the user preferences (preferred day of the week and time) the Patient Station and the Portable Station will trigger a reminder.
- **Feedback Exercise progress/ compliance:** after the exercise session the Portable Station will prompt a feedback that will depend on the performance of the exercise. Three possible scenarios have been identified:
 - **The completed session.** The feedback will depend on the exercise performances (measured through the exercise index) and the perceived exertion.
 - **The interrupted session:** the patient interrupts the session for a specific reason: the onset of a sudden symptom during the exercise; the user feels exhausted; weather conditions (the endurance session will be performed in an outdoor scenario in the majority of cases.)
 - **There was a technical error during the execution of the exercise.** The error is related to the quality of the biological data gathered by the sensor, a communication error between the Portable Station and the wearable sensor or an error in the application running on the software of the Portable Station.

For each scenario a feedback has been designed. The following table shows the definition of the messages:

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Exercise Scenario	Portable Station	Patient Station
User completed the endurance exercise session	<p>Well done, you finished your exercise session! Your exercise index score for this session is [score].</p> <p>IF [score]==100 (State 1: Followed the plan perfectly) Great! This means you have been within the target range of HR during your session. Keep up the good work!</p> <p>IF 75<=[score]<100 (State 2: Followed the plan extremely well) Very good! You have been following your exercise plan extremely well! Keep up the good work!</p> <p>IF 50<=[score]<75 (State 3: Followed the plan rather well) Well done! You have been able to follow the targets well.</p> <p>IF 25<=[score]<50 (State 4: Followed the plan occasionally) You have been exercising occasionally at your target heart rate. By exercising at the target heart rate you will be able to improve the score.</p> <p>IF [score]<25 (State 5: Followed the plan poorly) You can rise the score by exercising at the target heart rate range.</p>	<p>See tables:</p> <p>Table 44 Feedback after the exercise session of the Portable Station (1/2)</p> <p>Table 45: Feedback after the exercise session of the Portable Station (2/2)</p>

User delayed the exercise and performed later.	Same	You didn't do the exercise the day you scheduled it. Just make sure that you will have rest days between exercises if possible.
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Table 41: Feedback on the status of the endurance exercise session (1/2)

Exercise Scenario	Portable Station	Patient Station
User interrupts the exercise session because has a mild symptoms	IF severe: Since you are experiencing severe symptoms, contact your doctor for further advice.	Obviously, you were experiencing severe symptoms. You were advised to contact your doctor. We hope you are feeling better now.
User interrupts the exercise session because has a severe symptoms	IF mild: Since you are experiencing some symptoms, you should rest. If the symptoms persist, contact your doctor.	Obviously you were experiencing some symptoms but they were mild. You were advised to rest. I hope you are feeling better now.
User interrupted the session because exhausted	It is normal to break a sweat and get slightly out of breath. This way your body is getting stronger. Perhaps exercising with a friend or mp3 player helps to follow the exercise plan.	Obviously you interrupted the exercise because you were feeling exhausted. This can be normal, especially in the beginning. When your condition improves, you will feel better. However, If the exercise plan seems too hard for you, contact your Guided Exercise professional. Better exercising next time!

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User interrupted or cancel the session because of bad weather	We can't change the weather so just try exercising another day. Remember also to dress properly. It will help you to resist different weather conditions.	Obviously you interrupted the exercise because of the weather. Sometimes, it will help to wear properly when you go exercising outside. Looking outside and checking the thermometer before you go might help choosing the proper clothing or the right time. Better exercising next time!
User has a technical problem during the exercise session	Contact the maintenance service. They will help fixing the problems with the garment.	Obviously, you interrupted the exercise because of the technical problems. Contact the Guided Exercise maintenance service when these kinds of problems occur.

Table 42: Feedback on the status of the endurance exercise session (2/2)

Type of error	Patient Station
The was an error of data quality during the connection with the wearable sensor	The exercise session was obviously interrupted by an error in the signal quality. We apologize for this inconvenience. If the problem persists, contact the Guided Exercise maintenance service. Don't get downhearted because of this. You still can do some exercising without the PDA.
Error of the wearable sensor	The exercise session was obviously interrupted by an error in the sensor. We apologize for this inconvenience. If the problem persists, contact the Guided Exercise maintenance service. Don't get downhearted because of this. You still can do some exercising without the PDA.
Error of the PDA	The exercise session was obviously interrupted by an error in the PDA. We apologize for this inconvenience. If the problem persists, contact the Guided Exercise maintenance service. Don't get downhearted because of this. You still can do some exercising without the PDA.

Table 43: Error messages of the Portable station

Exercise index		Borg Scale		
		Low intensity	Target intensity	Too high intensity
	Very low (0-25)	Your EXERCISE INDEX for the session is [score]. This means that you seem to struggle following the heart rate targets. You can improve the index by exercising at the target heart rate range. The PDA will help you with this while exercising. If the exercise plan seems too easy, contact your Guided Exercise professional. Exercising at the right intensity will improve your condition!	Your EXERCISE INDEX for the session is [score]. This means that you seem to struggle following the heart rate targets. You can improve the index by exercising at the target heart rate range. The PDA will help you with this while exercising.	Your EXERCISEINDEX for the session is [score]. This means that you seem to struggle following the heart rate targets. You can improve the index by exercising at the target heart rate range. The PDA will help you with this while exercising. If the exercise plan seems too hard for you, contact your Guided Exercise professional. Exercising at the right intensity will improve your condition!
	Low (25-50)	Your EXERCISE INDEX for the session is [score]. This means that you have been exercising occasionally at your target heart rate. You can improve the index by exercising at the target heart rate range. The PDA will help you with this while exercising. If the exercise plan seems too easy, contact your Guided Exercise professional. Exercising at the right intensity will improve your condition!	Your EXERCISE INDEX for the session is [score]. This means that you have been exercising occasionally at your target heart rate. You can improve the index by exercising at the target heart rate range. The PDA will help you with this while exercising.	Your EXERCISE INDEX for the session is [score]. This means that you have been exercising occasionally at your target heart rate. You can improve the index by exercising at the target heart rate range. The PDA will help you with this while exercising. If the exercise plan seems too hard for you, contact your Guided Exercise professional. Exercising at the right intensity will improve your condition!

Table 44 Feedback after the exercise session of the Portable Station (1/2)

		Borg Scale		
		Low intensity	Target intensity	Too high intensity
	Normal (50-75)	Your EXERCISE INDEX for the session is [score]. This means that you have been able to follow your targets well. You can improve the index by exercising at the target heart rate, for example. The PDA will help you with this while exercising. If the exercise plan seems too easy, contact your Guided Exercise professional	Your EXERCISE INDEX for the session is [score]. This means that you have been able to follow your targets well. You can improve the index by exercising at the target heart rate, for example. The PDA will help you with this while exercising.	Your EXERCISE INDEX for the session is [score]. This means that you have been able to follow your targets well. You can improve the index by exercising at the target heart rate, for example. The PDA will help you with this while exercising. If the exercise plan seems too hard for you, contact your Guided Exercise professional
	Good (75- 100)	Your EXERCISE INDEX for the session is [score]. This means that you have been following your targets extremely well. Very good! This is very important! Continue the good work! If the exercise plan seems too easy, contact your Guided Exercise professional	Your EXERCISE INDEX for the session is [score]. This means that you have been following your targets extremely well. Very good! This is very important! Continue the good work!	Your EXERCISE INDEX for the session is [score]. This means that you have been following your targets extremely well. Very good! This is very important! If the exercise plan seems too hard for you, contact your Guided Exercise professional
	Best (100)	Your EXERCISE INDEX for the session is the maximum 100! Excellent! This means you have been within the target range of HR during your session. This is very important! Continue the good work! If the exercise plan seems too easy, contact your Guided Exercise professional.	Your EXERCISE INDEX for the session is the maximum 100! Excellent! This means you have been within the target range of HR during your session. This is very important! Continue the good work!	Your EXERCISE INDEX for the session is the maximum 100! Excellent! This means you have been within the target range of HR during your session. This is very important! If the exercise plan seems too hard for you, contact your Guided Exercise professional

Table 45: Feedback after the exercise session of the Portable Station (2/2)

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	No resistance exercise performed	Less resistance exercise performed than planned	Resistance exercise performed to plan	More resistance exercise performed than planned
No resistance exercise performed	It appears you haven't exercised last week. You may have a particular reason for this that you need to discuss with your doctor or nurse.	Please look at your balance of endurance and resistance exercising. While it is good that you are trying to do your resistance exercises you didn't do any endurance exercises last week. Endurance training sets the foundations for improving your condition. This is a new week to reach your goals.	Please look at your balance of endurance and resistance exercising. While it is good that you are achieving your planned resistance exercise goals, you didn't do any endurance exercises last week. Endurance training sets the foundations for improving your condition. This is a new week to reach your goals.	Please look at your balance of endurance and resistance exercising. You didn't do any endurance exercises last week. Endurance training sets the foundations for improving your condition. Try to work to increase your endurance and stick to the planned amount of resistance training
Less endurance exercise performed than planned	Nearly there with the last week's exercises! This week you have another chance to	It's great that you are exercising! Perhaps you can reach your exercise goals this week.	Great to see you exercising! Perhaps you can also reach your endurance exercise target this week.	You did more resistance exercises than planned last week. It is better to follow the exercise plan.

	reach your goals!			
Endurance exercise performed to plan	You did great work with your endurance training last week. Why not also start strength training this week?	You did great work with your endurance training last week. Perhaps you can also reach your resistance exercise target this week.	Congratulations! Last week, you completed all your prescribed exercise sessions. Do it again this week!	You did great work with your endurance training last week. However, you did more resistance exercises than planned last week. It is better to follow the exercise plan.
More endurance exercise performed than planned	You did more endurance exercises than prescribed. Try to stick to the plan this week.	You did more endurance exercises than prescribed. Try to stick to the plan this week.	It's good that you completed the planned amount of resistance exercises. However, you did more endurance exercises than prescribed. Try to stick to the plan this week.	Take it easy! You exercised over the prescribed level last week. Try to stick to the plan this week.

Table 46: Feedback to balance endurance and resistance exercise

	No resistance exercise performed	Less resistance exercise performed than planned	Resistance exercise performed to plan	More resistance exercise performed than planned
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No resistance exercise performed	It appears you haven't exercised last week. You may have a particular reason for this that you need to discuss with your doctor or nurse.	Please look at your balance of endurance and resistance exercising. While it is good that you are trying to do your resistance exercises you didn't do any endurance exercises last week. Endurance training sets the foundations for improving your condition. This is a new week to reach your goals.	Please look at your balance of endurance and resistance exercising. While it is good that you are achieving your planned resistance exercise goals, you didn't do any endurance exercises last week. Endurance training sets the foundations for improving your condition. This is a new week to reach your goals.	Please look at your balance of endurance and resistance exercising. You didn't do any endurance exercises last week. Endurance training sets the foundations for improving your condition. Try to work to increase your endurance and stick to the planned amount of resistance training
Less endurance exercise performed than planned	Nearly there with the last week's exercises! This week you have another chance to reach your goals!	It's great that you are exercising! Perhaps you can reach your exercise goals this week.	Great to see you exercising! Perhaps you can also reach your endurance exercise target this week.	You did more resistance exercises than planned last week. It is better to follow the exercise plan.
Endurance exercise performed to plan	You did great work with your endurance training last week. Why not also start strength training this week?	You did great work with your endurance training last week. Perhaps you can also reach your resistance exercise target this week.	Congratulations! Last week, you completed all your prescribed exercise sessions. Do it again this week!	You did great work with your endurance training last week. However, you did more resistance exercises than planned last week. It is better to follow the exercise plan.

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More endurance exercise performed than planned	You did more endurance exercises than prescribed. Try to stick to the plan this week.	You did more endurance exercises than prescribed. Try to stick to the plan this week.	It's good that you completed the planned amount of resistance exercises. However, you did more endurance exercises than prescribed. Try to stick to the plan this week.	Take it easy! You exercised over the prescribed level last week. Try to stick to the plan this week.
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DESIGN OF THE CARDIO-REHABILITATION SYSTEM

Text	Linked educational Content	Condition
Dear \$PATIENTNAME, to ensure that your exercise prescription meets your needs we would like you to review your own level of exertion – that is how hard you feel your body is working. To do this we will ask you to indicate how hard you have been exercising at the end of each session by using a tool called the Borg scale. The Borg scale is a simple way of recording your effort. To understand more about the Borg scale and how to record your effort please take a look at the topic called ‘The Borg Scale’ within the education section.	The Borg scale	IMPROVEMENT A @ 2 nd use
Dear \$PATIENTNAME, to get the most out of your exercise sessions we would know like to offer you some more practical tips. Please take a look at the topic ‘Better exercising’ within the education section.	Tips for Better exercising (correct breathing, preparation of the exercise, importance of warm up, importance of stretching	IMPROVEMENT A @4 th use
Dear \$PATIENTNAME, many people do not fully understand the reason for their heart attack. If you are unsure why not have a look at the topic ‘Introduction to Coronary Artery Disease’ within the education section.	Introduction to coronary artery disease (definition, causes, etc.)	IMPROVEMENT B, @2 nd use
<Dear \$ PATIENTNAME, know that you know more about what causes a heart a heart attack perhaps you would like to know what a heart attack really is? Why not have a look at the topic ‘What is a Heart Attack’ within the education section.	What is a Heart Attack?	IMPROVEMENT C @2 nd use
Dear \$ PATIENTNAME, today HeartCycle team would like to give you some suggestion about Coronary heart disease management. Enjoy it!	How I can manage C.A.D?	IMPROVEMENT C @4 th use

Table 47: Example of messages recommending a specific educational content

5.2.3 Validation of the persuasive design

Another usability round and patient interviews were arranged in the Castle Hill Hospital (Kingston Upon Hull, Yorkshire UK) in order to assess the progress of the development of the concept and the proposed strategy.

The interview followed this scheduling:

Section	Subject	Time
Introduction	Introduction to Guided Exercise system Introduction to the interview Informed consent	5''
General questions	User information	5''
GEx introduction	Introduction of GEx system	5''
Unobtrusive observation of user's tasks	<ul style="list-style-type: none"> User read a new message in the Patient Station User perform a 'simulated' exercise session using the Portable Station The user synchronize the two devices (Portable Station and Patient Station) using a USB cable User sees the global results of the training program using the Patient Station User report a endurance exercise using the Patient Station User read an educational content in the Learning section of the Patient Station User performs a Quiz (the misconception questionnaire, suggested by the Patient Station via a message). 	20
Questionnaires	Acceptability, user experience, user expectations	10''
Conclusion	Conclusions, acknowledgments, gift for users	5''

Table 48: Scheduling of the second usability round with the patients

Eleven subjects were interviewed. 18.18% of the subjects were female and 81.82% male. 45,45% of those interviewed recently suffered a MI and were in the recovery phase. The rest of the patients (54,55%) had returned to normal life. The technological background check highlighted that the mobile technology is well consolidated in this target population. Personal Computer and Internet use is high but in only one case did the subject have experience with the tele-monitoring system.

Figure 105: Technology background chart

System were introduced to the system and after they were invited to perform the following seven user's task:

- Read a message from the Patient Station. User has to use the learning section of the system and navigate into them.
- Execute an exercise session in the Portable Station. User has to wear the wearable sensor and perform a simulated session of exercise in which the Portable Station executes the complete flow of the exercise session. The Portable Station had been previously configured to perform a simulated exercise of shorten length that the real (1 min)
- Synchronizing the two devices using a USB cable. At the end of exercise, user follows the screen instructions and connects the two devices that automatically are synchronized. A New message appears on the screen.
- Read and understand the exercise result. User read the message with the exercise feedback.
- Report an endurance exercise. User is introduced to the resistance exercise; the specific educational content is shown of the learning section of the Patient Station. The interviewer asks to the user how to report a performed resistance exercise.
- Read some educational content. User is asked to navigate in the preferred content of the learning section.
- Quiz: the Patient Station triggers a message to propose the a quiz for the user. User is ask to read the message and perform the quiz.

The 11 users finalized all the task and minor usability problem have been identified. The issue had been identified while user was using the educational content: the text was too large and the scrolling did not allow the user to go to the next content. User can exit from the content pressing the learning button in the menu. The problem affects In a scoring scale from 1 (very easy) to 10 (very difficult) the task were considered easy to perform (score <5), with an average of 2,31 for all the tasks. The task related with the educational content was the most difficult task for the user (4,1) as can be also shown in the radial chart for every specific patient (Figure 106: Task result overview) and in the chart of the task difficulty (Figure 107: Rating of task difficulty chart,). Table 49: Averages on task difficulties)

Figure 106: Task result overview

Despite this usability issue users still reported that the tests were easy to perform according to the following table:

	Average 1=very difficult 10=very easy	St. Dev.
Read Message (Patient Station)	1,6	0,69
Exercise (Portable Station)	2,1	0,83
Sync with USB	1,5	0,67
Results (Patient Station)	2,4	1,25
Report (Patient Station)	2,2	1,00
Educational content (Patient Station)	4,1	2,00
Quiz (Patient Station)	2,3	1,22

Table 49: Averages on task difficulties

Figure 107: Rating of task difficulty chart

The identified problem can be considered of minor relevance and it will be addressed in the next phase of proposed methodology. Globally the acceptance of the proposed system was high, as can be shown in the following figures of global acceptance of the portable station, the IMAGE sensor, and the Patient Station.

Figure 108: Global acceptance of the Portable Station

The sensor was the least accepted device: even though the score was positive overall, two patients gave a negative score because they didn't like the idea of wearing a sensor or the t-shirt.

Figure 109: Global acceptance of the image sensor

The patient station received the highest score, it was highly appreciated as a tool for assisting and educating users at home. Also, in the global acceptance questionnaires the seven target behaviours were defined in order to validate the intention of the system.

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Figure 110: Global acceptance of the Patient Station

The range of acceptance also includes the target behaviours that have been defined for the application. According to the proposed design methodology, they should be validated and approved by the end users. The following table summarises the results. The following table shows the results of the target behaviour rating. The acceptance score was calculated using a weighted average from the Likert scale questionnaire (from 1 to 5).

Target Behaviour	Question	Acceptance	Discussion
TB1: User starts using the system.	I would be able to use the system, PC can help me to start the exercise session	E: 97,72% A: 88,64%	Level of easiness (E) and acceptance (A) is high, patients gave very positive feedback about usefulness
TB2: User exercises using the system.	I think system could help me to exercise	87,11%	Patients performed a simulated session. The results of the task are positive. Some usability improvements are required in the educational content area. Sensor seems to be the device that could reduce the level acceptance.
TB3: User intensifies the exercise programme.	If I use the system I can intensify the exercise programme	89,39%	Patients appreciated the idea of having an individualized exercise
TB4: User understand the benefits of the exercise	PC can help me to understand benefits of exercise	95,45%	The users appreciated the educational content and the exercise instructions. The also appreciate the guided exercise endurance session and the ability to report the resistance exercise.
TB5: The patient has general knowledge about CVD, heart attacks and risk factors.	System could help me to have more knowledge about CVD and risk factors	91.66%	The users readily accepted the educational content and the quiz proposed by the system.
TB6: The patient has knowledge about how to reduce and control risk factors.	System could help me to have more knowledge about CVD and risk factors	91.66%	The users readily accepted the educational content and the quiz proposed by the system.
TB7: The patient continues exercising and engages in healthy behaviours even without using the system.	I think system could help me to change my lifestyle habits.	78.78%	Even if positive it received the lowest acceptance score. Some patients (3 of 11) raised some doubts about the capacity to modify lifestyle habits. The persistence of the habits will be validated in the next iteration.

Table 50: Validation of the desired behavior

The global acceptance was measured with 9 questions (6 questions with a positive valence and 3 with negative valence). The results show that the Guided exercise system received a positive acceptance as Figure 111 and Figure 112 show:

Figure 111: Global acceptance of the Guided Exercise system

Figure 112: Global acceptance of the Guided Exercise system

Users appreciated the idea to use technology to join a cardio rehabilitation program that could help to improve the physical status and the level of knowledge. Nevertheless, it can be noticed that users were more sceptical (but even with positive score) in thinking that the system could help them to change the lifestyle. One of the eleven users stated that he was not agree, the rest gave positive or neutral score as shown in Figure 111. Also two users consider that system invade the privacy, because of the use of the wearable sensor. Globally the result of the usability study has been positive, as the global trends of the presented charts can show. The conclusions of this validation phase are the following:

1. System had a very high rate of acceptance, patients were enthusiastic and asked when they could start using it.
2. System is coherent and easy to use, when patient had a problem finalising an activity they understood the suggestion given by the interviewer and said “it’s just the first time I’m using it”.
3. Users felt that the system could help them as a tool for improving exercise habits and living a healthier lifestyle.

Also the intentions of the strategy have been validated: the seven questions related to the target behaviours (Table 50) receive positive scoring and a less positive scoring (78,78%).

At this step the O5 (Verify that users accept the technology and its intentions) has been achieved.

5.3 Development

During this iteration the system was developed and tested; then a clinical study was set up for the final clinical study. The following architecture design was developed together with a team of engineers from the HeartCycle consortium:

Figure 113: Final system architecture

The final system architecture is comprised of four elements:

- The Professional Station (referred to as the Clinical Server in the previous iteration): it was powered by the NomhadChronic telemonitoring platform, a system developed by the TSB company from Valencia. This system was personalised for the specific application scope through the creation of a Nomhad GEx plugin. This was developed by the company TSB and is not part of this research. The platform met the requirements that were identified in the previous iterations.
- The Patient Station: this device was developed using the pHP tool as a parallel technological research project on platform technology for personalised health systems (Salvi, 2014). Thanks to this system it was easy to meet the requirements that were defined in the previous two iterations. This research defined the screen to be developed and the rules of feedback and messages, along with the educational content of the application.
- The Portable Station: this device is an ad-hoc implementation of the HeartCycle project; the main requirements are following the medical questionnaires and the exercise plans. Engineers and programmers from the HeartCycle consortium developed a native app for the PDA QTEK s200 (based on Microsoft Compaq Framework).
- The Image Sensor: composed of a garment of clothing and an electronic device, it is used during the endurance exercise session. The garment of clothing was designed by +CLOTH and the electronics by CSEM. For more details, see the Annexes.

This section reports only the contribution for this research that was performed using the pPHP platform (described in Figure 59: Architecture of the pPHP framework). The very high level of programming of the pPHP allowed for the opportunity to focus solely on the development of the intervention strategy by defining the feedback messages, rules, and educational content. I developed the rules using Drools rule engine library and a query language to retrieve data from the Patient Station database. Other partners of the HeartCycle Consortium developed the screens of the Patient Station and of the Portable Station.

5.3.1 Final developed system

The following diagram shows the final architecture that developed in the HeartCycle project. The professional system manages the exercise plan of the patients, but not the tailoring of the educational content. The system will be automated using the scheduled strategy that has been defined and the messages that were defined during the second iteration.

Figure 114: Final system architecture

5.3.2 Development of the Strategy

The strategy was developed using the Rule Engine library of the pHP platform. It was possible to develop a rule-based logic on top of the Graphical User Interface defined during the design of the extended persuasive context. The Rule Engine of pHP is based on the JBoss Libraries and provides rules to trigger messages, feedback and reminders for the user. Eclipse (Helios version) was used as IDE in which rules and contents were programmed. Development was carried out in two specific software packages of the libraries:

- *Patientstation.ruleengine*: this package contains the rules that have been developed. It also provides the option to simplify the high-level language rules by defining an expander. The expander maps the situation of the user (e.g. the health professional changed the training plan, the patient is not performing the exercise) to an SQL language that retrieves the data from the Data Collection Engine, a context-aware framework of the pHP platform.
- *Patientstation.guiengine.localization*: this package contains all the messages and content that are prompted to the user in the Patient Station. The messages have been specified in XML language and the content using the HTML mark-up language to specify the images of the education content. The educational content has been developed using existing educational content from the Health Manual under the revision and requirement of the Health Manual Team. Specific educational content has been developed to provide specific information of the tools that have been developed.

The following rules have been defined:

- Care-Plan Rules: messages that inform about the changes of the exercise plan. The system informs about the changes of the exercise plan and proposes an incremental set of target behaviour by triggering messages, educational content and quiz. The set of rules is responsible for the execution of the global intervention plan. In order to be more effective, it also provides redundancy by setting reminder rules.
- Feedback: these rules provide the feedback to the users depending on the performance of a defined task. The following types of messages have been developed:
 - Exercise Messages: these messages will be triggered after the exercise session, when patient is at home and syncs the Portable Station with the Patient Station (through USB connection).
 - Weekly Results: every week the Patient Station will trigger a message to inform about the global progress.
 - Global Results: the global results show the statistics on the performances of a whole stage (e.g. initial, training, etc).
 - Misconception Messages and Reinforcement Tips: the specific suggested educational content has been developed.

According to the defined rules, the information flow is mapped based on the final architecture.

Figure 115: Information flows and decision rules for the execution of the strategy

5.3.2.1 Development of the rules

The rule-based strategy has been developed in the Patient Station using an event-based context awareness library of the pPHP platform. It was possible to model all the event and user situations that have been defined in the design of the extended persuasive context of *Well.Be.Sign*. The rules trigger content that will be localized according to the language preferences of the users. The rules have been used to develop the conditions defined in the Configuration of the strategy (section 5.2.2.4).

The rules have been developed using the Drools rule language. For every rule, two parameters have been defined:

- When: the condition that triggers the rule.
- Then: the action that the system will take, in this case the action is to trigger the message to the user under the specific condition.

One example of a rule that has been developed is a message that instructs the patient to perform a new set of resistance exercises. The condition is that this is included in the care plan that has been defined by the cardiologists. When they change the exercise plan, the system triggers a message to inform the user about a new set of exercises and provide information about the specific content proposed.

```

rule "Extra exercise support"
when
    extra exercise of active plan
then
    Insert message type "TIP" title label "title_extra_exercise" message label "extra_exercise" link "wf_edu_7"
end

```

Figure 116: Example 1 of rule

Along with conditional messages, there are also scheduled messages. The following example shows the implementation of the table of messages. In this case, depending on the daily use number and on the stage of the cardio-rehabilitation, a questionnaire about lifestyle changes is triggered.

```

rule "2nd use INITIAL stage"
when
    Current use number is 2 and stage is "INITIAL"
then
    Insert message type "QUESTIONNAIRE" title label "questTitle_1" message label "quest_1" link "MisconceptionQuestionnaire1"
end

```

Figure 117: Example 2 of rule

This example shows the implementation of a rule that trigger a message if a user did not perform any endurance session:

```

rule "weekly progress first message when user did not perform any endurance session"
timer (int: 0s 1d)
when
    not Message having title "title_weekly_progress" has been created
    current careplan started more than one week ago
    this week the user did not performed any endurance exercise
then
    Insert message type "TIP" title label "title_weekly_progress" message label "weekly_endurance_no_exercise" link ""
end

```

Figure 118: Example 3 of rule

This rule schedules a message prompted during the next day of use as a reinforced educational message related to a the patient's misconception; patient misconceptions are identified through the misconception questionnaire

```

rule "q2 misconception exercise"
when
    #conditions
    AnswerUID is "misQues2" and value is "DISAGREE"
then
    #actions
    Schedule message type "SIMPLE" title label "titleMisTips" message label "misTip2"
end

```

Figure 119: Example 4 of rule

The rule language has been simplified defining an expander of Drools. The programmers defined a DLS file in which the grammar of the rules was mapped to a specific query to the data collection engine of the pHP framework. These codes have been defined by the programmers and provide a simplified syntax to define the rules. In the expander, the programmers developed the specific logic for the condition of the rule (the *when* statement) and of the consequence (the *then* statement).

```
[condition][[] this week the user did not performed any resistance exercise =
    eval (DataModelUtilityFunctions.getResistanceExDone() == 0)
[condition][[] this week the user has completed resistance exercise
    = eval (DataModelUtilityFunctions.getResistanceExDone() ==
    DataModelUtilityFunctions.getResistanceWeeklyFreq())
[condition][[] this week the user has partially completed resistance exercise
    =eval (DataModelUtilityFunctions.getResistanceExDone() <
    DataModelUtilityFunctions.getResistanceWeeklyFreq())
[condition][[] this week the user has done too much resistance exercise =
    eval (DataModelUtilityFunctions.getResistanceExDone() >
    DataModelUtilityFunctions.getResistanceWeeklyFreq())
```

Figure 120: Example of the code of the expander

5.3.3 Content repository

The content repository contains two kinds of content: the text of the messages that have been programmed with the rules and the educational content. The messages were developed in 3 languages: English, Spanish and German. The NHS and VTT teams revised the first original English version that was later translated to Spanish and German. The content has been revised by native speakers available in the HeartCycle Consortium and the UPM department. Every message has been associated to a unique label and declared in a XML file. The label was associated as *id* property of the *loctext* XML tag. The translated messages were declared using the following example syntax:

```
<loctext id="new_plan_for_pda">
<text lang="EN">Hello $PATIENTNAME
Your Doctor has prescribed a new exercise plan for you.
Please connect your Portable Station (PDA) to the Patient Station (Tablet PC)
in order to activate and view your new prescribed plan.</text>
<text lang="ES">Hola $PATIENTNAME
Su médico le ha prescrito un nuevo plan de ejercicio.
Por favor, conecte su Estación Portátil (PDA) a su Estación de Paciente (Tablet PC)
para activar y ver el nuevo plan que se le ha prescrito.</text>
<text lang="DE">Hallo $PATIENTNAME
Ihr Arzt hat Ihnen einen neuen Übungsplan verschrieben.
Bitte schließen Sie Ihre tragbare Station (PDA) an die Patientenstation (Tablet PC)
an, um Ihre neuen verschriebenen Übungen zu aktivieren und anzuzeigen.</text>
</loctext>
```

Figure 121: Example of XML content

DESIGN OF THE CARDIO-REHABILITATION SYSTEM

To improve the learning experience, the educational content was developed using the HTML format in order to support the layout of the content and the hypertext features (hyperlink and multimedia support).

The content has been re-structured into 5 structured chapters:

- **Practical Information:** This contains the system overview (a simplified electronic version of the user manual) and how to manage setbacks such as symptoms (cardiac, cramps and injuries) and barriers to exercise (back to work, holidays, no time, exercise is boring, low energy of the user, user is not feeling comfortable when exercising).
- **Exercising:** This contains a quiz for exercising (the user can complete it or the system will propose it according to the strategy), the information about how to exercise with the Guided Exercise system, and the benefits of the exercise. It also includes practical tips to exercise and weather consideration for the outdoors exercise, the types of exercise that are supported by the Guided Exercise system (endurance, resistance, stretching and mobilization) and tips to make persistent exercise habits (be able to find time to exercise, exercising at home and at work).
- **My Heart Condition:** This contains the cardiac misconception questionnaire, how the heart works, information about the CHD, what is a heart attack, things to remember about the condition and issues about the recurrence of the MI.
- **Recovering from Heart Attack:** this provides a set of positive thoughts about the recovery phase, about the recovery of the heart, about the possible bad feelings and tips to better recovery.
- **Managing My Condition:** this provides the lifestyle checklist questionnaire (that will be used to propose personalized content), tips for a healthy diet, weight control, quitting smoking, controlling blood pressure and dealing with emotions.

The following images show the home menu of the learning module of the Patient Station:

Figure 122: Table of content of the learning module

5.3.4 Testing of the platform.

The programmers adopted the continuous integration methodology to develop the Portable Station and the Patient Station: a Maven framework continuously tests the application by launching a set of unitary tests and integration tests to verify the correct functioning of the components. The programmers analysed the rules and performed unitary tests that will be periodically triggered.

The feasibility of the monitored exercise session was also proven: the Portable Station and the Wearable Sensor were previously used in a pre-clinical test (E. Skobel et al., 2014). The pre-clinical test demonstrated that the measured Heart Rate of the sensor is comparable with the standard in-hospital monitored session based on Cardiac Stress Test and spiroergometry.

5.3.5 Deployment

Eighty systems were prepared and delivered to three clinical centers. The final system includes:

- The Patient Station: a tablet to be used at home to see progress and receive messages and educational content.
- The Portable Station: a PDA that will be used to perform outdoor exercise.
- An arm-band to wear the Portable Station during the endurance exercise session.
- A set of rubber bands to be used for resistance exercise.
- The user manual: a little paper book with instructions for setting up and using the system.

- A bag to contain all the pieces of the system.

Every device has been labelled following the standard of quality of the clinical studies (ISO/CD 15223-1). The Nomhad Chronic platform managed the logistics and the assignment of devices to patients. The health professionals of the cardiology units of the affiliated hospitals (3) were responsible for selecting the patients, introducing them to the system and collecting a set of data for the study (clinical data, questionnaires about usability, knowledge). They also provided direct support to the users. If technical problems occur, the system will be replaced and the technical team will be informed via email.

5.4 Final results

The system has been validated in a controlled, randomized clinical trial. This trial was conducted in three hospitals in Europe: Hull¹⁰⁹, Aachen¹¹⁰ and Madrid¹¹¹. The study was registered at ClinicalTrials.gov with the identifier NCT01761448. Every clinical centre received the approval of the local ethical committee. The main objective of the study was to compare the control group receiving standard rehabilitation with the intervention group that received the rehabilitation through the GEx system for a period of 21 weeks. The study was defined as follows:

The object of this study is to determine the improvement obtained in long-term adherence to home-based rehabilitation programs (cardiac rehabilitation phase III) when following a guided exercise training prescription supervised by an innovative system specifically designed to optimize the training effects and maximize the patient's security, compared to the standard usual care given in each country for this kind of patients. The improvement due to the use of this system will be measured by comparing the exercise capacity on both approaches (Schauerte et al., 2011).

The secondary goal of the study was to measure the global acceptance of the specific devices. The questionnaire also gathered remarks and problems of users. The questionnaire was developed following the Technology Acceptance Model (F. Davis, 1989). These dimensions were defined based on Likert Scale questions:

- The **perceived benefit and usefulness** of the proposed rehabilitation methods. The following dimensions have been defined: increased motivation for exercising, sense of security and safeness during the exercise, maintaining heart rate in ranges, increased motivation due to messages and better compliance through the system's feedback.
- **The educational level:** the patient's knowledge about the disease and the cause, measured in form of questionnaires. The scale was built selecting six of the 17 questions of the Cardiac Knowledge Questionnaire proposed (Maeland & Havik, 1987).

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¹¹⁰ Germany, Cardiac and pulmonary rehabilitation clinic "An der Rosenquelle"

¹¹¹ Servicio de Cardiología Hospital Clínico Universitario San Carlos de Madrid

- **Perception of the illness:** 6 dimensions of the Brief Illness Questionnaire (Broadbent et al., 2006) were selected and adapted to the clinical context. Questions focused on how the disease affects daily life, the control of the disease, the understanding of the condition, relations about physiological status and emotions, and how the exercise could improve the health condition.
- **Exercise habits:** the exercise based on the iPAQ (International Physical Activity Questionnaire) (Craig et al., 2003). Between uses of the system, the exercise adherence was measured by using the data generated by the system.

Scale	Enrolment	1st week	5th week	End of study	6 month after
User acceptance		x	x	x	
Knowledge	x			x	
user perception	x			x	
Exercise habits	x	Adherence to GEx	Adherence to GEx	Adherence to GEx	x

Table 51: Scheduling of the questionnaires for the final validation

5.4.1 Study overview

The trial started in April 2011, when 132 patients (59±14 years, 11% females) were enrolled: 33 in Germany, 44 in the UK and 55 in Spain. 118 users entered the study; 63 were assigned to the intervention group and 55 to the control group. Twelve patients did not agree to enter the study, and 2 others were prevented by health problems (chronic infection and back pain). In total, 41 patients received the system. Only 19 users completed the study, 15 other patients started the study late (less than 2 months before the end of the study) and 7 users dropped out because they had technical problems performing the endurance exercise session. The drop-out of the 7 users was associated with technical problems during the execution of the endurance session using the Portable Station and the Wearable Sensor. At the beginning of the study there was a bug in the software of the Portable Station that caused interruption in each exercise session because the user's blood pressure was not considered within safe ranges. Other reported cases are connection problems with the Wearable Sensor that made it impossible to perform the endurance session. These situations frustrated the user experience and caused the 7 drop-outs.

Figure 123: study details

The questionnaires available for the analysis are less than expected. There is a significant drop off in the questionnaire that users completed at home (after one week and after five weeks), mainly because users did not complete it or the medical team forgot to remind users and confirm the completion.

Scale	First use	After one week	After 5 weeks	End of study
Global acceptability	35	9	6	19
Portable Station acceptability	-	9	5	16
IMAGE Sensor acceptability	-	9	5	17
Patient Station acceptability	-	9	6	16

Table 52: Available number of answer of users of the system.

5.4.2 Acceptance

The results of the global acceptance of the system are all above the positive threshold (3). The system is scored highly interesting at the beginning of the study, with a

decrease after one week and a slow increase during the rest of the period of the study (5 week questionnaire and end of the study). The same trend can be observed for the attribute 'stimulating'. Another observed trend of other dimensions is the lower scoring at the beginning of the study (when users were introduced to the system) that increases with the first uses of the system; this evolution can be seen in the dimension related with easiness, causing fright, and fit in daily life.

Figure 124: Global acceptance of GEx concept

5.4.2.1 Acceptance of the three subsystems

The three subsystems (Patient Station, Portable Station and Images Sensor) were scored individually and their results highlight differences of the users' opinions about each one. The Patient Station is the device that receives the most positive global score. The impression of the system does not change significantly over time except for the easiness and interesting dimensions, in which an increase is noticed after 5 weeks and a decrease at the end of the study. The other dimensions have a more stable trend over time. The lowest dimension is related to the aesthetics of the system.

Figure 125: Acceptance of the Patient Station

The Portable Station is the second best accepted device. The trends of the scores over time have more variations. There are three dimensions that have a lower score at the end of the study than the beginning of the study (pleasant, stimulating, easy to use). Globally, the acceptance is positive.

Figure 126: Acceptance of the Portable Station over time

The Image Sensor received the lowest score. It is the only device that has 2 negative scores (scale <3) and one neutral score. Easiness and not causing fright scored highest.

Figure 127: acceptance of the sensor over time

The following table provides the detailed statistics with the standard deviations.

			Interesti ng	Not scary	Pleasant	Stimulati ng	Easy to use	N
1 Week	Patient Station	Mean	4,22	4,44	3,78	3,89	3,89	9
		St. Dev	0,97	0,88	0,83	0,78	0,78	
	Portable Station	Mean	4,11	4,44	3,89	4,00	4,00	9
		St. Dev	0,93	0,88	0,78	0,87	0,71	
	Sensor	Mean	3,22	4,33	3,33	2,78	4,00	9
		St. Dev	1,48	0,87	0,87	1,20	1,12	
5 week	Patient Station	Mean	4,50	4,60	3,80	4,17	4,60	3-5
		St. Dev	0,55	0,55	0,45	0,75	0,55	
	Portable Station	Mean	4,67	4,80	3,80	4,17	3,80	6
		St. Dev	0,52	0,45	0,45	0,75	1,64	
	Patient Station	Mean	3,00	4,67	3,75	3,67	4,80	3-5
		St. Dev	1,73	0,58	0,50	0,58	0,45	
End	Portable Station	Mean	4,13	4,63	3,81	4,06	4,13	16
		St. Dev	0,89	0,89	1,33	0,85	1,02	
	Portable Station	Mean	4,00	4,56	3,56	3,69	3,56	16
		St. Dev	0,89	0,81	0,81	0,87	1,50	
	Sensor	Mean	2,75	4,44	3,44	3,00	4,24	16-17
		St. Dev	1,29	0,81	0,81	1,03	0,97	

Figure 128: Variation of the acceptance of the three devices over time

5.4.3 Impact of the intervention on the user

Apart from the clinical outcome that demonstrated the improved exercise capacity for the controlled group, this research focused on other aspects related to the effectiveness of the designed technology to change users' attitude and behaviours. Three dimensions are presented: the user's perception, the knowledge about CVD and the exercise habits. This analysis has been carried out comparing the results of the intervention group and controlled group. The following tables show the available data for the analysis:

	Intervention		Control	
	Enrolment	End of study	Enrolment	End of study
User's perception	40	22	51	24
Cardiac knowledge	40	21	52	23

Table 53: Available data

5.4.3.1 Perception of illness

The questionnaire was based on a Lickert scale from 1 to 10. The questions have been compared between the intervention group and the control group. The following results were found:

- Effect of illness on life: over time both groups decreased the perception that the illness (a CAD that provoked an MI) affected their life. Both groups have the same trend.
- Control over illness: both groups improved the perception of control over the illness; the intervention group increased more (7.00 compared to 6.38 in the control group).
- Both groups positively (>5) scored the understanding of the disease.
- Both groups were more concerned about the disease at the beginning of the study; this concern decreased over time. The intervention group showed slightly higher concern (0,29).

Figure 129: user's perception questionnaire

5.4.3.2 Knowledge of the user

Fourteen questions were proposed to the user to measure the level of knowledge about the coronary heart disease and the exercise benefits. The questionnaire can be found in the Annexes. The following topics were investigated:

- Question about causes of the MI (MI1, MI2)
- Effect of exercise in MI (EXE-MI1, EXE-MI2, EXE-MI3)
- Question about function of coronary arteries (COR-ART)
- Question about atherosclerosis (ATHER)
- Question about Angina (ANGINA)
- Question about blood cholesterol (CHOL)
- Question about the importance of warming up before exercise (WARM-UP)
- Question about the cool-down phase after exercise (COOL-DOWN)
- Physiological consequences of the exercise (PHYSIO)
- Symptoms during exercise (SYMP)
- Effort after exercise (EFFOR)

Both groups answered questions about MI (MI-1, M1-2) positively, with stable results over time (at the beginning and after 6 months). No relevant differences between the two groups were found. Nevertheless, some slight differences can be found in some specific question (ATHER, ANGINA, SYMP) in which the intervention group scored more positively at the end of the study than the control group.

Figure 130: Comparison of the cardiac knowledge questionnaire results

Figure 131: Global variation of the exercise knowledge questionnaire

5.4.4 Persistence of exercise habits

The exercise habit questionnaire has been filled at the beginning of the study and after 1 year. After six month the users finished the rehabilitating program and no other clinical follow up was defined in the study; this time spam caused that was not possible to contact again the patient and there was a dramatic drop off of the number of questionnaires. In the intervention group from 32 questionnaires at the end of the study just 9 filled questionnaires have been collected after 6 months. On the control group the drop down is greater: from 41 initial users the final available questionnaire

after one year are just 8.

	Intervention	Control
Beginning of the study	32	41
1 year after	9	8

Table 54: Data availability of the exercise habit questionnaire

Exercise habits were collected asking 5 questions. The three dimensions refer to time per week, the average duration (in minutes) of the exercise session, and intensity of daily activity. At the beginning of the study the two groups displayed similar exercise habits (the same score for the intensity of daily activity, 4.0) and very slight difference in the average duration of the exercise session. Relevant differences (from 5.30 to 2.85) can be found at the beginning of the study in the average time/week in which users perform an intense activity.

Figure 132: Exercise habits

The last two questions specify the type of activity and that users perform during the week and the average in time. The questionnaire is a set of multiple-choice questions that allowed users to specify one or more activities. The results demonstrate high

variability and the lack of data (n=8 for the intervention group and 5 for the control).

Figure 133: Distribution of the exercise habits (1/2)

Figure 134: Distribution of exercise habit (2/2)

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	Baseline				End			
	Control (N=41)		Intervention (N=32)		Control (N=9)		Intervention (N=8)	
	Reported	Average of minutes (of selected)	% Performing	Average of minutes (of selected)	% Performing	Average of minutes (of selected)	% Performing	Average of minutes (of selected)
Running	12,20 %	73,00	9,38%	68,33	0,00%	0,00	37,50%	277,00
Aerobics	9,76%	19,00	6,25%	90,00	0,00%	0,00	12,50%	900,00
Swimming	14,63 %	64,17	12,50%	45,00	0,00%	0,00	25,00%	37,50
Bicycle	21,95 %	92,22	34,38%	167,82	60,00%	331,67	87,50%	348,43
Trekking	31,71 %	55,00	40,63%	65,00	60,00%	168,00	100,00 %	301,50
Walking	80,49 %	153,64	87,50%	181,79	100,00 %	388,00	50,00%	297,50
Tennis	4,88%	500,00	9,38%	313,33	0,00%	0,00	12,50%	120,00
Musculat ion	12,20 %	100,00	6,25%	504,50	40,00%	330,00	50,00%	137,50
Sky	0,00%	0,00	0,00%	0,00	0,00%	0,00	0,00%	0,00
Yoga	2,44%	10,00	3,13%	100,00	20,00%	400,00	0,00%	0,00
Other	29,27 %	131,67	18,75%	165,00	40,00%	60,00	25,00%	550,00

Table 55: Exercise habits results

06.

OTHERS STUDIES

The chapters presents two studies in which a negative emotional state affects the health status of the user and the acceptance of the technology.

6 Other studies

This chapter presents two case studies in which mood and emotions are shown to play a key role and, inasmuch, should be taken into account during the design of persuasive technology in health care. The first study demonstrates the intrinsic connection between health status and emotions; the second shows an example of how mood and emotional status could impact technology.

6.1 Case 1: relationship between symptoms and emotions

The first presented case is about a somatic cardiology disease: Heart Failure. This chronic disease occurs when the heart is not able to supply enough blood pressure to meet the body's demand. Depending on the level of severity (NYHA class I-II-III and IV) symptoms include shortness of breath, tiredness, and swelling in ankles and feet. This is a progressive disease that can produce other cardiac complications such as atrial fibrillation, arrhythmias, MI, mitral or tricuspid regurgitation and excessive preload reduction (due to the prescribed diuretics, commonly used to reduce the accumulation of water in the lungs). This disease is highly associated with low QoL, high mortality and high incidence of depression and stress. During the first iteration of the design of the Cardio Rehabilitation solution (June 2009), it was possible to interview patients in the cardiology unit suffering from Heart Failure. Eleven users participated to test a prototype and perform an interview including two questions about the relationship of symptoms and emotions. The participants included 6 females and 5 males (NYHA class II; only three participants did not have any other comorbidities); ages ranged from 61 to 78 years (average 71,2). The participants answered the following questions:

- How does your emotional status (e.g. stress or depression) influence your health condition?
- Do some symptoms make you worry or affect your mood in any way?

Ten of 11 patients stated that emotional status influenced their health status. Three of 10 recognized the relationship and reported using some internal cues (emotional control, relax, breathing positive attitude). The last seven users described some situations in which emotions are related with a physical response.

The table shows the detailed results of the answers:

Emotional status	Tired	Weakness	Bad health status	Good health status	Tachycardia	Arrhythmia	Patients
Sad	1	1	3			1	7
Happy				3			
Worries							
Depression		1					
Angry					1		
Patients that are aware and apply some (internal) cue	Emotional control, Positive attitude, Tranquility, Calm, Accept physical condition						3
Patient stated that the emotion does not influence the health status	1						1
Total							11

Table 56: Relations between emotions and physical condition.

From the 11 interviewed, two also mentioned the life trigger that caused a negative emotion and caused a worsening of the condition (death and severe disease of a family member). The second question represents a reverse question about how physical conditions influence the emotional response of the user. 27% of the users state that there is not any influence. One interviewed patient reported an effort to manage the emotional response, eight persons indicated that there is influence and stated some examples. The following table summarize the results:

	Nervous	Worries	Sad	Negative thinking	Anxiety	Scared	Total
Defibrillator shock						1	7
BP increasing						1	
Limited walk					1		
Fatigued	1	1					
Angina	1	1					
Bad health status			1	1			

	Nervous	Worries	Sad	Negative thinking	Anxiety	Scared	Total
Patient state yes, with an effort to manage the emotional response							1
Patient stated that the symptoms does not influence the emotions							3
Total							11

Table 57: Relations between physical symptoms and emotional response.

From this short interview it can be concluded that users with a severe and chronic condition such as HF recognize (91%) that emotions influence physical status, and in 73% of the cases state that certain physical situations influence the emotional response of the individual. A small number of users are aware of this relationship and adopt internal cues to manage negative emotions and reduce the emotional response when facing a physiological condition.

The results of this interview also demonstrate high variability in the emotions and situations involved in this process.

6.2 Case 2: mood status and technology

The second case shows the results of the final validation of the Psyche project (presented in the section 3.3.2) in which 26 users tested an app with a Wearable Sensor for a period of 3 months. The users were enrolled in three European clinics in Genève, Strasbourg and Pisa. The users included in the study were bipolar patients in stable phase, hospitalized users with depressive symptoms and cyclothymic users. Users received an Android-based app and a Wearable Sensor to be used on a daily basis to report mood (using a simple scale). Two times a week users were asked to read a test (voice was recorded and used for mood assessment), and answer two assessment questionnaires (Bauer and Panas). Two nights per week users slept with the Wearable Sensor and answered a sleep quality questionnaire the following day. Tools were also provided for medication, a diary and a chart to see the evolution of the mood. All the data was gathered to assess and forecast the mood status of the user. Two dimensions are presented for this context of research: the acceptance (ACC) and the usability (USA) of the system. The questionnaires were collected on three occasions during the study:

- Upon enrolment in the clinical facility: After signing the informed consent, professionals introduced the user to the Psyche system and they gave the user the tele-monitoring system that included: a Smartphone, a wearable device, the user manuals and other accessories. The user completed the acceptance questionnaire.
- During the second follow-up visit in the clinical facility: After the follow-up visit, professionals invited users to complete the usability questionnaire.

HUMAN EMOTIONS IN WELL.BE.SIGN

- At the end of the study: During the last visit in the clinical facility, patients were invited to complete usability and acceptance questionnaires.

The following table gives a summary of the scheduled questionnaire and of the data collected:

	Total	Enrolment questionnaire (ACC)	After one week questionnaire (USA)	End of the study (ACC, USA)
Cyclothymic	9	7	7	7
Bipolar (stable during enrolment)	6	4	4	5
Hospitalized bipolar	11	10	6	4
Total	26	21	17	16

Table 58: Availability of the questionnaire for the case study 3

6.2.1 User acceptance

The questionnaire has been scored using a negative Lickert scale, in which the value 1 represents the full level of agreement and the score 5 total disagreement with the sentence. The results of questionnaires that were completed during the first use show that hospitalized users accept the system less: three scales have negative scoring (score>3), the easiness and idea that the system fits in the user's life, and that learning to use it is easy. The other two groups (cyclothymic users, and stable bipolar patients) reported higher acceptance in all the dimensions. Globally, the system has been scored of 2.41 (as weighted average of the 5 dimensions of all the users).

Figure 135: Comparison of the NO acceptance at the first use

The same questions were asked after three months: the results show that acceptance increased (the score went down from 2,41 to 1,9 globally). Again, the users with depression showed less acceptance of the system compared with the other two groups. This is confirmed in the 5 dimensions of the questionnaire. There is a variation in the trend of the cyclothymic group, which scored the helpfulness of the system similarly with the hospitalized group. Cyclothymic users are not medically treated and do not feel that they have a health problem.

Figure 136: Comparison of the user NO acceptance (end of the study)

6.2.2 System usability

The patients scored the usability of the Psyche system 15 days after having received the system and at the end of the study (after 3 months). Five questions were defined to score five modules of the system:

- Mood agenda: on a daily basis, users completed a scale with the level of emotions (excitement, depression, anxiety, irritability).
- Sleep agenda: on a daily basis, users reported their quality of sleep.
- The questionnaire module: subjects completed the questionnaires in the Smartphone 2 times per week.
- The diary: a module that patients used to report daily habits.
- The Sensor Module: the screens that assisted the subjects in conducting the monitoring session during the night using the SEW device. This module was used 2 times per week.
- The voice module: patients record their voice while describing an image or reading a text. The frequency of use was 2 times per week.

The scale used for the questions was a negative Lickert scale (1 very easy, 5 very difficult). The results of the analysis show that the system received positive (score <3)

usability scoring in most groups and dimensions of the functions. The hospitalized group negatively scored (3.17) the functionality of completing the questionnaire about sleep quality. In these results, the hospitalized group gave less positive scores to the six functionalities of the app. Globally, the score of the app was positive with a weighted average of 2.03 (that corresponded to the level of ease in the Lickert scale).

Figure 137: Comparison of the NO usability scores (2nd questionnaire)

At the end of the study, the global usability score remained constant (the average is 2.05), but it can be noticed that the hospitalized group negatively scored the acceptance, with a more negative score compared to the second-week questionnaire. The other two groups have a reverse tendency; in this last questionnaire, the weighted average of the 6 dimensions is 1.8 for the bipolar patients and 1.55 for the cyclothymic users.

Figure 138: comparison of the NO usability scores (end of the study)

07.

CONCLUSIONS

The chapter revises the results of this research and draws conclusions and future works.

7 Conclusions

This research proposes an approach to design technology to foster healthy habits in users affected by a specific health problem; the approach is based on three pillars: the health status of a person, the emotional state and the support that technologies can give to adopt the change. This paradigm has been applied in the context of health care to design technologies to provide tele-care and also promote the physical and emotional well being of the patients. Three methods have been proposed: a theoretical framework that proposes patterns to be defined during the process of design, the influence diagram that shows the opportunity of persuasion in the context of health care and a design process that shows the steps to be followed to design this type of technology. The methods have been applied to design a system to deliver a home-based rehabilitation programme of post MI patients. The system has been specified and it was used in a randomized clinical study. Also, two case studies have been presented to show the relationships between health status and emotions, and how mood status such as depression influences the perception of the technology.

This chapter draws the conclusions from the achieved results. First, the results are discussed and verified according to the objective of the work, and then the conclusions are drawn for every stated hypothesis. After the verification of the achievement of the work, a discussion is presented about the work of this research and future works are presented to share next activities linked to this research.

7.1 Discussion of the results

This research proposed three hypotheses that have been demonstrated through the accomplishment of 9 objectives. Those are presented and discussed below:

O1: Define a theoretical framework to design systems to promote well being and health status.

A theoretical framework has been defined combining principles of persuasive technologies (PSD of Oinas-Kukkonen) and user interaction models (the Holistic Interaction Model of Villalba), and a theoretical framework of behaviour change (the Health Belief Model, and the Trans Theoretical Model) has been used to create a user model (the intra personal context) and a strategy (model of change). Health and Emotional status have been included in the model and, depending on the application context, specific interventions are defined. The theoretical framework is specific for the use in health care, and proposes a context of design ('the extended clinical context') which contains a process (assessments, intervention and strategy) that has been tailored to specify the design of mobile-based systems.

O2: Contextualize the persuasive technologies in the domain of well being in health care.

CONCLUSIONS

Persuasive technologies focus on how technology could change human behaviours: its use has been contextualized defining an influence diagram that shows the role of the persuasive technology, the types of social actors and how these could influence the user's attitude.

03: Define a method to design and develop technologies to promote well being.

A combination of methodologies to design the Human Computer Interaction has been proposed to define a method to cover the whole process of product development, from the design phase to the development and validation. The methods have been conceived to follow two relevant issues of the design of technologies to foster healthy habits.

- Respect user willingness: the product is built first focusing on users' needs and preferences, then is 'extended' with persuasive design and is validated again with the users. Also, the intention of the system is validated with the end users.
- Co-design with clinical experts: the methods have been defined to co-design the system with health professionals: the process has been divided into one more specific to the treatment of the disease and another of support. This separation allows specialists to focus on the treatment of the disease and identifying the necessary lifestyle recommendations, and other medical experts focus on the design of the proper strategies of user empowerment and to promote well being.

04: Apply the proposed design methods to design and develop a cardio rehabilitation system.

The methodologies that have been defined in 03 (the design process) have been applied to design a system to deliver in-home cardio-rehabilitation in post MI patients. During the first iteration GDD design has been used, and the second iteration applied the design of the proposed theoretical framework; the last step was the development.

05: Verify that users accept the technology and its intentions.

The system has been validated iteratively with the end users 2 times during the design phase and at the end in a clinical study. In all the tests, acceptance was demonstrated to be positive (>3) as the following table summarizes:

	N	Mean	SD
User acceptance 1 iteration	3	4,6	0,78
User acceptance 2 iteration	11	4,2	1,17
Final acceptance (beginning of the study)	35	4,22	0,94
Final acceptance (end of study)	19	4,0	1,03

Table 59: Summary of the technology acceptance of the GEx system

The intents of the technology have been validated by validating the target behaviors that have been defined in the persuasive design iteration. The global scoring (from 1 to 5) is 4.3 ± 1.29 . This result demonstrates high acceptance of the intentions of the system, even if some participants of the study were skeptical about the capacity of the

system's ability to help (when asked if system could help to change habits, 2 were neutral and 1 user disagreed).

O6: Verify the effectiveness of the health intervention on the user.

Two dimensions have been taken into account in this research: perception of illness and knowledge. The study measures these dimensions at the beginning and at the end of the study (after 6 months). The results show that users of both groups have similar levels of knowledge about cardiovascular disease and exercise, as the following table shows.

	Start		End of study	
	C	I	C	I
Cardiac knowledge	83,3%±14	81,2%±15	78,47%±17	86,36%±7
Exercise Knowledge	85,82%±10	83,65% ±9	87,5%±5	89,2%±10

Table 60: Statistics of correct answer of the knowledge questionnaires

The users' knowledge about cardiovascular disease and exercise has been compared with a control group following the standard rehabilitation practice. The intervention group has a significantly higher score of correct answer (+7.89% at the end).

The perception of the users is similar in the two groups. Both groups have the same trends over time: there are two dimensions that increase over time (users are less emotionally affected and less concerned about the illness) and others that are stable over time (both groups have the same perceptions on how illness affects their lives and about the understanding of the disease). Different trends have been found in the perceptions of control of the disease and the perceived benefits of the exercise: over time these dimensions decrease in the control group and increase in the intervention group.

Scale (from 0 to 10)	Control				Intervention			
	Start (N= 51)		End (N= 24)		Start (N= 41)		End (N= 23)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Not affects life	5,71	2,66	6,71	1,73	5,55	2,69	6,36	2,20
Controls illness	5,92	2,53	5,83	2,41	6,24	2,49	6,54	2,18
Understands illness	7,28	2,38	6,88	2,58	7,04	2,53	6,62	2,74
Not concerned about illness	3,90	2,68	5,04	3,06	4,38	3,02	4,48	2,43
Illness not affects emotions	5,48	3,12	7,25	2,31	6,25	3,01	6,38	2,83
Exercise helps with illness	8,82	1,21	7,88	1,96	8,63	1,97	8,60	2,15
Global scoring	6,18	2,43	6,60	2,34	6,35	2,62	6,50	2,42

Table 61: Descriptive statistic of the perceptions of the users

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Furthermore, the Guided exercise system has been demonstrated to improve the exercise capacity of the users: this was the primary end point of the clinical study of the HeartCycle project. The VO_2 was the primary end point and the statistical analysis of the clinical partner as stated in the final report of the HeartCycle (Deliverable 25.6):

There were no significant differences in peak VO_2 at baseline between patients assigned to control or intervention, overall or in those with valid paired results. Peak VO_2 was similar at baseline and follow-up in the control group (19.9 ± 5.0 ml/kg/min to 19.5 ± 4.3 ml/kg/min) but increased in those assigned to intervention (19.5 ± 8.2 ml/kg/min to 22.0 ± 7.9 ml/kg/min). This difference was significant (t-test: mean difference (95%CI): -2.9 (-4.6 , -1.2) ml/kg/min; $p = 0.001$; Mann-Whitney U-test: $p = 0.003$) (Erik Skobel, 2013)

07: Verify the persistence of the habits over time.

The exercise habits were measured at the beginning and after one year. The system was used the first 6 months and for 6 months the users did not use the GEx system. Both groups increase weekly intense activity and the average of the exercise session. Since the follow-up was done 6 months after the end of the clinical study, there was a notable drop off of available data. Just 9 questionnaires of the controlled group were collected and 8 of the intervention group. Results indicate high variability and no statistical significance was found. An intra-subject analysis was completed and the population was reduced to 6 for the intervention group and 5 for the control group. It has been found that at the beginning of the study the 11 subjects (control + intervention) did not perform running activities, and at the end of the study 2 users (of 5) of the intervention group reported performing exercise. This result gives indications that the guided exercise system at least promoted the running activity, but no official conclusion can be drawn because of the low quality of the data.

08: Demonstrate the impact of emotions on the health status of patients with more severe CVD.

11 HF patients were interviewed to investigate how emotions could influence physical status. 91% of interviewed patients positively answer the question, and examples of daily life were given. In general, the highest scored relationship was the connection between happiness and health, and feeling sad worsening of the condition. Also, emotions influence specific symptoms of the chronic cardiovascular condition (tiredness and weakness, tachycardia and arrhythmias). Emotions have been investigated as response to specific symptoms: in this case 73% agreed on the fact that some symptoms lead to negative emotional states. Just a few participants reported applying techniques to control emotional status: in the first case (link between emotional status and health status), 27% of the interviewed people stated that they manage the emotional state and try to avoid negative emotions. In the second case (link between physical condition and emotional status), only 9% of the users reported applying an internal cue to control the negative emotional response.

09: Verify the impact of technology on people suffering from a mood disorder (e.g depression).

Results were presented from a usability and acceptability study of a system, in which three types of users used a system based on a mobile phone and a wearable system for 3 months. Three types of users participated in the study: stable bipolar patients, cyclothymic patients and hospitalized patients with depression. They used the system for a period of 3 months. The results show that patients with depression negatively score the system and over time the global acceptance and usability is worse, in reverse tendency of the other two groups. The following table shows the details of the results:

Acceptance								
Scale (1: agree 5: disagree)	All		Hosp		Bipolar		Cyclothymic	
	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN
I hope it will give me more control over my health status (start)	0,80	2,05	0,88	2,10	0,96	1,75	0,69	2,14
It gives me more control over my health status (end)	1,11	2,19	0,58	2,50	0,55	1,40	1,40	2,57
It seems easy to use (start)	1,06	2,71	0,92	3,20	0,96	2,75	1,00	2,00
It is easy to use (end)	0,62	1,63	0,50	2,25	0,55	1,60	0,49	1,29
I feel that I'll learn to use it quickly (start)	1,12	2,48	0,82	3,00	1,41	2,00	1,15	2,00
I learned to use quickly (end)	0,73	1,44	0,58	2,50	0,45	1,20	0,76	1,00
I am curious to use it (start)	0,80	2,05	0,79	2,20	0,96	2,25	0,76	1,71
I am satisfied with it (end)	0,76	2,00	0,58	2,50	0,84	1,80	0,75	1,83
Psyche concept easily fits in my everyday life (start)	0,83	2,76	0,74	3,10	1,26	2,75	0,49	2,29
Psyche concept easily fits in my everyday life (end)	0,68	2,25	0,61	3,00	0,71	2,00	0,58	2,00
Average Start	0,92	2,41	0,83	2,72	1,11	2,30	0,82	2,03
Average End	0,78	1,90	0,57	2,55	0,62	1,60	0,80	1,74

Table 62: Acceptance results of the case study 3

Usability								
	All		Hosp		Bipolar		Cyclothymic	
	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN
User task								

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Report the daily mood status (2w)	1,05	1,88	0,98	2,83	0,96	1,75	0,38	1,14
Report the daily mood status (end)	1,14	1,87	0,5	3,25	1,34	1,6	0,48	1,28
Report the quality of the sleep (2w)	1,11	2,12	0,75	3,17	0,96	2,25	0,38	1,14
Report the quality of the sleep (end)	1,09	2	0,81	3	1,41	2	0,53	1,42
Fill the questionnaires in the Smartphone (2w)	0,95	1,82	0,75	2,83	0,58	1,50	0,38	1,14
Fill the questionnaires in the Smartphone (end)	1,08	1,87	0,81	3	1,30	1,8	0,48	1,28
Use the diary (2w)	1,25	2,13	0,75	2,83	0,71	1,50	1,50	1,71
Use the diary (end)	1,05	2	0,81	3	0	1	0,57	1,5
Record the voice (2w)	0,97	2,24	0,75	2,83	0,82	2,00	1,07	1,86
Record the voice (end)	1,07	2,31	0,81	3	1,14	2,4	1,06	1,85
Follow the Smartphone's instruction to use the sensor (2w)	0,94	2,00	0,84	2,50	0,50	1,25	1,00	2,00
Follow the Smartphone's instruction to use the sensor (end)	0,93	2,25	0,5	3,25	1	2	0,69	1,85
Average Start	1,04	2,03	0,81	2,83	0,75	1,71	0,78	1,50
Average End	1,07	2,05	0,71	3,08	1,03	1,80	0,64	1,54

Table 63: Usability result of the case study 3

7.2 Revision of the hypothesis

The first research hypothesis was:

It is possible to define methods to design technologies that maintain and promote the wellbeing (physical and emotional) of a person.

This research confirms that it is possible to design systems to promote physical and emotional status. The Well.Be.Sign methods can be applied to design technologies to deliver tele-care to patients with a specific health problem. The proposed theoretical framework included three contexts that comprise the relevant information required to design this type of technology:

- The intrapersonal context: it is a representation of the user's mental model. In this model, health status and emotional state have been included and mechanisms were specified (based on existing methods and approaches) that show the effect they can have on attitude and behaviours.
- The extended clinical context: in this context of research the methods were applied to provide health services and tele-care, and promote physical and mental well being. Three basic processes were defined to assess the user

condition, define a specific care plan and, based on these, build a tailored and specific intervention for the user.

- The technology context: definitions have been developed for how to design the technologies and how to tailor them according to the clinical requirements and the recommended clinical practice.

However, the methods describe the patterns to design these technologies and do not specify the intervention to be applied; the framework proposes a methodology to build the intervention with the health professional in order to identify the required intervention and specify the design using the Well.Be.Sign methods.

It is possible to apply the defined design methods and develop the technology to deliver a cardio-rehabilitation program of patients that suffered an myocardial infarction.

Well.Be.Sign methods have been applied to design a system to deliver a home-based rehabilitation program. The clinical requirements were defined by the cardiologists that specified an exercise program; the intervention was designed with the team of the Heart Manual that specified the global intervention requirements and a specific strategy to promote the exercise. According to the clinical requirements and the scope of the project in which the methods were applied, the system did not provide support to manage and improve the health status of the users. Nevertheless, improvements have been seen in terms of improvement of exercise capacity, improved control over the illness, perceived benefits of the exercise and improved knowledge about cardiovascular disease. Systems were shown to be accepted by the users and to have acceptable levels of easiness.

Technology that promotes wellbeing needs to provide reinforcement to negative emotions because they can impact on the health status and on the acceptance of the technology.

This hypothesis demonstrates the need to include the promotion of mental health in the design of technologies to promote health and lifestyle changes. This theory was validated taking other groups of population in which the emotional response and status can have impact on the user's daily life.

Two scenarios have been presented to show the role of emotions in two relevant cases:

- In people affected by a severe chronic disease as HF, in which a bidirectional connection between health status and emotions have been discussed with patients. Two correlations were demonstrated: the relationship between symptoms and negative emotional response, and that negative emotional status is correlated with worsening of chronic conditions.
- People with mood disorders: the study shows that emotions could also impact how the user perceives the technology..

The two studies demonstrate the foundations of the Well.Be.Sign's approach to promote both physical and emotional status. The potential positive effects of the Well.Be.Sign approach have not been demonstrated, but it has been shown that that it could be used in other selected target population.

7.3 Original contributions of this research

The original contributions of this research are:

- Definition of a specific mental model to design technologies to foster behavior change and well being. It has a psychological basis of the Health Belief Models and at the same time extend the Behaviour Change support system proposed by Kukkonen (Oinas-Kukkonen, 2013). It adds new elements of the A-B-C change construct of BCSS: health status, emotions, knowledge and barriers have clinical relevance and influence the attitude of the users. In designing technology for the health care part of this dimension, assessment can be carried out and the cue could be designed according to the user and clinical needs.
- Definition of a process to design technologies for health care: this extended clinical context has been defined to deliver care and physical and mental well being to patients. The proposed Well.Be.Sign method defines a step to design how to assess the health status and the general well being. Furthermore, the methods define how to tailor the specific intervention plans according to clinical and health psychology practices. Health professionals participate in the design of the technology to define a specific care plan, and propose a tailored intervention for the user implementing a specific theory for behavior change. The Well.Be.Sign framework helps to shape clinical protocol and health intervention using the State of the Art knowledge in persuasive technologies.
- Design of a cardio-rehabilitation system following persuasive system design and also best practice in health care. The existing system focuses on the rehabilitation service and on maximizing the benefits of the service, not on fostering behavior change and persistent habits. Just this year other research has been found that intends to use Persuasive Design (Sankaran, Supraja, Luyten, & Coninx, 2015).
- Study of the impact of emotional states in designing technology to promote health and behavior change: the role of emotions is still an open issue in the design of a system to promote health. This research proposes an approach in which, if it is possible to assess the emotional state of the person, then it is also possible to design a specific cue to help users control the negative emotions. This intervention has not been developed, but there are existing practices based on Cognitive Behavioral Therapies and Mindfulness that demonstrate to be effective to improve the emotional status of users.

7.4 Future works

Three types of future works have been planned:

- Apply the proposed method to a more specific problem in which it is relevant to manage health and emotional status of patients and promote well being. Since a project has been already found, it is presented in the next section.
- Refinement and improvement of the framework
- Dissemination: a seminar about the design of user technologies using the Well.Be.Sign.Approach is planned.

The Nevermind project

The proposed research has already found a new potential project in which the methods will be applied and validated considering both emotional state and physical status of the person. In fact, a new project of the Horizon 2020 called NEVERMIND will be the opportunity to apply and improve the proposed methods.

NEVEMIND is the acronym of NEurobehavioural predictive and peRsonalised Modelling of depresslve symptoms duriNg primary somatic Diseases with ICT-enabled self-management procedures. The goal of the project is:

to empower people who suffer from symptoms of depression related to a serious somatic disease by placing them at the centre of their mental healthcare. Equipped with just a smartphone and a lightweight sensorised shirt, patients seeking care and treatment for their mental illness interact with these devices that collect data about their mental and physical health, and provide effective self-managing feedback to the patient.

The target user is suffering a severe somatic disease, in which the risk of depression is high: heart failure, cancer, led amputation and kidney failure. In the project, specific mobile based interventions will be designed to help users to cope with the severe conditions, and at the same time a panel of psychologists define an intervention to promote well being and prevent the onset of depressive symptoms.

The following diagram shows the problem and the approach of the project:

Figure 139: Approach of the Nevermind project

The following issues will be further investigated in the Well.Be.Sign. framework:

- Investigate the potential of the serious game, a new promising trend to create more engaging User Interaction Solutions.
- Investigate the approach of positive mental health, based on positive psychology, that is already demonstrated to be affective to improve the emotional state of the users.
- Develop interventions to address emotional control and develop interventions based on Mindfulness and Cognitive Therapy to help patients to improve the emotional status and prevent the onset of depressive symptoms.

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Refinement and improvement of the framework

The following activities have been planned to refine and improve the proposed methods:

- Validate the process with user Interaction Experts, and people working in the area of health and technology, launching an online survey to collect quantitative information and validate and refine the design patterns.
- Refine the theoretical model and attempt to create a mathematical model of the intrapersonal context.
- Include in the theoretical model common software patterns for the design of services for patients (e.g. model symptoms questionnaire, medication module, bio signal monitoring etc).

Dissemination of the Well.Be.Sign

One proposed activity is to create a guide to design technology for patients in health care using the Well.Be.Sign approach. This guide can be useful for students of bioengineering, designers, and user interaction experts and engineers.

08/09/10

PUBLICATIONS, BIBLIOGRAPHY AND ANNEXES

The section details the publication linked with this research, the revised bibliography and the annexes related to this work.

8 Publications

Persuasive and affective technology

R.Garcia, G.Fico, D.Salvi, M. T. Arredondo. Title: On the convergence of affective and persuasive technologies in computer- mediated health-care systems. Journal of human technology Vol. 11 pag. 71-93. ISSN: 1795-6889. May 2015.

Cardio Rehabilitation

W. Armitage, C. Deighan, M.Ottaviano, C. VeraTitle: "Telemonitoring Support For Optimal Exercise For People Post Myocardial Infarction: The Heartcycle Gex Programme" Conference, 'Partnership working to improve care'; Brighton, UK October 2011

Authors: Dario Salvi, Manuel Ottaviano, Cecilia Vera-Munoz, Sergio Salvi, Maria Teresa Arredondo Title: A platform for the development of patients applications in the domain of personalized health. Journal on Computer Methods and Programs in Biomedicine", Elsevier Editorial System (EES), special edition for "MEDICON 2010, conference July 2011

M. Ottaviano, C. Vera-Muñoz, M.T. Arredondo, D. Salvi, S. Salvi, J.M. Páez, A. Díaz de Barrionuevo: Innovative Self Management System for Guided Cardiac Rehabilitation,Proceedings of 33rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC 11). Boston, 2nd September 2011

C. Vera-Muñoz, M.T. Arredondo, I. Peinado, M. Ottaviano Title: Results of the Usability and Acceptance Evaluation of a Cariat Rehabilitation System Proceeding of the conference HCI International 2011, 9-14 July 2011, Hilton Orlando Bonnet Creek, Orlando, Florida, USA

M. Ottaviano, C. Vera-Muñoz, M.T. Arredondo, D. Salvi Title: A System to Promote Self-Behaviors of Patients with Coronary Heart Disease. Proceedings of the 32nd Annual International IEEE EMBS Conference of the IEEE Engineering in Medicine and Biology Society, pp. 3843-3846, ISBN: 9781424441242, Buenos Aires, Argentina, 2010

Bipolar disorders

G. Andrea, S.Salvi, M.Ottaviano, C. Gentili, G. Bertschy, D. de Rossi, E. Scilingo, and N. Vanello. "Smartphone Application for the Analysis of Prosodic Features in Running Speech with a Focus on Bipolar Disorders: System Performance Evaluation and Case Study." *Sensors* 15, no. 11 (November 6, 2015): 28070–87. doi:10.3390/s151128070.

M. Ottaviano, S. Salvi, M.T. Arredondo Waldmeyer Title: Novel system for daily monitoring of mood disorders. Conference: 7th International Workshop on Biosignal Interpretation, Como 3rd July 2012

M. Ottaviano, A. Arca, S. Salvi, M.T. Arredondo Waldmeyer Title: Psyche: Disease Management System for Bipolar Subjects Conference: Media Tablets & Apps for Medicine, Health, and Home- Care, Milano, 1-2 March 2012

Heart Failure

Villalba E, Ottaviano M, Salvi D, Peinado I, Arredondo MT., Iterative user interaction design for wearable and mobile solutions to assess cardiovascular chronic diseases Book: Advances in Human-Computer Interaction. ps: 335-354. ISBN: 978-953-7619-19-0. Publisher: InTech Education and Publishing

E. Villalba, D. Salvi, M. Ottaviano, I. Peinado, M. T. Arredondo, A. Akay. Title: Wearable and mobile system to manage remotely heart failure IEEE Transactions on Information Technology in Biomedicine (TITB),ISSN: 1089-7771

E. Villalba, D. Salvi, M. Ottaviano, I. Peinado, M. T. Arredondo. Title: Validation results of the user interaction in a heart failure management system. Proceedings of the International Conference on eHealth, Telemedicine, and Social Medicine eTelemed 2009, Cancún, México, 1-7 February

E Villalba, Mt Arredondo, M Ottaviano, D Salvi, E Del Hoyo-Barbolla, S Guillen Title: Heart Failure monitoring system based on Wearable and Information Technologies Journal: Journal of Communications, Academia Publisher ,ISSN: 1796-2021

E. Villalba, M. Ottaviano, D. Salvi, I. Peinado, M. T. Arredondo, M. Docampo. Title: User Interaction for people living with a chronic disease", Proceedings of the pHealth 2008, Valencia, España, Fecha: 23 May 2008.

E Villalba, M Ottaviano, Mt Arredondo, A Martinez, S Guillen title: Wearable Monitoring System For Heart Failure Assessment In A Mobile Environment Conference: Computers In Cardiology, 2006, Valencia, España.

E Villalba, D Salvi, M Ottaviano, I Peinado, Mt Arredondo, M Docampo Title: User-Centered System To Manage Heart Failure In A Mobile Environment Conference: Medicon 2007, Liubljana, Slovenia, June 2007

9 Bibliography

- Aase, O. (1999). Clinical Experience with a Decision Support Computer Program Using Bayes's Theorem to Diagnose Chest Pain Patients. *Cardiology*, 92(2), 128–134. <http://doi.org/10.1159/000006960>
- Abadie, F., Lluch, M., Lupiáñez Villanueva, F., Maghiros, I., Villalba Mora, E., & Zamora Talaya, M. B. (2012). *Strategic Intelligence Monitor on Personal Health Systems phase 2 (SIMPHS 2) Market developments – Remote Patient Monitoring and Treatment, Telecare, Fitness/Wellness & mHealth* (EUR - Scientific and Technical Research Reports No. JRC71141). European Commission. Retrieved from <http://publications.jrc.ec.europa.eu/repository/handle/JRC71141>
- Ades, P. A., Waldmann, M. L., McCann, W. J., & Weaver, S. O. (1992). Predictors of cardiac rehabilitation participation in older coronary patients. *Archives of Internal Medicine*, 152(5), 1033–1035.
- Aguilo, J., Ferrer-Salvans, P., Garcia-Rozo, A., Armario, A., Corbi, A., Cambra, F. J., ... Garzon-Rey, J. M. (2015). Project ES3: attempting to quantify and measure the level of stress. *Revista De Neurologia*, 61(9), 405–415.
- Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179–211. [http://doi.org/10.1016/0749-5978\(91\)90020-T](http://doi.org/10.1016/0749-5978(91)90020-T)
- Alvaro, C., Lyons, R. F., Warner, G., Hobfoll, S. E., Martens, P. J., Labonte, R., & Brown, E. R. (2010). Conservation of resources theory and research use in health systems. *Implementation Science*, 5(1), 79. <http://doi.org/10.1186/1748-5908-5-79>
- American College of Sports Medicine. (2014). *ACSM's guidelines for exercise testing and prescription*. (L. S. Pescatello, Ed.). Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins Health.
- Anchala, R., Pinto, M. P., Shroufi, A., Chowdhury, R., Sanderson, J., Johnson, L., ... Franco, O. H. (2012). The Role of Decision Support System (DSS) in Prevention of Cardiovascular Disease: A Systematic Review and Meta-Analysis. *PLoS ONE*, 7(10), e47064. <http://doi.org/10.1371/journal.pone.0047064>
- Andrew, G. M., Oldridge, N. B., Parker, J. O., Cunningham, D. A., Rechnitzer, P. A., Jones, N. L., ... Sutton, J. R. (1981). Reasons for dropout from exercise programs in post-coronary patients. *Medicine and Science in Sports and Exercise*, 13(3), 164–168.
- Andrews, P. W., & Thomson, J. A. (2009). The bright side of being blue: Depression as an adaptation for analyzing complex problems. *Psychological Review*, 116(3), 620–654. <http://doi.org/10.1037/a0016242>
- Antypas, K., & Wangberg, S. C. (2014). An Internet- and Mobile-Based Tailored Intervention to Enhance Maintenance of Physical Activity After Cardiac Rehabilitation: Short-Term Results of a Randomized Controlled Trial. *Journal of Medical Internet Research*, 16(3), e77. <http://doi.org/10.2196/jmir.3132>
- Austin, M. A., King, M. C., Vranizan, K. M., & Krauss, R. M. (1990). Atherogenic lipoprotein phenotype. A proposed genetic marker for coronary heart disease risk. *Circulation*, 82(2), 495–506. <http://doi.org/10.1161/01.CIR.82.2.495>
- Ayyagari, S. S. D. P., Gupta, K., Tait, M., & Billingham, M. (2015). *CoSense: Creating Shared Emotional Experiences* (pp. 2007–2012). ACM Press. <http://doi.org/10.1145/2702613.2732839>

- Balady, G. J., Ades, P. A., Bittner, V. A., Franklin, B. A., Gordon, N. F., Thomas, R. J., ... Yancy, C. W. (2011). Referral, Enrollment, and Delivery of Cardiac Rehabilitation/Secondary Prevention Programs at Clinical Centers and Beyond: A Presidential Advisory From the American Heart Association. *Circulation*, 124(25), 2951–2960. <http://doi.org/10.1161/CIR.0b013e31823b21e2>
- Balady, G. J., Ades, P. A., Comoss, P., Limacher, M., Pina, I. L., Southard, D., ... Bazzarre, T. (2000). Core Components of Cardiac Rehabilitation/Secondary Prevention Programs: A Statement for Healthcare Professionals From the American Heart Association and the American Association of Cardiovascular and Pulmonary Rehabilitation Writing Group. *Circulation*, 102(9), 1069–1073. <http://doi.org/10.1161/01.CIR.102.9.1069>
- Bandura, A. (1978). Self-efficacy: Toward a unifying theory of behavioral change. *Advances in Behaviour Research and Therapy*, 1(4), 139–161. [http://doi.org/10.1016/0146-6402\(78\)90002-4](http://doi.org/10.1016/0146-6402(78)90002-4)
- Bandura, A. (2001). Social Cognitive Theory: An Agentic Perspective. *Annual Review of Psychology*, 52(1), 1–26. <http://doi.org/10.1146/annurev.psych.52.1.1>
- Bandura, A., & Schunk, D. H. (1981). Cultivating competence, self-efficacy, and intrinsic interest through proximal self-motivation. *Journal of Personality and Social Psychology*, 41(3), 586–598. <http://doi.org/10.1037/0022-3514.41.3.586>
- Baran, P. (1964). On Distributed Communications Networks. *IEEE Transactions of the Professional Technical Group on Communications Systems*.
- Baroletti, S., & Dell'Orfano, H. (2010). Medication Adherence in Cardiovascular Disease. *Circulation*, 121(12), 1455–1458. <http://doi.org/10.1161/CIRCULATIONAHA.109.904003>
- Beasley, J. M., Riley, W. T., Davis, A., & Singh, J. (2008). Evaluation of a PDA-based dietary assessment and intervention program: a randomized controlled trial. *Journal of the American College of Nutrition*, 27(2), 280–286.
- Belle, A., Thiagarajan, R., Soroushmehr, S. M. R., Navidi, F., Beard, D. A., & Najarian, K. (2015). Big Data Analytics in Healthcare. *BioMed Research International*, 2015, 1–16. <http://doi.org/10.1155/2015/370194>
- Bensabat, I. (2010). HCI Research: Future Challenges and Directions. *Transactions on Human-Computer Interaction*, 2, 16–21.
- Bethell, H. J. (2000). Cardiac rehabilitation: from Hellerstein to the millennium. *International Journal of Clinical Practice*, 54(2), 92–97.
- B.J. Fogg. (2009). A Behaviour Model for Persuasive Design. In *Persuasive'09*, ACM. Retrieved from http://bjfogg.com/fbm_files/page4_1.pdf
- Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine & Science in Sports & Exercise*, 14(5), 377–81.
- Bowling, N. A., Beehr, T. A., Wagner, S. H., & Libkuman, T. M. (2005). Adaptation-level theory, opponent process theory, and dispositions: an integrated approach to the stability of job satisfaction. *The Journal of Applied Psychology*, 90(6), 1044–1053. <http://doi.org/10.1037/0021-9010.90.6.1044>
- Broadbent, E., Petrie, K. J., Main, J., & Weinman, J. (2006). The brief illness perception questionnaire. *Journal of Psychosomatic Research*, 60(6), 631–637. <http://doi.org/10.1016/j.jpsychores.2005.10.020>
- Brown, T. (2008). Design Thinking. In *Harvard Business Review* (pp. 84–95). Retrieved from https://www.ideo.com/images/uploads/thoughts/IDEO_HBR_Design_Thinking.pdf
- Bucci, S., Barrowclough, C., Ainsworth, J., Morris, R., Berry, K., Machin, M., ... Haddock, G. (2015). Using mobile technology to deliver a cognitive behaviour therapy-informed intervention in early psychosis (Actissist): study protocol for a randomised controlled

- trial. *Trials*, 16(1). <http://doi.org/10.1186/s13063-015-0943-3>
- Burke, L. E., Wang, J., & Sevvick, M. A. (2011). Self-Monitoring in Weight Loss: A Systematic Review of the Literature. *Journal of the American Dietetic Association*, 111(1), 92–102. <http://doi.org/10.1016/j.jada.2010.10.008>
- Butler, G. (1993). Definitions of stress. *Occasional Paper (Royal College of General Practitioners)*, (61), 1–5.
- Cai, Y. (2006). Empathic Computing. In Y. Cai & J. Abascal (Eds.), *Ambient Intelligence in Everyday Life* (Vol. 3864, pp. 67–85). Springer Berlin Heidelberg. Retrieved from http://dx.doi.org/10.1007/11825890_3
- Calvo, R. A., & D'Mello, S. (2010). Affect Detection: An Interdisciplinary Review of Models, Methods, and Their Applications. *IEEE Transactions on Affective Computing*, 1(1), 18–37. <http://doi.org/10.1109/T-AFFC.2010.1>
- Cameron, J., & Pierce, W. D. (1994). Reinforcement, Reward, and Intrinsic Motivation: A Meta-Analysis. *Review of Educational Research*, 64(3), 363–423. <http://doi.org/10.3102/00346543064003363>
- Carey, J., Galletta, D. F., Kim, Y., & Wildemuth, B. (2004). The Role of Human Computer Interaction in Management Information Systems Curricula: A Call to Action. *Communications of the Association for Information Systems*, 13, Article 23.
- Carlisle, J. H. (1975). Why Human-Computer Interaction Doesn't Work Like Human Dialogue. Presented at the ASIS Annual Meeting, Boston.
- Ceja, E., Osmani, V., & Mayora, O. (2015). Automatic Stress Detection in Working Environments from Smartphones’ Accelerometer Data: A First Step. *IEEE Journal of Biomedical and Health Informatics*, 1–1. <http://doi.org/10.1109/JBHI.2015.2446195>
- Chambless, L., Keil, U., Dobson, A., Mahonen, M., Kuulasmaa, K., Rajakangas, A.-M., ... Tunstall-Pedoe, H. (1997). Population Versus Clinical View of Case Fatality From Acute Coronary Heart Disease: Results From the WHO MONICA Project 1985–1990. *Circulation*, 96(11), 3849–3859. <http://doi.org/10.1161/01.CIR.96.11.3849>
- Chawla, N. V., & Davis, D. A. (2013). Bringing Big Data to Personalized Healthcare: A Patient-Centered Framework. *Journal of General Internal Medicine*, 28(S3), 660–665. <http://doi.org/10.1007/s11606-013-2455-8>
- Chen, C., Haddad, D., Selsky, J., Hoffman, J. E., Kravitz, R. L., Estrin, D. E., & Sim, I. (2012). Making Sense of Mobile Health Data: An Open Architecture to Improve Individual- and Population-Level Health. *Journal of Medical Internet Research*, 14(4), e112. <http://doi.org/10.2196/jmir.2152>
- Chittaro, L. (2015). Mobile Persuasion for Health and Safety Promotion (pp. 878–882). ACM Press. <http://doi.org/10.1145/2786567.2786570>
- Choi, S., Kim, S., Yang, J.-S., Lee, J.-H., Joo, C., & Jung, H.-I. (2014). Real-time measurement of human salivary cortisol for the assessment of psychological stress using a smartphone. *Sensing and Bio-Sensing Research*, 2, 8–11. <http://doi.org/10.1016/j.sbsr.2014.08.001>
- Cleland, J., & Naujokat, E. (2008, August 26). Technical specifications Deliverable 4.1. HeartCycle project.
- Coon, D., & Mitterer, J. O. (2013). *Introduction to psychology: gateways to mind and behavior* (13th ed). Belmont, CA: Wadsworth Cengage Learning.
- Cooper, A. (2007). *About face 3: the essentials of interaction design* ([3rd ed.], Completely rev. & updated). Indianapolis, IN: Wiley Pub.
- Cooper, A. (2014). *About face: the essentials of interaction design, 4th edition* (4th edition). Indianapolis, IN: John Wiley and Sons.
- Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., ... Oja, P. (2003). International physical activity questionnaire: 12-country reliability and

- validity. *Medicine and Science in Sports and Exercise*, 35(8), 1381–1395. <http://doi.org/10.1249/01.MSS.0000078924.61453.FB>
- Dalal, H. M. (2003). Achieving national service framework standards for cardiac rehabilitation and secondary prevention. *BMJ*, 326(7387), 481–484. <http://doi.org/10.1136/bmj.326.7387.481>
- Dalal, H. M., Zawada, A., Jolly, K., Moxham, T., & Taylor, R. S. (2010). Home based versus centre based cardiac rehabilitation: Cochrane systematic review and meta-analysis. *BMJ*, 340(jan19 4), b5631–b5631. <http://doi.org/10.1136/bmj.b5631>
- Dale, L., Whittaker, R., Jiang, Y., Stewart, R., Rolleston, A., & Maddison, R. (2014). Improving coronary heart disease self-management using mobile technologies (Text4Heart): a randomised controlled trial protocol. *Trials*, 15(1), 71. <http://doi.org/10.1186/1745-6215-15-71>
- Davis, F. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quart*, 13(3), 319–339.
- Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. *Management Science*, 35(8), 982–1003. <http://doi.org/10.1287/mnsc.35.8.982>
- Davis, J. (2010). Generating Directions for Persuasive Technology Design with the Inspiration Card Workshop. In T. Ploug, P. Hasle, & H. Oinas-Kukkonen (Eds.), *Persuasive Technology* (Vol. 6137, pp. 262–273). Springer Berlin Heidelberg. Retrieved from http://dx.doi.org/10.1007/978-3-642-13226-1_26
- DeBusk, R. F., Miller, N. H., & Raby, L. (2010). Technical Feasibility of an Online Decision Support System for Acute Coronary Syndromes. *Circulation: Cardiovascular Quality and Outcomes*, 3(6), 694–700. <http://doi.org/10.1161/CIRCOUTCOMES.109.931915>
- de Waure, C., Lauret, G.-J., Ricciardi, W., Ferket, B., Teijink, J., Spronk, S., & Myriam Hunink, M. G. (2013). Lifestyle Interventions in Patients with Coronary Heart Disease. *American Journal of Preventive Medicine*, 45(2), 207–216. <http://doi.org/10.1016/j.amepre.2013.03.020>
- Dienstbier, R. A. (1989). Arousal and physiological toughness: implications for mental and physical health. *Psychological Review*, 96(1), 84–100.
- Dimsdale, J. E. (2008). Psychological Stress and Cardiovascular Disease. *Journal of the American College of Cardiology*, 51(13), 1237–1246. <http://doi.org/10.1016/j.jacc.2007.12.024>
- Direito, A., Jiang, Y., Whittaker, R., & Maddison, R. (2015). Apps for IMproving FITness and Increasing Physical Activity Among Young People: The AIMFIT Pragmatic Randomized Controlled Trial. *Journal of Medical Internet Research*, 17(8), e210. <http://doi.org/10.2196/jmir.4568>
- Dixit, S., Pletcher, M. J., Vittinghoff, E., Imburgia, K., Maguire, C., Whitman, I. R., ... Marcus, G. M. (2015). Secondhand smoke and atrial fibrillation: Data from the Health eHeart Study. *Heart Rhythm*. <http://doi.org/10.1016/j.hrthm.2015.08.004>
- Drenth, P. J. D., Thierry, H., & Wolff, C. J. de (Eds.). (1998). *Handbook of work and organizational psychology* (2nd ed). East Sussex: Psychology Press.
- Drew, B. J. (2004). Practice Standards for Electrocardiographic Monitoring in Hospital Settings: An American Heart Association Scientific Statement From the Councils on Cardiovascular Nursing, Clinical Cardiology, and Cardiovascular Disease in the Young: Endorsed by the International Society of Computerized Electrocardiology and the American Association of Critical-Care Nurses. *Circulation*, 110(17), 2721–2746. <http://doi.org/10.1161/01.CIR.0000145144.56673.59>
- Ducatel, K., Bogdanowicz, M., Scapolo, F., Leijten, J., & Burgelman, J.-C. (2001). *Scenarios for Ambient Intelligence in 2010*.

- Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes*. Fort Worth, TX: Harcourt Brace Jovanovich College Publishers.
- Ekman, P., & Davidson, R. J. (Eds.). (1994). *The nature of emotion: fundamental questions*. New York: Oxford University Press.
- Elley, C. R. (2003). Effectiveness of counselling patients on physical activity in general practice: cluster randomised controlled trial. *BMJ*, 326(7393), 793–793. <http://doi.org/10.1136/bmj.326.7393.793>
- Evenson, K. R., & Fleury, J. (2000). Barriers to outpatient cardiac rehabilitation participation and adherence. *Journal of Cardiopulmonary Rehabilitation*, 20(4), 241–246.
- Fanning, J., Mullen, S. P., & McAuley, E. (2012). Increasing Physical Activity With Mobile Devices: A Meta-Analysis. *Journal of Medical Internet Research*, 14(6), e161. <http://doi.org/10.2196/jmir.2171>
- Faurholt-Jepsen, M., Vinberg, M., Christensen, E. M., Frost, M., Bardram, J., & Kessing, L. V. (2013). Daily electronic self-monitoring of subjective and objective symptoms in bipolar disorder--the MONARCA trial protocol (MONitoring, treAtment and pRediCtion of bipolAr disorder episodes): a randomised controlled single-blind trial. *BMJ Open*, 3(7), e003353–e003353. <http://doi.org/10.1136/bmjopen-2013-003353>
- Festinger, L. (2001). *A theory of cognitive dissonance* (Reissued by Stanford Univ. Press in 1962, renewed 1985 by author, [Nachdr.]). Stanford: Stanford Univ. Press.
- Fogg, B. (2009). Creating persuasive technologies: an eight-step design process (p. 1). ACM Press. <http://doi.org/10.1145/1541948.1542005>
- Fogg, B. J. (1998). *Charismatic Computers: Creating More Likable and Persuasive Interactive Technologies by Leveraging Principles from Social Psychology*. Stanford University, Stanford, CA, USA.
- Fogg, B. J. (2002). Persuasive technology: using computers to change what we think and do. *Ubiquity*, 2002(December), 2. <http://doi.org/10.1145/764008.763957>
- Fogg, B. J. (Ed.). (2007). *Mobile persuasion: 20 perspectives on the future of behavior change*. Stanford, Calif: Stanford Captology Media.
- Fontana, J. M., Farooq, M., & Sazonov, E. (2014). Automatic Ingestion Monitor: A Novel Wearable Device for Monitoring of Ingestive Behavior. *IEEE Transactions on Biomedical Engineering*, 61(6), 1772–1779. <http://doi.org/10.1109/TBME.2014.2306773>
- Frasere-Smith, N., Lesperance, F., & Talajic, M. (1995). Depression and 18-Month Prognosis After Myocardial Infarction. *Circulation*, 91(4), 999–1005. <http://doi.org/10.1161/01.CIR.91.4.999>
- Fredrickson, B. L. (2004). The broaden-and-build theory of positive emotions. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 359(1449), 1367–1377. <http://doi.org/10.1098/rstb.2004.1512>
- Fulton, S. (2003). Empathic design: Informed and inspired by other people's experience. In *Empathic design: User experience in product design* (Koskinen I, Battarbee K, Mattelmäki T, editors.: IT Press, p. 52). Helsinki, Finland.
- Gardner, H. (1999). *Intelligence reframed: multiple intelligences for the 21st century*. New York, NY: Basic Books.
- Gergen, K. J. (2002). Perpetual Contact. In J. E. Katz & M. A. Aakhus (Eds.), *Perpetual contact: mobile communication, private talk, public performance* (pp. 227–241). Cambridge, UK ; New York: Cambridge University Press.
- Ghassemi, M., Celi, L., & Stone, D. J. (2015). State of the art review: the data revolution in critical care. *Critical Care*, 19(1), 118. <http://doi.org/10.1186/s13054-015-0801-4>
- Giddens, A. (1991). *Modernity and Self-Identity: Self and Society in the Late Modern Age*.

- Stanford: Stanford University Press. Retrieved from <http://www.sup.org/books/title/?id=2660>
- Glanz, K., Rimer, B. K., & Viswanath, K. (Eds.). (2008). *Health behavior and health education: theory, research, and practice* (4th ed). San Francisco, CA: Jossey-Bass.
- Go, A. S., Bauman, M. A., Coleman King, S. M., Fonarow, G. C., Lawrence, W., Williams, K. A., & Sanchez, E. (2014). An Effective Approach to High Blood Pressure Control: A Science Advisory From the American Heart Association, the American College of Cardiology, and the Centers for Disease Control and Prevention. *Hypertension*, 63(4), 878–885. <http://doi.org/10.1161/HYP.0000000000000003>
- Gonzalez-Landaeta, R., Casas, O., & Pallas-Areny, R. (2007). Heart Rate Detection from an Electronic Weighing Scale (pp. 6282–6285). IEEE. <http://doi.org/10.1109/IEMBS.2007.4353791>
- Gordon, N. F. (2004). Physical Activity and Exercise Recommendations for Stroke Survivors: An American Heart Association Scientific Statement From the Council on Clinical Cardiology, Subcommittee on Exercise, Cardiac Rehabilitation, and Prevention; the Council on Cardiovascular Nursing; the Council on Nutrition, Physical Activity, and Metabolism; and the Stroke Council. *Circulation*, 109(16), 2031–2041. <http://doi.org/10.1161/01.CIR.0000126280.65777.A4>
- Goud, R., de Keizer, N. F., ter Riet, G., Wyatt, J. C., Hasman, A., Hellemans, I. M., & Peek, N. (2009). Effect of guideline based computerised decision support on decision making of multidisciplinary teams: cluster randomised trial in cardiac rehabilitation. *BMJ*, 338(apr27 2), b1440–b1440. <http://doi.org/10.1136/bmj.b1440>
- Grudin, J. (2005). Three Faces of Human-Computer Interaction. *IEEE Annals of the History of Computing*, 46–62.
- Grundey, S. M. (1998). Hypertriglyceridemia, Atherogenic Dyslipidemia, and the Metabolic Syndrome. *The American Journal of Cardiology*, 81(4), 18B–25B. [http://doi.org/10.1016/S0002-9149\(98\)00033-2](http://doi.org/10.1016/S0002-9149(98)00033-2)
- Guidi, A., Salvi, S., Ottaviano, M., Gentili, C., Bertschy, G., de Rossi, D., ... Vanello, N. (2015). Smartphone Application for the Analysis of Prosodic Features in Running Speech with a Focus on Bipolar Disorders: System Performance Evaluation and Case Study. *Sensors*, 15(11), 28070–28087. <http://doi.org/10.3390/s151128070>
- Gustad, L. T., Laugsand, L. E., Janszky, I., Dalen, H., & Bjerkset, O. (2014). Symptoms of anxiety and depression and risk of acute myocardial infarction: the HUNT 2 study. *European Heart Journal*, 35(21), 1394–1403. <http://doi.org/10.1093/eurheartj/ehu387>
- Hale, T. M., Pathipati, A. S., Zan, S., & Jethwani, K. (2014). Representation of Health Conditions on Facebook: Content Analysis and Evaluation of User Engagement. *Journal of Medical Internet Research*, 16(8), e182. <http://doi.org/10.2196/jmir.3275>
- Hans, S. (1957). The Stress of Life. *The Journal of Bone & Joint Surgery*, 39(2), 479–479.
- Harjumaa, M., & Muuraiskengas, S. (2013). Building the Persuasiveness into Information Systems. In *Proceedings of the 7th European Conference on IS Management and Evaluation* (pp. 23–25).
- Harjumaa, M., Segerstahl, K., & Oinas-Kukkonen, H. (2009). Understanding persuasive software functionality in practice: a field trial of polar FT60 (p. 1). ACM Press. <http://doi.org/10.1145/1541948.1541952>
- Hewett, Baecker, Card, Carey, Gasen, Mantei, ... Verplank. (1992). *Human-Computer Interaction. ACM SIGCHI Curricula for Human-Computer Interaction* (Association for Computing Machinery, Inc.). Association for Computing Machinery, Inc.
- Hjorth, L., & Lim, S. S. (2012). Mobile intimacy in an age of affective mobile media. *Feminist Media Studies*, 12(4), 477–484. <http://doi.org/10.1080/14680777.2012.741860>

- Holliday, A., Batey, C., Eves, F. F., & Blannin, A. K. (2014). A novel tool to predict food intake: The Visual Meal Creator. *Appetite*, 79, 68–75. <http://doi.org/10.1016/j.appet.2014.04.001>
- Hopkins, D. P. (2015). Clinical Decision Support Systems Recommended to Prevent Cardiovascular Disease. *American Journal of Preventive Medicine*, 49(5), 796–799. <http://doi.org/10.1016/j.amepre.2015.03.041>
- Hulley, S. B., Rosenman, R. H., Bawol, R. D., & Brand, R. J. (1980). Epidemiology as a Guide to Clinical Decisions: The Association between Triglyceride and Coronary Heart Disease. *New England Journal of Medicine*, 302(25), 1383–1389. <http://doi.org/10.1056/NEJM198006193022503>
- Institute for the Future. (2010). *The future of Persuasion*. Institute for the Future. Retrieved from http://www.iftf.org/uploads/media/SR-1321_IETF_FutureofPersuasionReport-1.pdf
- Janz, N. K., & Becker, M. H. (1984). The Health Belief Model: A Decade Later. *Health Education & Behavior*, 11(1), 1–47. <http://doi.org/10.1177/109019818401100101>
- Jolly, K., Lip, G. Y. H., Taylor, R. S., Raftery, J., Mant, J., Lane, D., ... Stevens, A. (2009). The Birmingham rehabilitation uptake maximisation study (BRUM): a randomised controlled trial comparing home-based with centre-based cardiac rehabilitation. *Heart*, 95(1), 36–42.
- Jospe, M. R., Fairbairn, K. A., Green, P., & Perry, T. L. (2015). Diet App Use by Sports Dietitians: A Survey in Five Countries. *JMIR mHealth and uHealth*, 3(1), e7. <http://doi.org/10.2196/mhealth.3345>
- Khattab, A. A., Knecht, M., Meier, B., Windecker, S., Schmid, J.-P., Wilhelm, M., & Saner, H. (2013). Persistence of uncontrolled cardiovascular risk factors in patients treated with percutaneous interventions for stable coronary artery disease not receiving cardiac rehabilitation. *European Journal of Preventive Cardiology*, 20(5), 743–749. <http://doi.org/10.1177/2047487312447751>
- Khayyam-Nekouei, Z., Neshatdoost, H., Yousefy, A., Sadeghi, M., & Manshaee, G. (2013). Psychological factors and coronary heart disease. *ARYA Atherosclerosis*, 9(1), 102–111.
- Kim, J. H. (2014). Health Avatar: An Informatics Platform for Personal and Private Big Data. *Healthcare Informatics Research*, 20(1), 1. <http://doi.org/10.4258/hir.2014.20.1.1>
- Kim, J., & Park, H.-A. (2012). Development of a Health Information Technology Acceptance Model Using Consumers' Health Behavior Intention. *Journal of Medical Internet Research*, 14(5), e133. <http://doi.org/10.2196/jmir.2143>
- Kleinsmith, A., & Bianchi-Berthouze, N. (2013). Affective Body Expression Perception and Recognition: A Survey. *IEEE Transactions on Affective Computing*, 4(1), 15–33. <http://doi.org/10.1109/T-AFFC.2012.16>
- Kok, G., Gottlieb, N. H., Peters, G.-J. Y., Mullen, P. D., Parcel, G. S., Ruiter, R. A. C., ... Bartholomew, L. K. (2015). A taxonomy of behaviour change methods: an Intervention Mapping approach. *Health Psychology Review*, 1–16. <http://doi.org/10.1080/17437199.2015.1077155>
- Koole, S. L., & Jostmann, N. B. (2004). Getting a grip on your feelings: effects of action orientation and external demands on intuitive affect regulation. *Journal of Personality and Social Psychology*, 87(6), 974–990. <http://doi.org/10.1037/0022-3514.87.6.974>
- Koskinen, I. (Ed.). (2003). *Empathic design: [user experience in product design]*. Edita, Finland: IT Press.
- Kraft, P., Drodz, F., & Oisen, E. (2009). ePsychology: Designing Theory-Based Health Promotion Interventions. *Communications of the Association for Information Systems*, 24(24). Retrieved from <http://aisel.aisnet.org/cais/vol24/iss1/24>

- Kubaneck, J., Snyder, L. H., & Abrams, R. A. (2015). Reward and punishment act as distinct factors in guiding behavior. *Cognition*, 139, 154–167. <http://doi.org/10.1016/j.cognition.2015.03.005>
- Kwan, G., & Balady, G. J. (2012). Cardiac Rehabilitation 2012: Advancing the Field Through Emerging Science. *Circulation*, 125(7), e369–e373. <http://doi.org/10.1161/CIRCULATIONAHA.112.093310>
- la Cour, P., & Petersen, M. (2015). Effects of Mindfulness Meditation on Chronic Pain: A Randomized Controlled Trial: Mindfulness and Chronic Pain. *Pain Medicine*, 16(4), 641–652. <http://doi.org/10.1111/pme.12605>
- Lanata, A., Greco, A., Valenza, G., & Scilingo, E. P. (2015). Robust Head Mounted Wearable Eye Tracking System for Dynamical Calibration. *Journal of Eye Movement Research*, 8(5), 1–15.
- Lane, D., Carroll, D., & Lip, G. Y. H. (2003). Anxiety, depression, and prognosis after myocardial infarction. *Journal of the American College of Cardiology*, 42(10), 1808–1810. <http://doi.org/10.1016/j.jacc.2003.08.018>
- Lazarus, R. S., & Folkman, S. (2008). *Stress, appraisal, and coping* (Nachdr.). New York: Springer Publ.
- Lehto, T., Oinas-Kukkonen, H., & Drozd, F. (2012). Factors Affecting Perceived Persuasiveness Of A Behavior Change Support System. In *Human behavior in it adoption and use*. Orlando: AIS Electronic Library (AISeL).
- Leon, A. S. (2005). Cardiac Rehabilitation and Secondary Prevention of Coronary Heart Disease: An American Heart Association Scientific Statement From the Council on Clinical Cardiology (Subcommittee on Exercise, Cardiac Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity), in Collaboration With the American Association of Cardiovascular and Pulmonary Rehabilitation. *Circulation*, 111(3), 369–376. <http://doi.org/10.1161/01.CIR.0000151788.08740.5C>
- Leor, J., Kloner, R. A., & The Investigators. (1996). The Northridge earthquake as a trigger for acute myocardial infarction. *The American Journal of Cardiology*, 77(14), 1230–1232. [http://doi.org/10.1016/S0002-9149\(96\)00169-5](http://doi.org/10.1016/S0002-9149(96)00169-5)
- Lerner, R. M. (1990). Weaving Development Into the Fabric of Personality and Social Psychology--On the Significance of Bandura's Social Foundation of Thought and Action. *Psychological Inquiry*, 1(1), 92–96. http://doi.org/10.1207/s15327965pli0101_24
- Levine, S. A. (1952). "ARMCHAIR" TREATMENT OF ACUTE CORONARY THROMBOSIS. *JAMA: The Journal of the American Medical Association*, 148(16), 1365. <http://doi.org/10.1001/jama.1952.02930160001001>
- Levine, S. B. (1991). Psychological intimacy. *Journal of Sex & Marital Therapy*, 17(4), 259–267. <http://doi.org/10.1080/00926239108404350>
- Lithgow, B. J., & Moussavi, Z. M. (2013). 2201 – The diagnosis of neurological conditions using electrovestibulography (EVestG). *European Psychiatry*, 28, 1. [http://doi.org/10.1016/S0924-9338\(13\)77074-3](http://doi.org/10.1016/S0924-9338(13)77074-3)
- Locke, E. A., & Latham, G. P. (2002). Building a practically useful theory of goal setting and task motivation: A 35-year odyssey. *American Psychologist*, 57(9), 705–717. <http://doi.org/10.1037//0003-066X.57.9.705>
- Loewenstein, G. F., Weber, E. U., Hsee, C. K., & Welch, N. (2001). Risk as feelings. *Psychological Bulletin*, 127(2), 267–286.
- Ludden, G. D., van Rompay, T. J., Kelders, S. M., & van Gemert-Pijnen, J. E. (2015). How to Increase Reach and Adherence of Web-Based Interventions: A Design Research Viewpoint. *Journal of Medical Internet Research*, 17(7), e172.

- <http://doi.org/10.2196/jmir.4201>
- Maddison, R., Pfaeffli, L., Stewart, R., Kerr, A., Jiang, Y., Rawstorn, J., ... Whittaker, R. (2014). The HEART Mobile Phone Trial: The Partial Mediating Effects of Self-Efficacy on Physical Activity among Cardiac Patients. *Frontiers in Public Health*, 2, 56. <http://doi.org/10.3389/fpubh.2014.00056>
- Maeland, J. G., & Havik, O. E. (1987). Measuring Cardiac Health Knowledge. *Scandinavian Journal of Caring Sciences*, 1(1), 23–31. <http://doi.org/10.1111/j.1471-6712.1987.tb00296.x>
- Mahmood, S. S., Levy, D., Vasan, R. S., & Wang, T. J. (2014). The Framingham Heart Study and the epidemiology of cardiovascular disease: a historical perspective. *The Lancet*, 383(9921), 999–1008. [http://doi.org/10.1016/S0140-6736\(13\)61752-3](http://doi.org/10.1016/S0140-6736(13)61752-3)
- Mampuya, W. M. (2012). Cardiac rehabilitation past, present and future: an overview. *Cardiovascular Diagnosis and Therapy; Vol 2, No 1 (March 2012); Cardiovascular Diagnosis and Therapy*. Retrieved from <http://www.thecdt.org/article/view/108>
- Mani, M., Kavanagh, D. J., Hides, L., & Stoyanov, S. R. (2015). Review and Evaluation of Mindfulness-Based iPhone Apps. *JMIR mHealth and uHealth*, 3(3), e82. <http://doi.org/10.2196/mhealth.4328>
- Martínez-Pérez, B., de la Torre-Díez, I., López-Coronado, M., & Herreros-González, J. (2013). Mobile Apps in Cardiology: Review. *JMIR Mhealth and Uhealth*, 1(2), e15. <http://doi.org/10.2196/mhealth.2737>
- Mathers CD, & Claudia Stein. (2002). Global Burden of Disease 2000. Version 2: methods and results. In *Global Programme on Evidence for Health Policy Discussion Paper No. 50*. Geneva: World Health Organization.
- Matsumoto, K., & Ren, F. (2011). Estimation of word emotions based on part of speech and positional information. *Computers in Human Behavior*, 27(5), 1553–1564. <http://doi.org/10.1016/j.chb.2010.10.028>
- Mayou, R., Hawton, K., Feldman, E., & Ardern, M. (1991). Psychiatric problems among medical admissions. *International Journal of Psychiatry in Medicine*, 21(1), 71–84.
- Mazzaglia, G., Piccinni, C., Filippi, A., Sini, G., Lapi, F., Sessa, E., ... Caputi, A. P. (2014). Effects of a computerized decision support system in improving pharmacological management in high-risk cardiovascular patients: A cluster-randomized open-label controlled trial. *Health Informatics Journal*. <http://doi.org/10.1177/1460458214546773>
- McClung, H. L., Sigrist, L. D., Smith, T. J., Karl, J. P., Rood, J. C., Young, A. J., & Bathalon, G. P. (2009). Monitoring Energy Intake: A Hand-Held Personal Digital Assistant Provides Accuracy Comparable to Written Records. *Journal of the American Dietetic Association*, 109(7), 1241–1245. <http://doi.org/10.1016/j.jada.2009.04.015>
- McDonald, T., & Siegal, M. (1992). The Effects of Technological Self-Efficacy and Job Focus on Job Performance, Attitudes, and Withdrawal Behaviors. *The Journal of Psychology*, 126(5), 465–475. <http://doi.org/10.1080/00223980.1992.10543380>
- McGovern, P. G., Jacobs, D. R., Shahar, E., Arnett, D. K., Folsom, A. R., Blackburn, H., & Luepker, R. V. (2001). Trends in Acute Coronary Heart Disease Mortality, Morbidity, and Medical Care From 1985 Through 1997 : The Minnesota Heart Survey. *Circulation*, 104(1), 19–24. <http://doi.org/10.1161/01.CIR.104.1.19>
- McLean, A. S., & Huang, S. J. (2012). Cardiac biomarkers in the intensive care unit. *Annals of Intensive Care*, 2(1), 8. <http://doi.org/10.1186/2110-5820-2-8>
- McLeroy, K. R., Bibeau, D., Steckler, A., & Glanz, K. (1988). An ecological perspective on health promotion programs. *Health Education Quarterly*, 15(4), 351–377.
- Mesa, I., Sanchez, E., Toro, C., Diaz, J., Artetxe, A., Graña, M., ... De Mauro, A. (2014). Design and Development of a Mobile Cardiac Rehabilitation System. *Cybernetics and Systems*,

- 45(2), 92–108. <http://doi.org/10.1080/01969722.2014.874804>
- Milani, R. V., & Lavie, C. J. (2007). Impact of Cardiac Rehabilitation on Depression and Its Associated Mortality. *The American Journal of Medicine*, 120(9), 799–806. <http://doi.org/10.1016/j.amjmed.2007.03.026>
- Mohino-Herranz, I., Gil-Pita, R., Ferreira, J., Rosa-Zurera, M., & Seoane, F. (2015). Assessment of Mental, Emotional and Physical Stress through Analysis of Physiological Signals Using Smartphones. *Sensors*, 15(10), 25607–25627. <http://doi.org/10.3390/s151025607>
- Morris, J. N., & Heady, J. A. (1953). Mortality in Relation to the Physical Activity of Work: A Preliminary Note on Experience in Middle Age. *British Journal of Industrial Medicine*, 10(4), 245–254.
- Mukkamala, R., Hahn, J.-O., Inan, O. T., Mestha, L. K., Kim, C.-S., Toreyin, H., & Kyal, S. (2015). Toward Ubiquitous Blood Pressure Monitoring via Pulse Transit Time: Theory and Practice. *IEEE Transactions on Biomedical Engineering*, 62(8), 1879–1901. <http://doi.org/10.1109/TBME.2015.2441951>
- Nakamura, J., & Csikszentmihalyi, M. (2009). Flow Theory and Research. In S. J. Lopez & C. R. Snyder (Eds.), *The Oxford Handbook of Positive Psychology* (2nd ed.). Oxford University Press. Retrieved from <http://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780195187243.001.0001/oxfordhb-9780195187243>
- Nakhasi, A., Shen, A. X., Passarella, R. J., Appel, L. J., & Anderson, C. A. (2014). Online Social Networks That Connect Users to Physical Activity Partners: A Review and Descriptive Analysis. *Journal of Medical Internet Research*, 16(6), e153. <http://doi.org/10.2196/jmir.2674>
- National Cholesterol Education Program. (2002). *Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III)* (No. NIH publication No. 02-5215). National Institutes of Health, National Heart, Lung, and Blood Institute.
- Naughton, J., Lategola, M. T., & Shanbour, K. (1966). A physical rehabilitation program for cardiac patients: a progress report. *The American Journal of the Medical Sciences*, 252(5), 545–553.
- Nichols, M., Townsend, N., Scarborough, P., & Rayner, M. (2012). *European cardiovascular disease statistics*.
- Nielsen, J., & Molich, R. (1990). Heuristic evaluation of user interfaces. In *Proceedings of ACM CHI'90*. Seattle.
- Nohara, R., Kambara, H., Mohiuddin, I. H., Ono, S., Okuda, K., Makita, S., ... Hayashi, M. (1990). Cardiac sports rehabilitation for patients with ischemic heart disease. *Japanese Circulation Journal*, 54(11), 1443–1450.
- Obermair, C., Reitberger, W., Meschtscherjakov, A., Lankes, M., & Tscheligi, M. (2008). perFrames: Persuasive Picture Frames for Proper Posture. In H. Oinas-Kukkonen, P. Hasle, M. Harjumaa, K. Segerståhl, & P. Øhrstrøm (Eds.), *Persuasive Technology* (Vol. 5033, pp. 128–139). Berlin, Heidelberg: Springer Berlin Heidelberg. Retrieved from http://link.springer.com/10.1007/978-3-540-68504-3_12
- Oinas-Kukkonen, H. (2010a). Behavior Change Support Systems: A Research Model and Agenda. In T. Ploug, P. Hasle, & H. Oinas-Kukkonen (Eds.), *Persuasive Technology* (Vol. 6137, pp. 4–14). Berlin, Heidelberg: Springer Berlin Heidelberg. Retrieved from http://link.springer.com/10.1007/978-3-642-13226-1_3
- Oinas-Kukkonen, H. (2010b). Behavior Change Support Systems: The Next Frontier for Web Science. In *Web & Methodology* (pp. 4–14). Raleigh, NC - US: Springer-Verlag Berlin, Heidelberg. http://doi.org/10.1007/978-3-642-13226-1_3

- Oinas-Kukkonen, H. (2013a). A foundation for the study of behavior change support systems. *Personal and Ubiquitous Computing*, 17(6), 1223–1235. <http://doi.org/10.1007/s00779-012-0591-5>
- Oinas-Kukkonen, H. (2013b). A foundation for the study of behavior change support systems. *Personal and Ubiquitous Computing*, 17(6), 1223–1235. <http://doi.org/10.1007/s00779-012-0591-5>
- Oinas-Kukkonen, Harri and Harjumaa, Marja. (2009). Persuasive Systems Design: Key Issues, Process Model, and System Features. *Communications of the Association for Information Systems*, 24(28). Retrieved from <http://aisel.aisnet.org/cais/vol24/iss1/28>
- Oinas-Kukkonen, H., & Harjumaa, M. (2008). Towards Deeper Understanding of Persuasion in Software and Information Systems (pp. 200–205). IEEE. <http://doi.org/10.1109/ACHI.2008.31>
- Oinas-Kukkonen, H., & Harjumaa, M. (2009). Persuasive Systems Design: Key Issues, Process Model, and System Features. *Communications of the Association for Information Systems*, 24, Article 28. Retrieved from <http://aisel.aisnet.org/cais/vol24/iss1/28>
- Ortiz, J., Ghefter, C. G. M., Silva, C. E. S., & Sabbatini, R. M. E. (1995). One-year mortality prognosis in heart failure: A neural network approach based on echocardiographic data. *Journal of the American College of Cardiology*, 26(7), 1586–1593. [http://doi.org/10.1016/0735-1097\(95\)00385-1](http://doi.org/10.1016/0735-1097(95)00385-1)
- Osheroff, J. A., Teich, J. M., Middleton, B., Steen, E. B., Wright, A., & Detmer, D. E. (2007). A Roadmap for National Action on Clinical Decision Support. *Journal of the American Medical Informatics Association*, 14(2), 141–145. <http://doi.org/10.1197/jamia.M2334>
- Ottaviano, M., Vera-Muñoz, C., Arredondo, M. T., & Salvi, D. (2010). A system to promote self-behaviors of patients with coronary heart disease (pp. 3843–3846). IEEE. <http://doi.org/10.1109/IEMBS.2010.5627694>
- Patel, V. L., & Kushniruk, A. W. (1998). Interface design for health care environments: the role of cognitive science. *Proceedings of the AMIA Symposium*, 29–37.
- Patnaik, L., Joshi, A., & Sahu, T. (2015). Mobile phone-based education and counseling to reduce stress among patients with diabetes mellitus attending a tertiary care hospital of India. *International Journal of Preventive Medicine*, 6(1), 37. <http://doi.org/10.4103/2008-7802.156267>
- Pelegris, P., Banitsas, K., Orbach, T., & Marias, K. (2010). A novel method to detect Heart Beat Rate using a mobile phone (pp. 5488–5491). IEEE. <http://doi.org/10.1109/IEMBS.2010.5626580>
- Pell, J., Pell, A., Morrison, C., Blatchford, O., & Dargie, H. (1996). Retrospective study of influence of deprivation on uptake of cardiac rehabilitation. *BMJ (Clinical Research Ed.)*, 313(7052), 267–268.
- Pesek, K., Pesek, T., & Rogini, S. (2011). The Importance of Risk Factors Analysis in the Prevention of Cardiovascular Disease (CVD). In K. Pesek (Ed.), *Atherosclerotic Cardiovascular Disease*. InTech. Retrieved from <http://www.intechopen.com/books/atherosclerotic-cardiovascular-disease/the-importance-of-risk-factors-analysis-in-the-prevention-of-cardiovascular-disease-cvd>
- Petty, R. E., Briñol, P., & Tormala, Z. L. (2002). Thought confidence as a determinant of persuasion: the self-validation hypothesis. *Journal of Personality and Social Psychology*, 82(5), 722–741.
- Petty, R. E., & Cacioppo, J. T. (1986). The Elaboration Likelihood Model of Persuasion. In R. E. Petty & J. T. Cacioppo, *Communication and Persuasion* (pp. 1–24). New York, NY: Springer New York. Retrieved from <http://link.springer.com/10.1007/978-1-4612->

- Pfaeffli, L., Maddison, R., Jiang, Y., Dalleck, L., & Löf, M. (2013). Measuring Physical Activity in a Cardiac Rehabilitation Population Using a Smartphone-Based Questionnaire. *Journal of Medical Internet Research*, 15(3), e61. <http://doi.org/10.2196/jmir.2419>
- Piazza, G., & Goldhaber, S. Z. (2009). Computerized Decision Support for the Cardiovascular Clinician: Applications for Venous Thromboembolism Prevention and Beyond. *Circulation*, 120(12), 1133–1137. <http://doi.org/10.1161/CIRCULATIONAHA.109.884031>
- Picard, R. W. (2000). *Affective computing* (1. paperback ed). Cambridge, Mass.: MIT Press.
- Picard, R. W. (2001). Affective Medicine: Technology with Emotional Intelligence. In *Future of Health Technology* (OIS Press).
- Prochaska, J. O., Butterworth, S., Redding, C. A., Burden, V., Perrin, N., Leo, M., ... Prochaska, J. M. (2008). Initial efficacy of MI, TTM tailoring and HRI's with multiple behaviors for employee health promotion. *Preventive Medicine*, 46(3), 226–231. <http://doi.org/10.1016/j.ypmed.2007.11.007>
- Prochaska, J. O., & Velicer, W. F. (1997). The Transtheoretical Model of Health Behavior Change. *American Journal of Health Promotion*, 12(1), 38–48. <http://doi.org/10.4278/0890-1171-12.1.38>
- Rachlin, H. (2012). Making IBM's Computer, Watson, Human. *The Behavior Analyst / MABA*, 35(1), 1–16.
- Ringh, M., Rosenqvist, M., Hollenberg, J., Jonsson, M., Fredman, D., Nordberg, P., ... Svensson, L. (2015). Mobile-Phone Dispatch of Laypersons for CPR in Out-of-Hospital Cardiac Arrest. *New England Journal of Medicine*, 372(24), 2316–2325. <http://doi.org/10.1056/NEJMoa1406038>
- Ripa, M. S. (2012). The ECG as decision support in STEMI. *Danish Medical Journal*, 59(3), B4413.
- Ritter, F. E., Baxter, G. D., & Churchill, E. F. (2014). *Foundations for Designing User-Centered Systems*. London: Springer London. Retrieved from <http://link.springer.com/10.1007/978-1-4471-5134-0>
- Roepke, A. M., Jaffee, S. R., Riffle, O. M., McGonigal, J., Broome, R., & Maxwell, B. (2015). Randomized Controlled Trial of SuperBetter, a Smartphone-Based/Internet-Based Self-Help Tool to Reduce Depressive Symptoms. *Games for Health Journal*, 4(3), 235–246. <http://doi.org/10.1089/g4h.2014.0046>
- Runti, H., Honka, A., & Chovarda, I. (2012). Biosignal processing methods to guide cardiac patients to perform safe and beneficial exercise for rehabilitation. Presented at the VII International Workshop on Biosignal Interpretation BSI2012, Como, Italy.
- Sahota, N., Lloyd, R., Ramakrishna, A., Mackay, J. A., Prorok, J. C., Weise-Kelly, L., ... the CCDSS Systematic Review Team. (2011). Computerized clinical decision support systems for acute care management: A decision-maker-researcher partnership systematic review of effects on process of care and patient outcomes. *Implementation Science*, 6(1), 91. <http://doi.org/10.1186/1748-5908-6-91>
- Saltin, B., Blomqvist, G., Mitchell, J. H., Johnson, R. L., Wildenthal, K., & Chapman, C. B. (1968). Response to exercise after bed rest and after training. *Circulation*, 38(5 Suppl), VII1–78.
- Salvi, D. (2014, January 30). *A model to develop a platform for personalized health applications* (Phd Thesis in Biomedical Engineering). Universidad Politecnica de Madrid, Madrid.
- Sankaran, S., Supraja, P., Luyten, K., & Coninx, C. (2015). Applying Behavior Change Theories For A Cardiac Rehabilitation Application. In *Workshop at British HCI 2015*. Newcastle: Culture Lab. Retrieved from <http://homepages.cs.ncl.ac.uk/james.nicholson/PersuasionHCI/Submissions/7.pdf>

- Scalvini, S., Zanelli, E., Comini, L., Tomba, M. D., Troise, G., & Giordano, A. (2009). Home-based exercise rehabilitation with telemedicine following cardiac surgery. *Journal of Telemedicine and Telecare*, 15(6), 297–301. <http://doi.org/10.1258/jtt.2009.090208>
- Schauerte, P., Bover, R., & Cleland, J. (2011, April 18). Validation Study: Guided Exercise for CAD patients. HeartCycle project, internal deliverable.
- Schwarz, N. (1990). Feelings as information: Informational and motivational functions of affective states. In *Handbook of motivation and cognition: Foundations of social behavior* (Guilford Press, Vol. 2, pp. 527–561). New York: R. Sorrentino & E. T. Higgins (Eds.).
- Scozzari, S., & Gamberini, L. (2011). Virtual Reality as a Tool for Cognitive Behavioral Therapy: A Review. In S. Brahnam & L. Jain (Eds.), *Advanced Computational Intelligence Paradigms in Healthcare 6. Virtual Reality in Psychotherapy, Rehabilitation, and Assessment* (Vol. 337, pp. 63–108). Springer Berlin Heidelberg. Retrieved from http://dx.doi.org/10.1007/978-3-642-17824-5_5
- Shneiderman, B. (2010). *Designing the user interface: strategies for effective human-computer interaction* (5th ed). Boston: Addison-Wesley.
- Sinek, S. (2011). *Start with why: how great leaders inspire everyone to take action* (Paperback ed. with a new preface and new afterword). New York, NY: Portfolio, Penguin.
- Skobel, E., Martinez-Romero, A., Scheibe, B., Schauerte, P., Marx, N., Luprano, J., & Knackstedt, C. (2014). Evaluation of a newly designed shirt-based ECG and breathing sensor for home-based training as part of cardiac rehabilitation for coronary artery disease. *European Journal of Preventive Cardiology*, 21(11), 1332–1340. <http://doi.org/10.1177/2047487313493227>
- Slovic, P., Finucane, M., Peters, E., & MacGregor, D. G. (2002). The Affect Heuristic. *Heuristics and Biases: The Psychology of Intuitive*, New York: Cambridge University Press, 397–420.
- Starks, K. (2014). Cognitive behavioral game design: a unified model for designing serious games. *Frontiers in Psychology*, 5. <http://doi.org/10.3389/fpsyg.2014.00028>
- Steele, C. M. (1988). The Psychology of Self-Affirmation: Sustaining the Integrity of the Self. In *Advances in Experimental Social Psychology* (Vol. 21, pp. 261–302). Elsevier. Retrieved from <http://linkinghub.elsevier.com/retrieve/pii/S0065260108602294>
- Stephens, Z. D., Lee, S. Y., Faghri, F., Campbell, R. H., Zhai, C., Efron, M. J., ... Robinson, G. E. (2015). Big Data: Astronomical or Genomical? *PLOS Biology*, 13(7), e1002195. <http://doi.org/10.1371/journal.pbio.1002195>
- Strecher, V. (2007). Internet methods for delivering behavioral and health-related interventions (eHealth). *Annual Review of Clinical Psychology*, 3, 53–76. <http://doi.org/10.1146/annurev.clinpsy.3.022806.091428>
- Teply, R. M., Packard, K. A., White, N. D., Hilleman, D. E., & DiNicolantonio, J. J. (2015). Treatment of Depression in Patients with Concomitant Cardiac Disease. *Progress in Cardiovascular Diseases*. <http://doi.org/10.1016/j.pcad.2015.11.003>
- Thomas, J. (2013). Empathic design: Research strategies. *Australasian Medical Journal*, 6(1), 1–6. <http://doi.org/10.4066/AMJ.2013.1575>
- Thomas Sarver, V. (1983). Ajzen and Fishbein's "Theory of Reasoned Action": A Critical Assessment. *Journal for the Theory of Social Behaviour*, 13(2), 155–164. <http://doi.org/10.1111/j.1468-5914.1983.tb00469.x>
- Thompson, P. D. (2003). Exercise and Physical Activity in the Prevention and Treatment of Atherosclerotic Cardiovascular Disease: A Statement From the Council on Clinical Cardiology (Subcommittee on Exercise, Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity). *Circulation*, 107(24), 3109–3116. <http://doi.org/10.1161/01.CIR.0000075572.40158.77>

- Thygesen, K., Alpert, J. S., Jaffe, A. S., Simoons, M. L., Chaitman, B. R., White, H. D., ... Mendis, S. (2012). Third Universal Definition of Myocardial Infarction. *Journal of the American College of Cardiology*, 60(16), 1581–1598. <http://doi.org/10.1016/j.jacc.2012.08.001>
- Triandis, H. (1977). *Interpersonal behaviour* (CA Brooks/Cole).
- Trivedi, M. H. (2004). The Link Between Depression and Physical Symptoms. *Primary Care Companion to The Journal of Clinical Psychiatry*, 6(suppl 1), 12–16.
- Turner, J., & Kelly, B. (2000). Emotional dimensions of chronic disease. *Western Journal of Medicine*, 172(2), 124–128.
- Vaingankar, J., Subramaiam, M., Lim, Y., Sherbourne, C., Luo, N., Ryan, G., ... Chong, S. (2012). From well-being to positive mental health: conceptualization and qualitative development of an instrument in Singapore. *Quality of Life Research*, 21(10), 1785–1794. <http://doi.org/10.1007/s11136-011-0105-3>
- Valenza, G., Gentili, C., Lanatà, A., & Scilingo, E. P. (2013). Mood recognition in bipolar patients through the PSYCHE platform: Preliminary evaluations and perspectives. *Artificial Intelligence in Medicine*, 57(1), 49–58. <http://doi.org/10.1016/j.artmed.2012.12.001>
- Valstar, M., Schuller, B., Smith, K., Eyben, F., Jiang, B., Bilakhia, S., ... Pantic, M. (2013). AVEC 2013: the continuous audio/visual emotion and depression recognition challenge (pp. 3–10). ACM Press. <http://doi.org/10.1145/2512530.2512533>
- van der Linden, J., Waights, V., Rogers, Y., & Taylor, C. (2012). A blended design approach for pervasive healthcare: Bringing together users, experts and technology. *Health Informatics Journal*, 18(3), 212–218. <http://doi.org/10.1177/1460458212442934>
- Varnfield, M., Karunanithi, M., Lee, C.-K., Honeyman, E., Arnold, D., Ding, H., ... Walters, D. L. (2014). Smartphone-based home care model improved use of cardiac rehabilitation in postmyocardial infarction patients: results from a randomised controlled trial. *Heart*. <http://doi.org/10.1136/heartjnl-2014-305783>
- Venkatesh, V., Morris, M. G., Davis, F. ., & Davis, G. . (2003). User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly*, 27, 425–478.
- Villalba Mora, E. (2008). *Holistic interaction model for people living with a chronic disease* (Phd Thesis). Universidad Politecnica, Madrid. Retrieved from <http://oa.upm.es/1804/>
- Vlek, C., & Jager, W. (n.d.). Modellen en strategieën voor gedragsverandering ter beheersing van collectieve risico's. *Nederlands Tijdschrift Voor de Psychologie*, 52, 174–191.
- Wang, W.-Y., Ko, L.-C., Huang, Y.-M., Liu, Y.-R., & Lin, S.-M. (2014). What is Affective Learning? In Y.-M. Huang, H.-C. Chao, D.-J. Deng, & J. J. Park (Eds.), *Advanced Technologies, Embedded and Multimedia for Human-centric Computing* (Vol. 260, pp. 177–181). Dordrecht: Springer Netherlands. Retrieved from http://link.springer.com/10.1007/978-94-007-7262-5_20
- Wannamethee, S. G., Shaper, A. G., & Walker, M. (2000). Physical Activity and Mortality in Older Men With Diagnosed Coronary Heart Disease. *Circulation*, 102(12), 1358–1363. <http://doi.org/10.1161/01.CIR.102.12.1358>
- Warren, T. Y., Barry, V., Hooker, S. P., Sui, X., Church, T. S., & Blair, S. N. (2010). Sedentary Behaviors Increase Risk of Cardiovascular Disease Mortality in Men: *Medicine & Science in Sports & Exercise*, 42(5), 879–885. <http://doi.org/10.1249/MSS.0b013e3181c3aa7e>
- Westmaas, J. L., GilRivas, V., & Cohen Silver, R. (2007). Interventions to Promote Health and Prevent Illness. In H. S. Friedman & R. C. Silver (Eds.), *Foundations of health psychology*. Oxford ; New York: Oxford University Press.
- WHO. (2013, March). Fact sheet N°317 about cardiovascular disease. Retrieved from <http://www.who.int/mediacentre/factsheets/fs317/en/>
- Wicks, P., Massagli, M., Frost, J., Brownstein, C., Okun, S., Vaughan, T., ... Heywood, J. (2010). Sharing Health Data for Better Outcomes on PatientsLikeMe. *Journal of Medical Internet*

- Research*, 12(2), e19. <http://doi.org/10.2196/jmir.1549>
- Widmer, R. J., Allison, T., Lerman, L., & Lerman, A. (2014). THE AUGMENTATION OF USUAL CARDIAC REHABILITATION WITH AN ONLINE AND SMARTPHONE-BASED PROGRAM IMPROVES CARDIOVASCULAR RISK FACTORS AND REDUCES REHOSPITALIZATIONS. *Journal of the American College of Cardiology*, 63(12), A1296. [http://doi.org/10.1016/S0735-1097\(14\)61296-1](http://doi.org/10.1016/S0735-1097(14)61296-1)
- Witte, D. R., Bots, M. L., Hoes, A. W., & Grobbee, D. E. (2000). Cardiovascular mortality in Dutch men during 1996 European football championship: longitudinal population study. *BMJ*, 321(7276), 1552–1554. <http://doi.org/10.1136/bmj.321.7276.1552>
- World Health Organization Staff. (2002). *Integrated Management of Cardiovascular Risk Report of a Who Meeting, Geneva, 9-12 July 2002*. Geneva; Herndon: World Health Organization Stylus Publishing, LLC [Distributor]. Retrieved from <http://libproxy.uregina.ca:2048/login?url=http://search.ebscohost.com/direct.asp?db=a9h&jid=22GA&scope=site>
- Worringham, C., Rojek, A., & Stewart, I. (2011). Development and Feasibility of a Smartphone, ECG and GPS Based System for Remotely Monitoring Exercise in Cardiac Rehabilitation. *PLoS ONE*, 6(2), e14669. <http://doi.org/10.1371/journal.pone.0014669>
- Wright, A., Sittig, D. F., Ash, J. S., Sharma, S., Pang, J. E., & Middleton, B. (2009). Clinical Decision Support Capabilities of Commercially-available Clinical Information Systems. *Journal of the American Medical Informatics Association*, 16(5), 637–644. <http://doi.org/10.1197/jamia.M3111>
- Yang, C.-H., Maher, J. P., & Conroy, D. E. (2015). Implementation of Behavior Change Techniques in Mobile Applications for Physical Activity. *American Journal of Preventive Medicine*, 48(4), 452–455. <http://doi.org/10.1016/j.amepre.2014.10.010>
- Yellowlees, P., Richard Chan, S., & Burke Parish, M. (2015). The hybrid doctor–patient relationship in the age of technology – Telepsychiatry consultations and the use of virtual space. *International Review of Psychiatry*, 1–14. <http://doi.org/10.3109/09540261.2015.1082987>
- Yusuf, S., Hawken, S., Ôunpuu, S., Dans, T., Avezum, A., Lanas, F., ... Lisheng, L. (2004). Effect of potentially modifiable risk factors associated with myocardial infarction in 52 countries (the INTERHEART study): case-control study. *The Lancet*, 364(9438), 937–952. [http://doi.org/10.1016/S0140-6736\(04\)17018-9](http://doi.org/10.1016/S0140-6736(04)17018-9)
- Zvárová, J., Tomecková, M., Stefek, M., Boudík, F., & Zvára, K. (1997). Decision support and data analysis tools for risk assessment in primary preventive study of atherosclerosis. *Studies in Health Technology and Informatics*, 43 Pt B, 625–628.

10 Annexes

10.1 Portable Station pre-exercise questionnaires.

The questionnaire investigates the presence of symptoms. Depending on the result the Portable Station will continue or not the exercise. In case of symptoms the system will send an alert to the central system to notify to the health professional the situation. The following diagram shows the symptoms check questionnaire.

Figure 140: Figure 141: Exercise pre symptoms questionnaire

The following questionnaire checks if the blood pressure is in the safe rate for exercising. In case that the ranges are not safe the system investigate the medication

intake and in case that patient did not take the short acting medication (e.g. Beta Blocker) he suggest to take the medication and to wait at least 15 minutes. After that time, system asks to check again the blood pressure and if is not on the safe range the exercise is aborted and a message on the screen recommend to the user to not perform the exercise and contact the GP. The system. When synchronized the portable station will send this information to the Portable Station that will notify the case to the professional platform.

Figure 142: pre-exercise blood pressure check questionnaire workflow.

10.2 Misconception questionnaire

NHS Lothian defined the misconception questionnaire. The following table shows the questions and the corrective instant feedback that will be given to the patient. A wrong answer also triggers the scheduling of future recommendations to reinforce the positive belief. The questionnaire has been taken from the deliverable of the project.

Misconception questionnaire						
Topics: Lifestyle, Stress/psycho wellbeing						
Question		IF the answer is	Corrective feedback	Message that will be send in the next days	Feedback if response is correct	Priority
1	Stress caused my heart attack	AGREE	No, Stress didn't cause your heart attack but learning to manage stress can help your recovery. For example by, making time for regular exercise, learning to relax and avoiding bad habits such as smoking.	Remember: stress didn't cause your heart attack but learning to manage stress can help your recovery. For example by, making time for regular exercise, learning to relax and avoiding bad habits such as smoking	You're right!	1
2	Coronary artery disease is often caused by lifestyle	DISAGREE	The coronary artery disease IS often caused by lifestyle! However, you can change an unhealthy lifestyle and reduce your chances of having another heart attack	Remember: the coronary artery disease IS often caused by lifestyle! However, you can change an unhealthy lifestyle and reduce your chances of having another heart attack	You're right!	1

3	I should avoid excitement	AGREE	No. Excitement that is enjoyable is safe and necessary for good health	Remember: excitement that is enjoyable is safe and necessary for good health	You're right!	1
4	I should avoid all stress.	AGREE	No, if you avoid all stress you might be protecting yourself unnecessarily from things which are enjoyable or confidence building	Remember: if you avoid all stress you might be protecting yourself unnecessarily from things which are enjoyable or confidence building	You're right!	1
5	I should carry on as my heart attack had never happened	AGREE	No, you need to make some changes to your lifestyle	Remember: you need to make some changes to your lifestyle	You're right!	1
6	I'll probably have another heart attack	AGREE	No. After a heart attack, many people become stronger, fitter and happier than they have been for years.	Remember: after a heart attack, many people become stronger, fitter and happier than they have been for years.	You're right!	1
7	Life can sometimes be better than before a heart attack	DISAGREE	Many people who have been on cardiac rehabilitation programmes have said that their life HAS improved after their heart attack	Remember: Many people who have been on cardiac rehabilitation programmes have said that their life HAS improved after their heart attack	You're right!	1
8	Eating a healthier diet can prevent another heart attack	DISAGREE	Not only can eating a healthier diet reduce your risk of having another heart attack, it can help to control blood pressure too	Remember: Not only can eating a healthier diet reduce your risk of having another heart attack, it can help to control blood pressure too	You're right!	1

Table 64: Misconception questionnaire about lifestyle

10.3 The IMAGE Sensor

The following images provide a description of the IMAGE sensor that was developed within the framework of the HeartCycle project. Two partners have been involved in this work: CSEM that developed a dry contact sensor and CLOTH+ that developed the garment in which the sensors will be plugged.

Figure 143: Leads of the IMAGE sensor

Figure 144: Images of the Garment

Figure 145: The electronic component of the IMAGE sensor

The sensor extract the following parameters:

- RR interval (RR) – from ECG, about 1 value per second, 8 bits
- Heart Rate (HR) – from ECG – every 5 seconds, 8 bits
- Breath rate (BR) – every 15 seconds, 8 bits
- Breath amplitude (BA) – every 5 seconds, 8 bits
- Peripheral oxygen saturation (SpO2) – every 1 second, 8 bits
- Activity level – every 5 seconds, 8 bits
- Activity classification – every 5 seconds, classes: lying, standing, resting, walking, running
- Energy consumption – every 1 minute, 8 bits

10.4 Questionnaires

This section shows the questionnaires that have been used in the Guided Exercise study.

GUIDED EXERCISE QUESTIONNAIRE

Annex B B.1.1 KNOWLEDGE QUESTIONNAIRE (BEGINNING AND END OF THE STUDY)

This questionnaire should be answered by the patients at the beginning and end of the clinical study. Instructions to respondents are included in the questionnaire.

1. Please mark each of the following statements as TRUE (T) or FALSE (F):

A heart infarction is caused by the blocking of the blood flow to a part of the heart

☐ True ☐ False

In a heart infarction a part of the heart gets too little oxygen

☐ True ☐ False

Physical training can reduce the symptoms in angina pectoris

☐ True ☐ False

After a typical heart infarction the patient must remain physically inactive for the first 6 weeks

☐ True ☐ False

A heart infarction is better tolerated if physical fitness is good

☐ True ☐ False

2. Please select the correct answer to the following questions:

1. The function of the coronary arteries is to

☐ Supply the heart muscle with blood and oxygen

☐ Connect the heart to the lungs

☐ Maintain an even rate of the heart

☐ Circulate blood to the rest of the body

☐ I don't know

2. Atherosclerosis is

☐ Chest pain not relieved by medication

☐ A clot in the coronary artery

☐ A build-up of cholesterol and other materials inside the arteries

☐ An inflammation around the sac covering the heart

☐ I don't know

GUIDED EXERCISE QUESTIONNAIRE

Annex B B.1.1 KNOWLEDGE QUESTIONNAIRE (BEGINNING AND END OF THE STUDY)

3. Angina or chest pain is caused by

- ☐ A muscle spasm of the chest
- ☐ A blood clot in the lungs
- ☐ Leaking of blood around the heart
- ☐ Lack of oxygen to the heart muscle
- ☐ I don't know

4. What type of fat does increase the levels of cholesterol in the blood?

- ☐ Polyunsaturated fat (corn oil, sunflower, soya, etc.)
- ☐ Saturated fat (lard, butter)
- ☐ Monounsaturated fat (Oily fish)
- ☐ I don't know

5. Warm up before exercise is important because it:

- ☐ Prevents injury to muscles
- ☐ Extends the exercise time period
- ☐ Reduces body fat
- ☐ Builds muscle strength
- ☐ I don't know

6. The cool down phase

- ☐ Increases blood pressure
- ☐ Decreases heart rate gradually
- ☐ Increases the chance of skipped heart beats
- ☐ Decreases the chance of having a heart attack
- ☐ I don't know

7. In general as the intensity of exercise increases,

- ☐ Blood pressure decreases
- ☐ Breathing rate decreases
- ☐ Heart rate increases
- ☐ I don't know

GUIDED EXERCISE QUESTIONNAIRE

Annex B B.1.1 KNOWLEDGE QUESTIONNAIRE (BEGINNING AND END OF THE STUDY)

8. What action should be taken when symptoms occur during exercise (chest discomfort, shortness of breath, etc.)?

- ☐ Heart rate should be kept in the heart rate range
- ☐ The heart rate can be exceeded
- ☐ The exercise should be gradually discontinued
- ☐ Exercise can be done even if symptoms occur
- ☐ I don't know

9. After your exercise session it is acceptable to feel

- ☐ Pleasantly tired
- ☐ Chest tightness and heaviness
- ☐ Your heart racing
- ☐ Dizzy and sweating
- ☐ I don't know

10. What are three major risk factors associated with the development of coronary artery disease that can be controlled?

☐ Smoking	☐ Cholesterol
☐ High blood pressure	☐ Obesity
☐ Age	☐ Diabetes
☐ Stress	☐ Sex
☐ Heredity	☐ I don't know

GUIDED EXERCISE QUESTIONNAIRE

HeartCycle

Annex B B.1.1 KNOWLEDGE QUESTIONNAIRE (BEGINNING AND END OF THE STUDY)

3. Please score from 0 to 10 the following questions:

1. How much does your illness affect your life?

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐

Not affected
at all

Severely
affects my life

2. How much control do you feel you have over your illness?

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐

Absolutely no
control

Extreme amount
of control

3. How well do you feel you understand your illness?

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐

Don't understand
at all

Understand
very clearly

4. How concerned are you about your illness?

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐

Not concerned
at all

Extremely
concerned

5. How much does your illness affect you emotionally? (E.g. does it make you feel angry, scared, upset or depressed?)

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐

Not emotionally
affected at all

Extremely emotionally
affected

6. How much do you think exercise can help to cope with your illness?

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐

Nothing at all

Extremely helpful

GUIDED EXERCISE QUESTIONNAIRE

Annex B B.2.1 FIRST QUESTIONNAIRE:@ THE HOSPITAL WHEN JOINING THE STUDY

This questionnaire should be answered by the patients at the hospital when joining the clinical study. Instructions to respondents are included in the questionnaire.

1- What is your general impression of the guided exercise (GEx) concept: what do you like or don't like about it? Why?

I like...

I don't like...

2- Do you consider the guided exercise concept to be:

Not interesting at all 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Very interesting

Scary 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Not scary

Not enjoyable 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Enjoyable

Dull 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Stimulating

Difficult to use 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Easy to use

3- Do you think that the guided exercise concept would be easy to fit into your everyday life?

Very difficult to fit in my daily life 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ No problem to fit in my daily life

4- Why do you think it is, or isn't easy to fit into your everyday life?

GUIDED EXERCISE QUESTIONNAIRE

HeartCycle

Annex B B.4.1 1ST QUESTIONNAIRE (AT HOSPITAL)

This questionnaire should be answered by the patients at the hospital when joining the clinical study. Instructions to respondents are included in the questionnaire.

Before the hospitalization, during the previous three months:

1- How many times per week were you active enough to break a sweat?

2- When you exercise, how long were you active? minutes

3- On a scale from 1 (very low) to 10 (very intense), how intense was your daily typical activity?

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐

Very Low

Very Intense

4- How many years have you been exercising?

Before the hospitalization, during the previous three months, how many minutes per week did you spend doing the following activities?

Running/Jogging minutes

Walking minutes

Aerobic minutes

Racquet Sports minutes

Swimming minutes

Weight Training minutes

Biking minutes

Skiing minutes

Stair Climber minutes

Yoga/Pilates minutes

Other minutes

GUIDED EXERCISE QUESTIONNAIRE

Annex B B.2.2 SECOND QUESTIONNAIRE: AT HOME, AFTER ONE WEEK OF USE

This questionnaire should be answered by the patients at home after one week of using the Guided Exercise system. Instructions to respondents are included in the questionnaire.

1- Now that you have tried the guided exercise concept at home, what is your general impression? What do you like or don't you like about it? Why?

I like...

I don't like...

2- Do you consider the guided exercise concept to be:

Not interesting at all 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Very interesting

Scary 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Not scary

Not enjoyable 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Enjoyable

Dull 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Stimulating

Difficult to use 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Easy to use

3- Do you think that the guided exercise concept would be easy to fit into your everyday life?

Very difficult to fit in my daily life 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ No problem to fit in my daily life

4- Why do you think it is, or isn't easy to fit into your everyday life?

GUIDED EXERCISE QUESTIONNAIRE

HeartCycle

Annex B B.2.2 SECOND QUESTIONNAIRE: AT HOME, AFTER ONE WEEK OF USE

5- What is your general impression of the shirt of the guided exercise concept: what do you like or don't you like about it? Why?

6- Do you consider the shirt to be:

Not interesting at all	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Very interesting
Scary	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Not scary
Very unpleasant	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Very pleasant
Dull	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Stimulating
Difficult to use	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Easy to use
Uncomfortable	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Comfortable

7- What is your general impression of the Portable Station (the PDA) of the guided exercise concept: what do you like or don't you like about it? Why?

8- Do you consider the Portable Station (the PDA) to be:

Not interesting at all	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Very interesting
Scary	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Not scary
Very unpleasant	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Very pleasant
Dull	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Stimulating
Difficult to use	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Easy to use

GUIDED EXERCISE QUESTIONNAIRE

Annex B B.2.2 SECOND QUESTIONNAIRE: AT HOME, AFTER ONE WEEK OF USE

9- What is your general impression of the Patient Station (the tablet PC) program of the guided exercise concept: what do you like or don't you like about it? Why?

10- Do you consider the PC program to be:

Not interesting at all 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Very interesting

Scary 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Not scary

Very unpleasant 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Very pleasant

Dull 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Stimulating

Difficult to use 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Easy to use

11- How many days after discharge from hospital could you first use HeartCycle in your home?

Days

GUIDED EXERCISE QUESTIONNAIRE

Annex B B.2.3 THIRD QUESTIONNAIRE @ HOME: ONE MONTH LATER

This questionnaire should be answered by patients at home after one month of using the Guided Exercise system. Instructions to respondents are included in the questionnaire.

1 - Now that you have been using the guided exercise concept at home for a month, what is your general impression? What do you like or don't like about it? Why?

I like...

I don't like...

2 - Do you consider the guided exercise concept to be:

Not interesting at all 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Very interesting

Scary 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Not scary

Not enjoyable 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Enjoyable

Dull 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Stimulating

Difficult to use 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Easy to use

3 - Do you think that the guided exercise concept easily fits into your everyday life?

Very difficult to fit in my daily life 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ No problem to fit in my daily life

4 - Why do you think it is, or isn't easy to fit into your everyday life?

GUIDED EXERCISE QUESTIONNAIRE

Annex B B.2.3 THIRD QUESTIONNAIRE: @ HOME: ONE MONTH LATER

5- What is your general impression of the shirt of the guided exercise concept: what do you like or don't you like about it? Why?

6- Do you consider the shirt to be:

Not interesting at all	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Very interesting
Scary	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Not scary
Very unpleasant	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Very pleasant
Dull	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Stimulating
Difficult to use	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Easy to use
Uncomfortable	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Comfortable

7- What is your general impression of the Portable Station (PDA) of the guided exercise concept: what do you like or don't you like about it? Why?

8- Do you consider the Portable Station (PDA) to be:

Not interesting at all	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Very interesting
Scary	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Not scary
Very unpleasant	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Very pleasant
Dull	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Stimulating
Difficult to use	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Easy to use

GUIDED EXERCISE QUESTIONNAIRE

Annex B B.2.3 THIRD QUESTIONNAIRE-@ HOME: ONE MONTH LATER

9- What is your general impression of the Patient Station (Portable station) program of the guided exercise concept: what do you like or don't you like about it? Why?

10- Do you consider the Patient Station (Tablet PC) program to be:

Not interesting at all	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Very interesting
Scary	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Not scary
Very unpleasant	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Very pleasant
Dull	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Stimulating
Difficult to use	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Easy to use

11- The Guided Exercise system increased my motivation to exercise

Fully disagree	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Fully agree
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12- It felt safer to exercise with the Guided Exercise system guiding me than without it

Fully disagree	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Fully agree
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13- The Guided Exercise system helped me to exercise within the heart rate range prescribed by my physician

Fully disagree	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Fully agree
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14- The exercise session feedback provided by the Guided Exercise system after each exercise session was most of the time motivating

Fully disagree	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Fully agree
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15- The exercise session feedback provided by the Guided Exercise system after each exercise session helped me to understand how I could improve compliance to my exercise prescription

Fully disagree	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	Fully agree
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GUIDED EXERCISE QUESTIONNAIRE

HeartCycle

Annex B 8.4.3 3RD QUESTIONNAIRE - 6 MONTHS AFTER THE STUDY

This questionnaire should be answered by the patients six months after the finalization of the Clinical Study. Instructions to respondents are included in the questionnaire.

Before the hospitalization, during the previous three months:

1- How many times per week were you active enough to break a sweat?

2- When you exercise, how long are you active? minutes

3- On a scale from 1 (very low) to 10 (very intense), how intense is your daily typical activity?

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐
Very Low Very Intense

During the last 6 months, how many minutes per week did you spend doing the following activities?

Running/Jogging minutes

Walking minutes

Aerobic minutes

Racquet Sports minutes

Swimming minutes

Weight Training minutes

Biking minutes

Skating minutes

Stair Climber minutes

Yoga/Pilates minutes

Other minutes

4- Are you satisfied with your level of physical activity?

- ☐ Yes, I think that is sufficient
- ☐ No, I would like to perform more exercises
- ☐ No, I would like to have a system like guided exercise system that supports me during the exercise session
- ☐ Yes, I don't need to exercise
- ☐ Other (please, describe it)