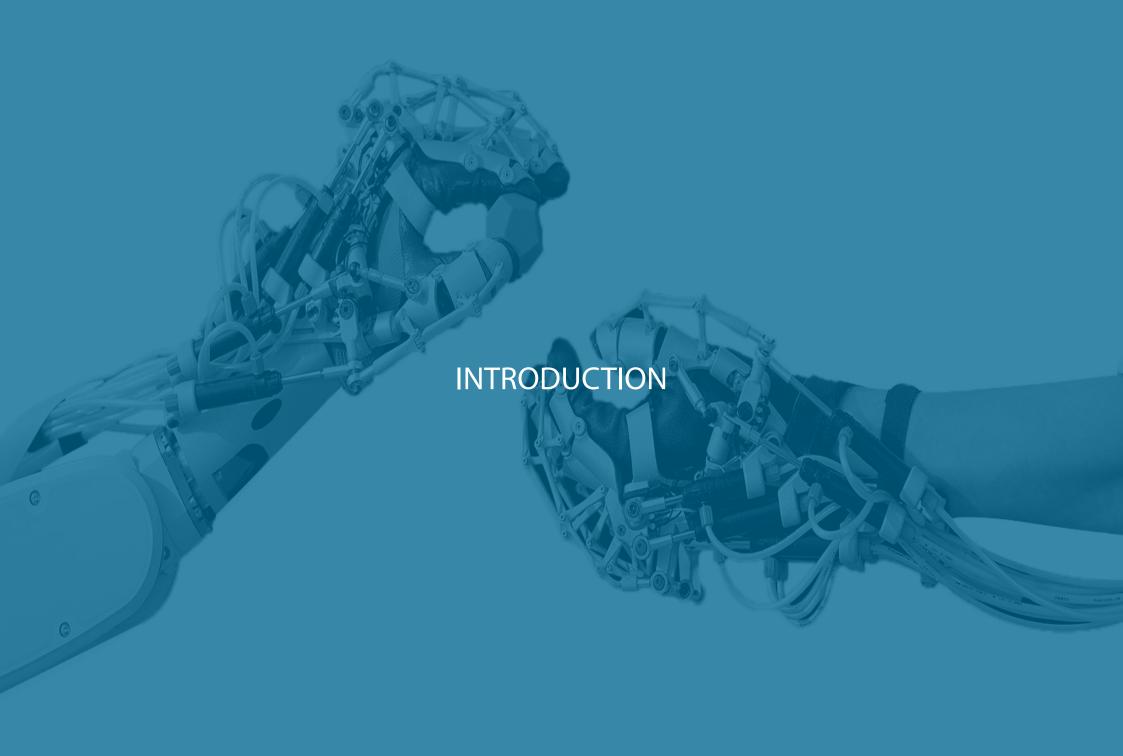
PREPARING FOR A SUSTAINABLE FUTURE WITH ASSISTED REHABILITATION

POWERED BY NOKIA



NOKIA LASSISTED REHABILITATION Personal motivation

PERSONAL MOTIVATION

During my time at Nokia I had the pleasure of working in a team that challenged the status quo and was always searching to make the best design. Whether it was to learn about new techniques to improve the life of the people we created products for or when it was to search for ways to create better products for the environment. This was the inspiration for me when I had to decide on the path of my thesis, to find a way to make sustainable designed products without compromising on the benefits it gives to human life.

This report describes the project background, work method as well as the final result of my master thesis in Advanced Product Design at Umeå Institute of Design.

The prevalent question of this thesis is "how can we improve life". There is no simple answer to this question, but we can at least say that it involves maximizing the human life in terms of length and quality.

The thesis question which I wished to tackle in this project was to see if and how so called "assistive devices" and smart textiles in the healthcare area can help us to achieve these goals and in which way?

I intend to explore how assistive devices can improve the treatment and rehabilitation process in the professional environment, and what impacts these devices can have on the overall experience (life improvement) of the patient.

The findings of this exploration was used to establish a concept that showed what role a technological driven global player such as Nokia can play in the healthcare environment, and in terms of how a product/service can be developed and implemented in this market segment.

COLLABORATION PARTNERS

This project was a collaboration between the Umeå Institute of Design, in Umeå, Sweden and Nokia Technologies in Espoo, Finland. The collaboration was done in support of the Masters thesis of Rik Oudenhoven and was placed under a non disclosure agreement with the company. Listed below are the people involved and their role in the project.



Umeå Institute of Design, Umeå University, Umeå Sweden

Project lead

Rik Oudenhoven rik_oudenhoven1@hotmail.com

Program director

Thomas Degn Thomas.degn@umu.se

Internal tutor

Oscar Björk Oscar.bjork@umu.se

External tutor

Simon Fredriksson simon@above.se



Nokia tech, Nokia, Espoo, Finland

Contact

Alejandro Sanguinetti Alejandro.sanguinetti@nokia.com

Contact

Ignacio Davola Ignacio.davola@nokia.com

Collaboration partner

THE COMPANY

Nokia was founded in 1865. It started out as a pulp mill, but has changed its focus on various industries in its time of existence. Since 1990 they focused mostly on large-scale telecommunications, technology development and licensing. Having assisted in the development of GSM, 3G and currently 5G, Nokia is a major contributor to the mobile phone industry. In 2011 Nokia entered a pact with Microsoft to exclusively use Windows Phone for future smart phones. Nokia mobile phone's business was bought by Microsoft with the deal being completed on 25th of April 2014.

Since then Nokia started focusing (amongst other areas) on healthcare, after the acquisition of the French digital health company Withings in May 2016. In the field of digital healthcare, Nokia aimed to make two clear divisions in terms of market and orientation: a professional area named Patient Care, and an area where they target consumers and where the product portfolio of Withings is to be found, named Preventive Healthcare. Currently Nokia is comprised of the following business groups:

MOBILE NETWORKS: Focuses on delivering a high quality and more reliable mobile broadband experience. The fourth largest telecom manufacturer.

FIXED NETWORKS: More bandwidth in more places giving communities more access to the world.

IP/OPTICAL NETWORKS: Massively scalable networks securely connecting everyone and everything to the Cloud.

APPLICATIONS & ANALYTICS: Intelligent software platforms optimizing and automating network performance.

NOKIA TECHNOLOGIES: Connected health devices; professional Virtual Reality capture and broadcast; and brand, intellectual property and technologies.

The company has it's headquarter located in Espoo Finland, and the headquarter of Nokia Technologies in San Fransisco (USA). The company is active in over one hundred countries worldwide and employed roughly 101 000 employees by the end of 2016. The net sales closed of in that year with roughly 23,6 billion euro with an investment in research and development of 4,9 billion euro¹.

VISION

As a well known motto for the past of Nokia, Connecting People used to be the company's mission defining most of its designs. Hence the shift to digital health-care and virtual reality, Nokia switches its mission as well towards enabling people to achieve more than before, aiming to empower what it means to be Human. It is Nokia's mission to enable human possibilities through a connected world:

"We create the technology to connect the world. Powered by the research and innovation of Nokia Bell Labs, we serve communications service providers, governments, large enterprises and consumers with the industry's most complete end-to-end portfolio of products, services and licensing. From the enabling infrastructure for 5G and the Internet of Things ("IoT") to emerging applications in Virtual Reality ("VR") and digital health, we are shaping the future of technology to transform the human experience.²"

The aim is to give people the tools to get the most out of certain activities. In the field of healthcare one of the main missions is related to the continuously increasing number of seniors in the society. The goal is to enable them to keep the independence they had throughout their lives, and avoid burdening their care takers and loved ones.

NOKIA

I ASSISTED REHABILITATION

Table of content

1.	INTRODUCTION			Research		5	Concept development	
	Personal motivation	3		ACL Injuries	38		Design guidelines Nokia	99
	Collaboration partners	3		Gender inequality	39		Design guidelines sustainability	100
	The company	4		ACL Diagnosis	40		Defining the experience	102
	Table of content	5		ACL Treatment	42		Moodboard patients & athlete	104
	145.6 6. 66.1.6.1.6			Minimizing problems	43		2D Concept exploration	106
2	WHY			Current rehabilitation	44		3D concept exploration	108
2.				Assistive devices	46		Prototyping and testing	110
	Background	8		Market overview	48		UI exploration	112
	Mission statement	8		Interview surgeons	50		Validation of concept	114
	Health	9		Interview therapists	52		Sustainability exploration	116
	Diseases / conditions	10		Interview patients	54		Detailing	118
	Treatment	12		Patient journey	56		-	
	Beyond treatment	12		Interview coaches	58	6	The concept	
	Quality over quantity	13		Problem analysis	60	_	Meet Ara	121
				Data to collect	62		The components	122
	Rehabilitation	14		Needs in rehabilitation	65		Onboarding	124
	Current rehabilitation process	15		Needs for surgeons & therapists	66		Feedback	125
	Rehabilitation stakeholders	16		Needs for prevention	67		Patient app	126
	The business in rehabilitation	17		Insights	68		Therapist app	129
				Scenario's	70		Prevention	130
	Opportunities	18		Design opportunity	73		Prevention app	131
	Personalization	19		Project frame	75		Charging	132
	Connected healthcare	21		Conclusion	76		Packaging	134
	Trends in healthcare	22		Goals and wishes	77		Sustainability	136
	Trends in robotics	23					Conclusions	142
	Human centered	24	4	What				
	Nokia's capabilities	25		Approaching the challenge	80	7	Appendices	
				Initial ideation	81	,	Reflection	145
	Assisted rehabilitation	29		Brainstorming	82		References	146
	Robotics in rehabilitation	30		Concepts	84		Planning	147
	Chosen direction	33		Validation	90		Concept and product overview	147
				Chosen direction	91		Technology overview	150
3	How			Refining the scenario	92		Persona's	150
	Knee injuries	36		Defining the ecosystem	94		Patient journeys	156
	Relevance of the project	36		Refining the ecosystem	97		Touch-point mapping	166
	• •				, ,		тойст-рошт шарріпд	100



NOKIA

Why - Abstract

ABSTRACT

Health is more than just being free from disease. It refers to a state of good physical and mental being. A well adjusted, positive individual who is able to undertake the tasks of their day without much difficulty. This means that health is a resource to support an individual's function in society. A healthy lifestyle provides the means to lead a full life.

In general we can say that almost all of us start out as being healthy. But when we start to feel sick or an incident happens, we will get diagnosed and a appropriate treatment will be described to make us "healthy" again. This period of diagnose and treatment is what we define as rehabilitation.

Unfortunately most of the current healthcare system is only focused on curring diseases and conditions. The problem with this is that only part of the human health is restored in the process. Recently a counter movement to this evidence-based medicine has arisen within nursing called person-centered care, which argues that in distancing itself from the patient, cure-centered medicine is failing to provide for human experience (Kvale & Bondevik, 2008). This movement suggest that there is a need to move beyond this cure centered perspective to a more holistic and person-centered healthcare. It suggest that we need to look beyond just the curing of patients and start threating their physical and mental conditions as well. It is time healthcare starts focusing on improving and maintaining not only the quantity of life, but also the quality.

It is for these reasons that healthcare exists. To help us as humans face and deal with the issues/limitations we might have to maintain/regain the optimal state of health possible. For these reasons I believe there to be a possibility for Nokia to focus more on the rehabilitation of physical diseases in healthcare, since the curing part is already well covered, and this part includes a lot of rehabilitation in collaboration between the patient and healthcare providers.

If we look at the general trends that we face for healthcare to stay feasible, it has to move from being acute and reactive to being proactive and preventive. It has to help people with long-term conditions manage their conditions, and prevent people from getting these situations in the first place. A great tool for this is the increase in so called *connected healthcare*.

Technologies such as these are starting to make promising changes in the area of rehabilitation. Through long-term monitoring and accurate data about the performance of exercises it allows people to improve their rehabilitation constantly and will in the long run lead to better results. It enables for personalization for each individual whilst still keeping the amount of time healthcare personnel has to invest in the patient to a minimum.

If we look at the trends and the capabilities of a company such as Nokia, it is these types of assistive and measuring tools that are very interesting to explore. The benefit with assisted rehabilitation in comparison with normal rehabilitation is that we can skip the periods in which the patient is forced to compensate. He/she can go directly from the initial recovery to independent and healthy functioning. By doing so they will create fewer bad habits. This will lead to a better result whilst optimizing the process both in time and cost and human suffering.

Why - Mission

BACKGROUND

Health is more than just the absence of diseases and impairments. It encompasses both the physical, mental and social wellbeing of a person³, and requires an unique approach for each individual. Nokia is not a stranger in the healthcare market. With the acquirement of the French company Withings they have acquired a solid insights in the personal healthcare segment.

The goal of this thesis was to explore the possibilities for a technology driven company such as Nokia, to not only focus on the personal healthcare, but immerse themselves on the professional healthcare market with business to business products.

Together we (Nokia tech and I) have set out the following motivation to create value and optimize the overall healthcare setting for both patient and practitioner:

WHY To innovate for patients to recover their health in a faster and easier way through a personalized and humanized rehabilitation plan.

HOW Through constant sensing we will provide an increased amount of insights for practitioners to take data and human driven decisions. This will result in a more informed, easier, faster and reassured rehabilitation experience for the patient.

WHAT Designing a concept that shows the future of assisted rehabilitation and how this can improve the patient treatment and experience.

MISSION STATEMENT

"Connecting People" is perhaps one of the most iconic motto's from the past. It used to be the company's mission defining most of its products, and hence explains the shift from mobile phones, to a network/service provider, to Virtual Reality, and finally to Digital healthcare. Nokia has defined their vision for healthcare as follows:

"Our vision is to reinvent healthcare by transforming the relationship people have with their wellbeing. We will lead the way towards vast improvements in collective health by unlocking the potential of connected health devices - revealing a new level of connectivity between individuals, their health, and healthcare professionals⁴."

It is Nokia's belief that the key to making a big impact on health is by providing the tools people need to make small but meaningful changes over time. For Nokia, the answers to healthcare's biggest challenges center on connecting people, practitioners, researchers and care takers with data, and data generated insights that can effect societal health improvements.

Through connected devices, connected communities and connected health solutions, Nokia seeks to improve the overall quality of life of patients and empower them in the process.

To answer the question what role Nokia can play in the Business to Business health-care market, the mission statement is defined as follow:

We will innovate for patients to recover their health in a faster and easier way through a personalized and humanized rehabilitation plan.

NOKIA

Why - Health

HEALTH

Health is more than just being free from disease. It refers to a state of good physical and mental being. A well adjusted, positive individual who is able to undertake the tasks of their day without much difficulty. This is in contrast to the general opinion where health simply means the 'absence of disease' or physical fitness. The best description of health is from the World Health Organization in 1948 and 1986:

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

"It is a resource for everyday life, not the objective of living. Health is a positive concept emphasizing social and personal resources, as well as physical capacities."

This means that health is a resource to support an individual function in society. A healthy lifestyle provides the means to lead a full life. More recently, researchers have defined health as the ability of a body to adapt to new threats and infirmities. They base this on the idea that modern science has dramatically increased human awareness of diseases and how they work in the last few decades. In health we can make a differentiation between the following areas:

MENTAL HEALTH. Refers to emotional, social, and psychological wellbeing. Mental health is as important as physical health to an active lifestyle.

PHYSICAL HEALTH. Bodily functions are working optimal, due not only to lack of disease, but also to regular exercise, balanced nutrition, and adequate rest.

Physical and mental health are often linked. If illness affects a persons ability to complete tasks, this may lead to stress, for example, due to money problems.

WHAT MAKES YOU UNHEALTHY?

It is obvious that you are unhealthy when diagnosed with cancer, lose control over your muscles after a stroke, put on dialysis or flattened by a heart attack. These types of health crisis will make you aware that something is wrong and in most cases can motivate someone to make healthy lifestyle changes, aimed at bringing balance back to your body.

So what does it truly mean to be unhealthy? In general it can be said that being 'unhealthy' is when suffering from one of the following cases:

DISEASE: An interruption or disorder of body functions, systems, or organs.

IMPAIRMENT: Any loss or abnormality of psychological, physiological, or anatomical structure or functions.

DISABILITY: Any restriction or lack of the ability to perform an activity in the manner or within the range considered normal for a human being.

FUNCTIONAL CAPACITIES: The ability possessed by the individual to meet or perform the behaviors, tasks, and roles expected in a social environment.

FUNCTIONAL LIMITATIONS: The inability to perform certain behaviors, fulfill certain tasks, or meet certain social roles as a consequence of a disability.

It is for these reasons that healthcare exists. To help us as humans face and deal with the issues and limitations we might have to maintain/regain the optimal state of health possible. This for example can be done through the help of a doctor/nurse in the hospital for your physical illnesses or talking with a therapist to face your psychological problems.

Why - Health

DISEASES / CONDITIONS

Disease is as broad a term as health is - but simply it is a disorder or malfunction of the mind or body that impairs the normal functioning of the body. Diseases usually have more than one factor, for example an attempted suicide might be a self-inflicted disease but is also a physical one. Acute diseases are sudden onset, rapidly changing disease with a short life span, whereas chronic diseases can continue for a long time (months or years).

In humans, disease is often used more broadly to refer to any condition that causes pain, dysfunction, distress, social problems, or death to the person afflicted, or similar problems for those in contact with the person. In this broader sense, it includes injuries, disabilities, disorders, syndromes, infections, isolated symptoms, deviant behaviors, and atypical variations of structure and function. Diseases can affect people not only physically, but also emotionally, as contracting and living with a disease can alter the affected person's perspective on life.

In developed countries, diseases such as chronic heart disease and cancer are much more common than in third world countries. This is as a result of developed countries having better healthcare, including vaccination and treatment against serious infectious diseases such as measles, polio, tuberculosis and malaria. Also, smoking and foods high in fat are more prevalent in developed countries.

Attitudes and laws towards drinking, smoking or obesity may affect a country overall occurrence of disease for example, the amount of people suffering from lung cancer are expected to fall following the United Kingdom's smoking ban in public places from 2007 as it stimulated people to quit and reduces the effects of so called "second hand" smoking.

This shows that not only the cause of the disease is important to keep in mind when trying to make people more healthy, but also the impacts of lifestyle and society.

After all the less people that smoke, the less tar you get into the lungs. For us as designers to come up with a solution for diseases, we can make a differentiation between the ones that need to be cured by medication or surgery, such as cancer, the flu or rabies, or the ones that also need some form of physical therapy, such as strokes, spinal cord injuries, bone fractures or hernia's.

The other separation we can make is in curability. If it is a degenerative or inherited disease they are often non-curable and the patient will need to be threated for their entire life.

In the graph to the right, diseases have been separated into nine categories. The separation is made on how they interact/come to be in the patients overall body/ health. What caused them, and what are some of the most common examples of each category. Finally there is a list with the most common ways to treat diseases in this category.

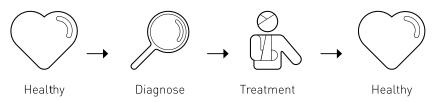


Туре	Description	Cause	Examples	Common Treatment
Deficiency	Nutritional diseases caused by an inadequite or unbalanced diet. One or more essential nutrients, such as vitamins or proteins are missing/short supply.	Unbalanced or inadequite diet	Scurvy Depression Rickets	Medication Supplements Lifestyle changes
Degenerative	Characterised by a gradual loss of function in one or several organs or tissues. Often result of failure in bodies repair mechanisms. Three main categories: • Diseases or skeletal, muscular and nervous tissues. • Cardiovascular diseases of the circulatory system • Cancers	Gradual decline in function	Alzheimer's disease Dystrophy Osteoarthritis Parkinson's disease Cancer Spinal disease	Medication Surgery Lifestyle changes Physiotherapy Radiation Compensation
Infectious	Pathogens such as viruses, bacteria, fungi, worms, insects, etc, causing disease within the body which can be transmitted from person to person	Organisms invading the body	Hepatitis HIV/Aids Flu	Medication Lifestyle changes Surgery
Non-infectious	All diseases, which are not caused by pathogens and cannot be passed on by physical contact.	Non-pathogens	Autoimmune disease Cancer Diabetes Allergies	Lifestyle changes Medication Surgery Radiation
Inherited	These diseases are caused by genes and can therefore be passed from parent to child. They are also sometimes called genetic diseases or disorders.	Faulty genes	Genetic disorder Cardiomyopathy Metabolic disorder	Medication Transplant Surgery Physiotherapy
Mental	These disorders affect a person's mind, but may b accompanied by physical symptoms. Some mental diseases are caused by degeneration of brain tissue, whilst others seem to be accompanied by changes in the blood flow to the brain.	Changes to the mind. Possibly with a physical trauma	Stress Alcoholism Eating disorder Anxiety	Medication Psychotherapy Lifestyle changes
Physical	Permanent or temporary damage to any part of the body	Damage to the body	Spinal cord injury Amputation / broken bones Diabetes Arthritis	Physiotherapy Medication Lifestyle changes Compensation Surgery
Self-inflicted	Willful damage to own persons body by themselves.	Psychological misbehaviour	Attempted suicide Self mutilation Drug use	Psychotherapy Medication Lifestyle changes
Social	How a persons life affects their health, exposing or protecting them from certain diseases. For example, deficiency diseases may be the result of lack of choice of food, due to shortage of money.	Environment or behaviour	Any as long as impacted by the environment/behaviour	

Why - Treatment

TREATMENT

In general we can say that almost all of us start out as being healthy. But when we start to feel sick or an incident happens we will get diagnosed and a appropriate treatment will be described to make us "healthy" again. This period of diagnose and treatment is what we define as rehabilitation.



In order for us to understand better where in the overall rehabilitation process Nokia can make an impact, it is important for us to understand where the current ideas of treatment come from.

In the book, The birth of the clinic (1963) by Michel Foucault, he discusses the change in health practices from the eighteenth century to the early nineteenth century. It is in this period where doctors got a better overall understanding of illnesses and the overall physical anatomy. He describes the shift from the human body as a whole to that of the body as a complex system of inter-working parts. The questions shifted from "what ails you?" to "what are your symptoms?" and "where does it hurt?". The patient turned into an object of medical attention, an entity to be studied rather than an individual to be cared for ⁵.

In todays healthcare we have gone more in depth and detail than ever before. We rely on measurable values, ranging from blood cell counts to PSA levels, where numbers define the difference between health and illness, as well as the success or failure to successfully treat/cure a patient from an illness. This number based approach in healthcare we call evidence-based medicine.

Evidence based medicine has been defined as an approach to healthcare that "integrated clinical expertise with the best available external clinical evidence from systematic research in order to ensure the best prediction of outcomes in medical treatment⁶" The strong emphasis of this clinical and evidence based research has as a result that physicians end up placing more importance upon test results and measurable variables, while distancing themselves from the less measurable aspects of health, such as patient wellbeing.

BEYOND TREATMENT

All of us have experienced or heard stories of peoples negative experiences when going through the current healthcare system. Often those stories are about the anxiety or impersonal treatment caused by the medical procedures and technologies used to diagnose and threat them. Another cause is the mismatch between the clinical interest of best curing results and the patients interest of having the best experience during these already tough times.

Unfortunately this results in the doctors/caretakers distancing themselves from less measurable aspects of a disease, such as patients reports of their bodily experiences and general well-being. They often forget to step back and take into account the patient as an individual. This is perhaps best explained by Norman (2008). "With so many numbers, we lose sight of the person. Scientists measure what they can measure and pronounce the rest to be unimportant. But the most important parts of life are qualitative". The negative impact of this evidence based medical approach has been recognized throughout nursing research, and much is being done from within this field to advocate for the personal wellbeing of the patient during treatment.

Even though evidence-based medical research has made invaluable advances in healthcare, there is a growing resistance towards this approach because it fails in providing for the human experience. In response to this increasing dissatisfaction,

NOKIA

Why - Treatment

healthcare professionals are starting to provide patient-centered care. Research has shown that there is a need for caregivers to "understand patients needs and engage in positive work with them" 8 to make them more in control and involve them in their own rehabilitation. It is time for us to see patients as individuals again, with the person's perspective as the center of care.

QUALITY OVER QUANTITY

As shown before the current healthcare system is focused on curing you from your symptoms and improving the quantity of your life. What I mean with this is that they want to keep you alive as long as possible, (this is even documented in the Hippocratic oath which is used up to this day as a document of professional ethics for healthcare providers). And this is all good and well, but I decided to focus on improving the overall quality of life.

I wished to explore how we can improve the physical and psychological part of healthcare and make the experience as easy and pleasant as possible for both the people that need to go through rehabilitation and the practitioners treating the patients. To enable this the project had have a human-centered design approach.

INSIGHTS

As shown in this chapter most of the current healthcare systems are focusing on curring diseases and conditions. The problem with this is that only parts of the human health is restored in the process. Recently a counter movement to this evidence-based medicine has arisen within nursing called person-centered care, which argues that in distancing itself from the patient, evidence-based medicine is failing to provide for human experience (Kvale & Bondevik, 2008). This movement suggest that there is a need to move beyond this cure-centered perspective to a more holis-

tic and person-centered healthcare. It suggest that we need to look beyond just the curing of patients and start threating their physical and mental conditions as well. It is time healthcare starts focusing on improving and maintaining not only the quantity of life, but also the quality.

It is for these reasons that healthcare exists. To help us as humans face and deal with the issues/limitations we might have to maintain/regain the optimal state of health possible. For these reasons I believe there to be a possibility for Nokia to focus more on the rehabilitation of physical diseases in healthcare, since the curing part is already well covered, and this part includes a lot of rehabilitation in collaboration between the patient and healthcare providers.

Why - Rehabilitation

REHABILITATION

After a person gets diagnosed with a disease/condition he or she has to go through a process of recovery. This period of diagnosing and recovery we call rehabilitation. Rehabilitation is the process of restoring an individual to the fullest physical, mental, social, vocational and economic capacity of which he or she is capable. It is about maximizing an individual's capabilities or resources to foster optimal independent functioning. This can be done through relearning former skills, or learning new skills necessary to adapt and live fully in an altered lifestyle (if the functions lost can not be recovered) There is a need for rehabilitation in the following cases?:

IMPAIRMENT

Any loss or abnormality of psychological, physical, or anatomic structure or function

DISABILITY

Any restriction or lack of an ability to perform an activity in the manner or within the range considered normal for a human being

HANDICAP

A disadvantage for a given individual resulting from an impairment or disability that limits or prevents fulfillment of a role that is normal for that particular individual

FUNCTIONAL LIMITATION

Any loss of ability to perform tasks and obligations of usual roles and normal daily life

CHRONIC ILLNESS

An irreversible presence, accumulation, or latency of disease states or impairments that involves the total human environment

The patient is the most important member of the team. He or she must be involved in planning the programs and learn about their disabilities, how to accomplish the goals and what options are available. Rehabilitation is directed toward the prevention of complications of disease or trauma and maintaining or restoration of functions. Basic rehabilitation can be used regardless of the cause of the disability. For efficient rehabilitation a team must give individualized care by developing goal-directed, comprehensive care plans for each patient.

The disability can have a number of effects on both the patient and the family, since the disability is not just physical, but often also psychological. What makes it even more difficult are the following problems¹⁰:

CARE VERSUS CURE

The focus of all rehabilitation should be on the patient's abilities, and should not only remind the patient on his/her disabilities since this will take away the motivation/stimulation for the patient to work hard on their rehabilitation process.

COST EFFICIENCY VS HUMAN CONTACT

Because of the high costs of rehabilitation, caregivers are forced to standardize rehabilitation. In the worst case the patient is send home with a brochure that will guide them through the rehabilitation process.

HIGH COST OF INTERDISCIPLINARY CARE VS LONG-TERM CARE

Rehabilitation is expensive and tiring. Because of this success it is sometimes seen as a return to productive employment, or when the patient is sufficiently independent that no caregiver is required. This does not mean that the patient is able to function like they could in the past and they will be limited in their daily lives.

Why - Rehabilitation

CURRENT REHABILITATION PROCESS

Before we can get a clear understanding where Nokia can make the biggest impact in rehabilitation, we first need to take a closer look at how the rehabilitation process is done currently for the physical skill recovery. In general we can say that the rehabilitation process consists of the following steps¹¹:



1. INITIAL RECOVERY

This happens after the injury happens. Whether it is a stroke or a broken leg, initial assessments will be made and the patient will need to recover from the injury and allow for things to heal/control the symptoms.



2. RESTORE INITIAL FUNCTIONING

Restore and retrain motion and functions of the impaired body parts. This part is usually done in collaboration with a doctor and/ or physical therapist. This means that for example you will be walking, but not in the same healthy way as you used to, you may be asymmetrical, you may not be balanced, etc.



3. PATHOLOGICAL FUNCTIONING

Independent functioning but with the utilization of assistive devices such as canes, wheelchairs, walkers, braces. (The main focus of this stage is for the patient to be able to survive on their own)



4. INDEPENDENT FUNCTIONING

In this phase the affected body parts will function without any assistance. The patient has full control, but in most cases will have lost their usual functioning. The goal is to relearn these more precise motor skills again.



5. HEALTHY FUNCTIONING

After having used the affected body parts for a longer period of time in the wrong way they will be weakened and quickly tired. In this phase the focus is on regaining the strength and endurance of the muscles.



6. EFFICIENT FUNCTIONING

The focus is on regaining the efficient functioning of the muscles again. To get back to the original state before the injury happened. Think of doing multiple things at a time, etc.



7. RETURN TO FUNCTIONING/REGAIN CONFIDENCE

After recovery from the injury and regained healthy and hopefully efficient functioning, the patient will return to activities similar to what caused the injury. He or she will need to learn to trust body again and regain confidence in their capabilities.

The goal is an independent healthy and efficient functioning. Unfortunately nowadays patients stay stuck in the phase of pathological functioning with assistive devices.

This means they have limitations in their daily lives, compensation devices, need to consider where they go and what they will do to be able to fully participate in these activities. That is why staying in this phase is such a problem.

This is one of the area's where Nokia can make the biggest impact. By assisting the patient from early on in the initial recovery process where the chance of recovery is the biggest, we allow them to skip these two phases or pass through them quicker so patients will regain an independent healthy functioning of the body again.

Why - Rehabilitation

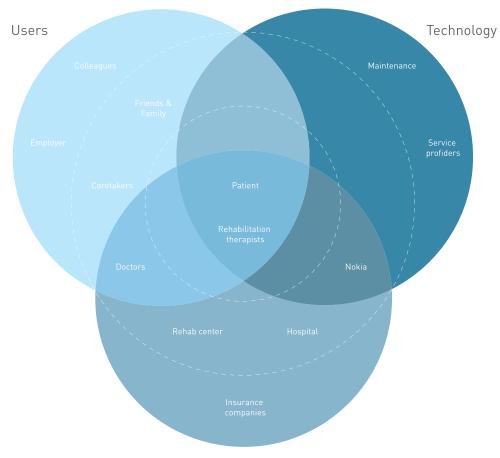
REHABILITATION STAKEHOLDERS

In the overall rehabilitation process there are many stakeholders. But the most important ones are the patients and the therapists that help them recover their health. It is for these people that the solution will be designed to enable optimal usage and adjustment of the recovery for the patient. And to create an experience that is as pleasant as possible for the patients and users, under these circumstances.

The technological stakeholders are the equipment producing company's, in this case Nokia, and the companies that function as service/maintenance providers for the product/service. They have the most important input in how the solution should work technically, so the products can be made and maintained. These are also the people who will usually be responsible for collecting the machines at the end of their life cycle.

The final stakeholders are clustered in the business category. These stakeholders are the ones that will decide to purchase the products and whether or not to use them for the rehabilitation of the patients. These stakeholders include the Rehabilitation centers, the Hospitals and the Insurance companies.

As we know the rehabilitation models are different depending on the country. For example in Sweden the doctor and therapist will be the final decision makers when to go for a type of rehabilitation, and how long it makes sense to continue with this treatment. However in countries like Germany and the Netherlands this is not the case. In these countries, the doctor has to prove to the insurance companies that the rehabilitation method is working for this patient and it will only then be allowed to continue with the treatment. For this reason it is important to also take the needs and issues of these providers into account.



Business

Why - Rehabilitation

THE BUSINESS IN REHABILITATION

One of the biggest problems we face with the current healthcare system is that it becomes less and less personal. As described before one of the main reasons is the evidence-based medical approach that focuses on curing. The other reason is that the current healthcare system in the future just wont be sustainable... With an increasing global population that gets older in general and also lives longer, the amount of people that require healthcare increases drastically.

To understand this problem of sustainability better, it is important to know where the financing for rehabilitation comes from and who makes the decisions for what methods to use.

Let's take a look a knee injuries. One of the most common is to the Anterior Cruciate Ligament (ACL). When this part of the knee is injured the patients will most likely will need to undergo surgery and requires (intensive) 9 to 12 months (on average) of rehabilitation.

In the USA, the average lifetime cost to society for a patient undergoing ACL reconstruction is \$38,121¹². This shows that the costs for society are substantial, and resources should be directed to developing innovations for injury prevention, and optimizing the treatment.

This money is mostly paid for by the government and by the insurance companies. This is why we need to take these two parties into account when designing a solution to create value in the system for them to change to the new Nokia products/services. For insurance companies and governments it is important to get more information about how the improvement of the patient is going. This can then be used for each individual case to make a more accurate decision whether or not to continue with financing the rehabilitation.

The hospital and healthcare centers are the ones who will eventually end up buying the equipment. For them it is important to get better physical and mental assistance, so they can optimize the time required for each patient better. Generate better communication between the different caretakers and doctors, and generate a more precise and personalized plan of recovery for each patient.



Why - Opportunities

PERSONALIZATION

Over the past decades technology has transformed our lives and business in a variety of ways. It started out with optimizing the speed and precision with which our work could be done, but currently its greatest impact may be in the capacity for personalization. Through technologies like 'big data' and AI, companies like Spotify manage to adjust the music experience to each individuals taste.

In healthcare, the effect could be even more profound. As the role of technology increases in medicine, it is now also starting to make promising changes in the area of rehabilitation. Through long-term monitoring and accurate data about the performance of exercises, it allows people to improve their stance for running or to retrain their muscle motion after a stroke.

"The consumer healthcare industry has already primed consumers to expect personalized experiences, whether it's a personal trainer, a customized yoga session, or a wearable tracker calibrated to your vital signs and habits. As the line blurs between these services and traditional medicine, "personalized healthcare" appears not just attainable, but expected" ¹³.

Healthcare is not just a collection of tests, therapies and procedures, but a journey towards better outcomes, that every human being undertakes many times and every journey is deeply personal. Everyone will need their personal tweaks to get stimulated and will face different obstacles along the way.

For example when we look into stroke rehabilitation in Sweden (in this case for relearning upper limb movement), we have 1 therapist for 6 patients. All the therapist does is monitor how the patients are performing the exercises, and as soon as they have mastered a specific movement, they are put on different exercises to make it more challenging or focus on another muscle group.

It is this constant changing of the difficulty level and stimulating the patient to focus on the muscles they do not control, that leads to the most successful and for the patient enjoyable experience possible.

Although this is how the rehabilitation is done currently in the rehabilitation center, most of the time patients will need to recover on their own, and don't have anything or anyone giving them feedback or adjusting the therapy along the way.

This is because there simply are not enough therapists and money available to give everyone the extensive amount of therapy they need to recover from their injuries. This shows that there is a clear need for a system that could, through constant monitoring, adapt the rehabilitation plan to each individual patients personal needs.

This would enable practitioners to take data and human driven decisions faster and more accurately. It would reassure the patients since they could get direct feedback and lead to an overall more efficient rehabilitation experience for the patients.

DEFINITION

"Connected healthcare is defined as patient-centered care resulting from process-driven health care delivery undertaken by health care professionals, patients and/or carer who are supported by the use of technology (software and/or hardware)."

Richardson, Ita (2015). "Connected Health: People, Technology and Processes

Why - Opportunities

CONNECTED HEALTHCARE

For healthcare to stay feasible it has to move from being acute and reactive to being proactive and preventive. It has to help people with long-term conditions manage their conditions, and prevent people from getting these conditions in the first place. A great tool for this is the increase of so-called connected healthcare.

The idea is that by encouraging patients to be involved in their own personal care, through continuous health monitoring, it will be possible to intervene before an issue becomes acute. This means fewer people will require hospitalization and expensive treatments. On the other side it is also about setting up support in a home environment so that, after any hospitalization, individuals can return home sooner. This idea is broadly supported, nearly three-quarters of healthcare professionals (73%) and the general population (72%) polled say connected care technology is important in improving the prevention of medical issues and that it can play an important role to enhance rather than replace the human touch in healthcare. Similar, when asked what aspect of healthcare connected care technology can benefit the most, the highest proportion (55%) of healthcare professionals chose home care-related aspects, mainly in terms of improving the long-term management and tracking of medical issues¹⁴.

The problem however is that currently there is no profit in this early prevention for the healthcare sector.

In general we can see that healthcare is opening up more and more to connected care solutions because of its positive effects. Furthermore healthcare is the industry that we trust the most when it comes to our personal data, roughly 44% of the human population¹⁵. So even though it has a long way to go, this is a very interesting trend to keep in mind when we are looking to design new solutions for the general healthcare and rehabilitation segment. Following are a few of the mayor benefits of connected healthcare:

THE EVOLUTION OF HEALTH MONITORING

The introduction of the smart phone put more processing power in our pocket than there was in our laptop. Some of the latest health monitors include advanced sensors (such as UV sensors). These health monitors are currently mostly lifestyle focused, but we can see the rise in programs which have been developed with medical experts, and an idea is that users can measure their vital signs with the devices, sync the data to the app, set personal health goals, monitor progress and gain insights into their own habits and behavior¹⁶.

THE NUDGE FACTOR

There are things we know we should do, but we don't always remember to do them. Sometimes, we need someone, or something, to nudge us in the right direction. Remember when a raised eyebrow prompted us to say please or thank you, or brush your teeth when you were a kid. According to behavioral scientists the nudge factor is based on the idea that indirect suggestions and positive reinforcement can be just as effective, if not more, than simply laying down the law.

It works because most of us are governed by an innate desire to do what we've agreed to do, to fit in with what everyone else is doing, and to minimize loss. And it's increasingly being used at both a macro and a micro level in the world of health¹⁷.

BIG DATA COLLECTION

Information is said to be power, but it's only powerful if you do something with it. Through the rise of Al and complex algorithms, we are now able to sift through this big data, getting rid of the noise and extracting the important bits, and through it give personalized advice/treatment. That's what connected care means¹⁸.

Why - Opportunities

TRENDS IN HEALTHCARE

If we wish to change the way that we consume, we need to develop new business models and ways of delivering performance to the people. First however we need to understand how the world is changing around us, and following are some important trends we should keep in mind (Trends from the Philips future health index¹⁹):



AGEING POPULATION

Developed and emerging countries are being exposed to an ageing population due to increased life expectancy. With an overall increasing life expectancy, the world population is estimated to reach 8.3 billion in 2030.



BIG DATA DRIVEN MEDICINE

Until now, medicine has an approach to give the same treatment to the ones with the same disease, but now it is possible to gather a bigger amount of data points by understanding the patient's profile in a deeper way.



EMPOWER THE PATIENTS

"There is a clear need to empower the population to feel they can take an active role in managing their own health" By doing so we will stimulate them to perform more exercises and increase the outcome.



FROM TREATMENT TOWARDS PREVENTION

"To create and maintain sustainable health systems, there needs to be a shift in focus from treatment to prevention" This will allow us to reduce the overall costs of healthcare and improve their wellbeing.



INCREASE OF OVERALL COSTS

The increase in population, leads to an increasing amount of people who need access to medical care. And because of the general increase in age we will also need access longer. It is this group (20% of population) that creates 80% of the current costs.



BEYOND TREATING

Healthcare providers start to look beyond just the curing of patients and start treating the physical and mental conditions as well. By doing so they start focusing on improving and maintaining not only the quantity of life, but also the quality.



RISE IN CONNECTED HEALTH PRODUCTS

Smart consumer health products are getting more capable/powerful every day. Through technologies like IoT, deep learning/artificial intelligence and exoskeletons it is believable that soon we can sense injuries better and perhaps even see them before they arise.



KNOWLEDGE SHARING

Healthcare providers are starting to look at better and more precise ways to share knowledge and expertise between caregivers. "An estimated 80 percent of serious medical errors involve miscommunication between caregivers when responsibility for patients is transferred.



TELEHEALTH/REMOTE MONITORING

There is an increase in so called "telehealth" in which the patients and caregivers communicate and have treatment through digital media. In just 20 % of the appointments a doctor has required him/her to physically touch the patient.

Why - Opportunities

TRENDS IN ROBOTICS

Robots are everywhere from science fiction to your local hospital, where they are changing healthcare. They are making a big impact on the field of healthcare. Robots help by relieving medical personnel from routine tasks, and make medical procedures safer and less costly for patients. This is why we also look at their trends:



ROBOTS ARE GETTING MORE COLLABORATIVE ...

By 2018 it is believed that 30% of all robotic deployments will be smart collaborative robots that operate three times faster and are safe to work around. They will be able to recognizing basic human behaviors and adapting the actions to respond. The aim is that collaborative robots will act as partners.



... AND MORE INTEGRATED IN OUR DAILY LIVES

Many respondents see advances in AI and robotics in nearly every aspect of daily life by 2025 in both distant manufacturing processes and the most mundane household activities. These technologies will be so integrated that they are nearly invisible to most users most of the time.



RENT A ROBOT FOR A SERVICE

In near future it is believed that 30% of commercial service robotic applications will be in the form of a robot-as-a-service (RaaS) business model. This will help cut costs for robot deployment.



ROBOTS WILL BE CONNECTED TO THE CLOUD

Robots will become connected to a cloud of shared intelligence. Resulting in a 200% improvement of operational efficiency. They will be able to deal with challenges that they couldn't before. This leads to the formation of a robotic cloud marketplace.



ROBOTS IN HEALTHCARE

Precision robotics made for surgical or lab settings. Disinfectant robots. Robot assistants for a better life, large focus on rehabilitation and elderly care. There is a big opportunity in medical robotics to have robot-to-human conversations.



INTELLIGENT PROSTHETICS

Advanced technology and increased demands from patients have opened up a new market segment for robotic limbs. Artificially intelligent prosthetics are capable of sensing movements and respond to its environment. Then adjusting its grip and movement to provide the most life like prosthetics ever.



SOFT ROBOTICS

By integrating bioinspired capabilities, adaptive and flexible interactions with unpredictable environments will emerge. Incorporating soft technologies can potentially reduce the mechanical and algorithmic complexity in robot design.



SOCIAL ROBOTICS

A social robot is an autonomous embodied robot that interacts and communicates with humans by following social behaviors and rules attached to its role. Social robots are popping up in multiple places: the home, classrooms, restaurants, stores etc. Social robots have shown improvements in peoples lives.

Why - Opportunities

HUMAN CENTERED

Currently healthcare is a result driven system. Through the pressure from governments and insurance companies, healthcare providers are forces to increase the treatment outcome and efficiency with less and less money. Because of this rehabilitation as a whole becomes more standardized. People are seen as objects with specific flaws that need to be fixed according to a specific/general way.

During my research I have heard of several of these examples, but I think the one that shocked me the most was about the rehabilitation of a knee injury in Finland. During this process of rehabilitation the patient was given a brochure in which the steps of the process were explained, and after his initial visit to the hospital, there was little to none communication with the people in charge of his rehabilitation.

He would just need to follow the formula written down on the brochure, and hope that the general method of solving this injury would suffice. As can be expected from this approach, the outcome was not at all optimal and still, years after the incident happened and finishing the prescribed rehabilitation, this person still needs a knee brace and will be limited by this injury in the daily activities.

By treating people like this we are robbing them from their health, since they will no longer be able to perform at their maximum capabilities. We focus on taking away the symptoms like pain and help them recover until they are able to function again through compensation methods or on their own, but will not focus on optimizing the muscles to work efficiently again.

It is not the drug that makes or brakes a course of treatment, but the actions and changes around it; when and how long does the treatment take, lifestyle changes the patient is making, how carefully the caretakers are tracking outcomes, how engaged they stay in the long term.

By keeping the human (patient) centered in this process, we will be able to map out and design the entire user experience, from the moment they will first encounter the products, how it helps them during their rehabilitation, how it communicates between the caretakers and the patient, how it gives advice, how the service/maintenance is provided, to what happens with the device/service when the patient is done and fully recovered.

The other person which we will then be able to design the experience for is the caregiver. It will allow us to optimize their work-flow, to give more in depth information about how the patients are doing and ensure that the communication done is efficient and helpful as possible. By doing this we will optimize the time they spend with patients and let them do what they love, helping the patient to get better.

HUMAN CONTACT

Through the technological advances and a more optimized and human centered solution we will be able to generate better contact between the patient and the doctor. "It's about augmenting our ability to deliver a human level of care, not replacing humanity²⁰".

A typical doctor's visit is consumed by repetitive tasks like measuring vital signs and asking boilerplate questions. All is perfectly poised to handle these, freeing overworked nurses and doctors to actually talk with their patients, improving outcomes and patient satisfaction.

SYMPATHY IS KEY

Assistive and sensing technology's are key in extending and supporting the human capabilities in healthcare. It will allow us to personalize and personalize in the rehabilitation process for people that will need our help the most. But what most therapists will tell you is that nowadays robotics in rehabilitation "are big and bulky machines focused on moving muscles" (Umeå stroke rehab center 2017). The devices are not designed with a human centered mindset in the overall process.

To solve this we need to understand the fears and wishes of these patients, and understand how it feels for them to need help to gain control over their own body, but most of all, how can we let humans stay human and not turn into machines?

Why - Opportunities

NOKIA'S CAPABILITIES

So what is it that Nokia can bring to the table in all of this? Nokia is a technological driven company and has made groundbreaking innovations over the last decades through constant research and research institutes like Bell laboratories. If we look more specifically for the healthcare area we can point out the following capabilities of the company which can have the biggest impact on this project:

SENSORS

Nokia has a lot of experience with the production and development of sensors to measure and track everything from sound to movement. This technology will allow us to better monitor the patients, for example their vitals, their motion (gait), or how the healing of certain muscles/bones is going. It will allow us to keep better track of the patient through life and constant monitoring and communicate this with the healthcare responsibles.

CONNECTIVITY

Through technologies like 5G, Nokia is able to connect people, services and products. For Nokia, the answers to healthcare's biggest challenges center on connecting people with data, data with insights, and insights with the clinicians and researchers that can effect societal health improvements.

ANALYTICS

A typical doctor's visit is consumed by repetitive tasks like measuring vital signs and asking generic questions. All is perfectly poised to handle these. Through the collection and sharing of data, Nokia has a lot of information which it can analyze and create systems that get more precise the more data they collect, to eventually build a database.

MATERIAL TECHNOLOGY

Through constant exploring and experimentation Nokia has broad knowledge

in materials and how to tweak them for the best performance. Think for example of smart textiles that could flex in one direction whilst being rugged in the other. Technology like this will allow for new and innovative devices to assist the patients.

Through these technologies/capabilities Nokia might be able to innovate in the overall healthcare/rehabilitation experience by collecting data throughout the recovery. This will enable them to make predictions of the injury and its current status. Adapt the recovery along the way, and possibly prevent future injuries from happening. This will make the overall communication between patient and practitioner more efficient, human focused and personalized to each individual (creation of a recovery plan based on the evolution of the treatment).

NOKIA'S STRATEGY

At the moment Nokia is re-balancing itself for growth, by putting the company and its resources at the heart of unprecedented technology and focusing on innovation.

The vision of the "Programmable World" continues to guide the corporate strategy, and they have identified six global mega-trends which they intend to pursue²¹. These mega-trends create massive technological requirements, impact the current and potential customers, change the lives of people and impact business operations on a global scale and ultimately provide opportunities for Nokia to diversify into new growth areas. The identified mega-trends are:

NETWORK, COMPUTE AND STORAGE

Ever present broadband capacity coupled with a distributed Cloud for ubiquitous compute and near infinite storage, allowing limitless connectivity and imperceptible latency.

INTERNET OF THINGS

In addition to people, trillions of things are connected to the internet, collecting unprecedented amounts of data in a private and business context.

AUGMENTED INTELLIGENCE

New tools transform the collected data into actionable insights, fundamentally changing the way decisions are made by businesses, governments and individuals, resulting in time savings, less waste, higher efficiency and new business models.

HUMAN AND MACHINE INTERACTION

A range of new form factors that fundamentally transform the way humans interact with each other and with machines, e.g. voice-based digital assistance, gesture control, smart clothes, implantable chips, robotics and Augmented and Virtual Reality.

SOCIAL AND TRUST ECONOMICS

Ubiquitous connectivity, compute and storage, as well as technologies such as block chain, enabling new business models based on sharing assets and distributed trust, allowing rapid scalability on a global level.

DIGITIZATION AND ECOSYSTEMS

Next level of digitization beyond content and information, digitizing atoms with additive printing in an industrial, consumer and medical context, fundamentally transforming production processes.

These mega-trends are driving massive new technology requirements, and linked together with their capabilities and vision, they give us a clear set of guiding rules into where the company can, should and is willing to invest in.

Why - Opportunities



NOKIA I ASSISTED REHABILITATION Why - Assisted rehabilitation

ASSISTED REHABILITATION

The area I wish to focus on during this thesis will be in the field of assisted rehabilitation. This is an up and coming area of rehabilitation in which (robotic) devices assist the patient with certain movements.

In the coming years, the need for assistive devices in healthcare will increase. One of the main reasons for this is that the world population has seen, and will continue to see an incredible growth in size (2.6 billion people in 1950, 7.6 billion people today and 9.7 billion people in 2050), but also in age. Today almost 20% of the world population is over 65, but in the year 2050 this figure is expected to exceed 35%²². This demographic shift in world population will impose an increasing burden on caregivers to treat the health risks associated with an aging population. It is expected that robotic solutions will be one of the main solutions to help tackle this.

The biggest benefit of this is shown in the graph below. As explained before, rehabilitation is a slow and intensive process in which the patient first need to recover initial functioning of the affected body part and learn to control it through compensation strategy's like strollers, or dragging of the limb. It usually stops when the patient is able to function independently, with or without assistive devices, and more often than not the patient will stay limited in their functions.

The benefit with assisted rehabilitation is that we can skip this period of compensation. "We can go directly from the initial recovery to independent and healthy functioning²³". By doing so they will create fewer bad habits. This will lead to a more healthy and efficient use of the motory skills in the end.















INITIAL FUNCTIONING

Restore functions of the impaired body parts. In collaboration with doctors and/or physical therapists.

PATHOLOGICAL FUNCT.

Functioning with compen sation strategy. For exam ple through use of robots

ASSISTED FUNCT.

Independent functioning but with the utilization of assistive devices such as canes.

INDEPENDENT FUNCT.

The affected body parts will function without any assistance.

HEALTHY FUNCTIONING

In this phase the focus is on regaining the strength and endurance in the weakened muscles.

EFFICIENT FUNCTIONING

Efficient functioning of the muscles. To come back to the original state before the injury happened.

Why - Assisted rehabilitation

ROBOTICS IN REHABILITATION

Todays robotic systems in healthcare focus on assistance and rehabilitation, to provide missing movement and sensing, to regain movement related functions easier and faster. Robotic prosthetics and exoskeletons are starting to provide dexterity, natural mobility, and sense of touch to missing or paralyzed limbs. Individuals suffering from hip or knee conditions can use a robotically intelligent walker or wheelchair to help prevent common accidents like slipping. Finally, robotic rehabilitation not only provides consistent and efficient therapy without tiring, it also has the potential to enhance the therapy beyond the abilities of the practitioner.

The field of robotic rehabilitation is a couple of steps ahead of prosthetics and exoskeletons, mainly because the robotic devices do not have to be worn by the user. This means that the robotic devices do not have the same power or size constraints. A variety of haptic devices for upper limbs [MIT-MANUS, PUMA (MIME), PHANTOM, WAM] and lower limbs (i.e., Lokomat) are used in research to show the clinical efficacy in physical therapy for stroke and other neurological disorders with movement disability.

The main challenge of this field lies in showing the efficiency of these regimes. While it is acceptable to show an equal amount of improvement compared to human therapists, if the robots are used as a tool to increase the volume/frequency of patients treated, we also would like to see that taking advantage of the robotic precision in sensing and actuation resulting in faster and more complete recovery than traditional therapy.

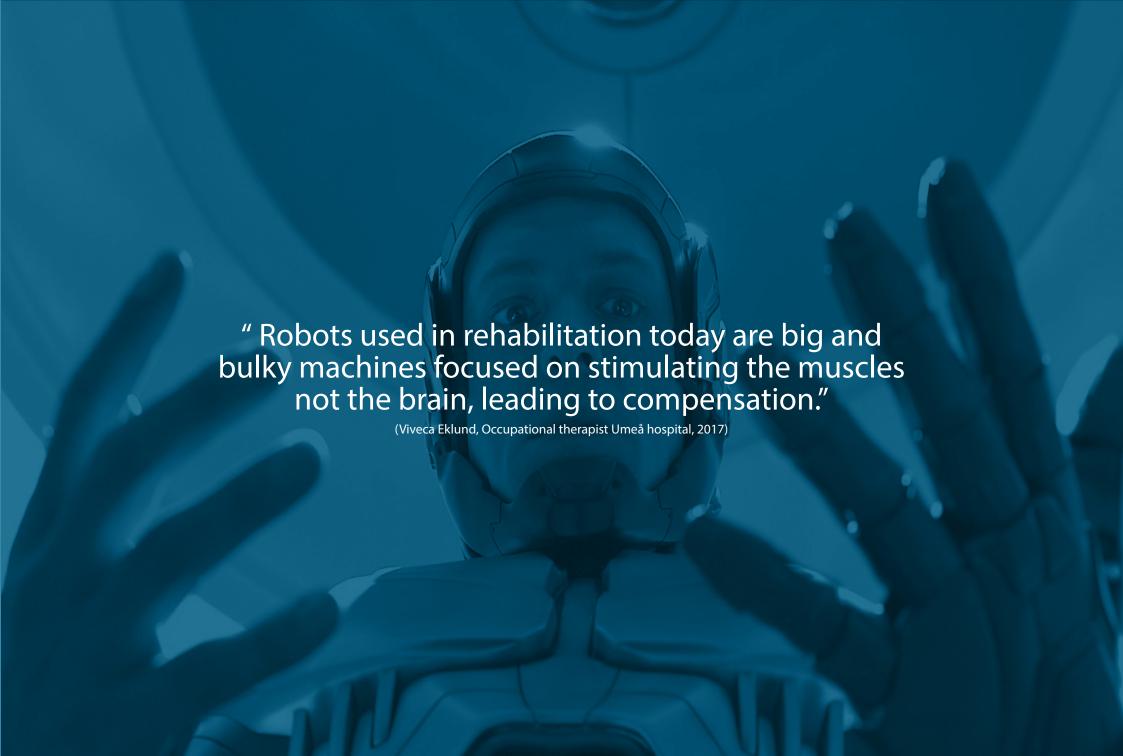
While there remain a number of things that only human therapists can do, many rehab exercises are highly repetitive. This is where robotic systems excel: They can perform the same task countless times, with precision and accuracy without fatigue or loss of attention.

Many researchers around the world have developed robotic devices for rehabilitation purposes. These devices are typically designed specifically to work on patients' paralyzed arms or legs. Many clinical studies confirm the effectiveness of automated therapy; in some cases it is even better than conventional therapy. However, there is still a long way to go.

Exoskeleton robots have prospective applications in rehabilitation and patient assistance. They can help weakened and paralyzed patients regaining independent life by restoring their mobility and ability to perform activities of daily living. Designing assistive exoskeletons, however, is challenging and complicated as the human factor plays a key role. It is realized that a successful design of an exoskeleton depends on a better understanding of the biomechanics of the human body motion and sensory mechanisms, which is a critical problem in the physical human–robot interaction.

Another benefit of robotic assistance is the integration of sensors and data collection. In cases where the patient is left impaired, for example by a stroke or injury, the integrated sensors would be able to constantly monitor the patients strength and how it develops. By doing so, it would allow for the motors to assist just as much as is required for the patient to perform optimally, to let their muscles do the most work as possible. This in turn will lead to quicker muscle growth.

The main downside of robotics however is their size and how they limit the patient-therapist interaction. Many therapists for example in the physical healthcare do not yet trust the machines enough to take over their tasks, and they do not like that they can no longer come up close to the patient to really feel and interact with the impaired body part. This, the general high costs and the fact that they often require a lot of space in the hospital environment is why for example they are not used in rehabilitation clinics/hospitals such as the one in Umeå.



Why - Assisted rehabilitation

CATEGORY	DESCRIPTION	CAUSE	TREATMENT	DATA
Stroke	Stroke is the leading cause of long term disability. Poor blood flow to the brain results in cell death, after which people can lose the (partial) functioning in one side of the body.	Because of a bleeding or lack of oxygen in the brain, part of it dies off.	Medication Surgery Physical therapy	15 million people, 50 % hemiplegia 9 month recovery
Spinal cord injury Paraplegia Tetraplegia	A spinal cord injury (SCI) is damage to the spinal cord that causes changes in its function, either temporary or permanent. These changes translate into loss of muscle function.	Usually through physical trauma that damages the vertebrae or spinal cord itself.	Medication Surgery Physical therapy	500 000 people, 12 months to permanent,
Knee	The majority of sports injuries involve the lower body, particularly knee injuries. Roughly 2,5 million people each year.	Sudden change, slowing down and trying to cut, pivot or change directions.	Surgery Therapy	2,5 million people 9 month recovery
Inguinal hernia	70 percent of all hernias, (British Hernia Center). These hernias occur when the intestines push through a weak spot or tear in the lower abdominal wall, often in the inguinal canal.	Hernias are caused by a combination of muscle weakness and strain. For example through age or lifting heavy weight.	Lifestyle changes Medication Surgery	20 million people 3-6 weeks after surgery
Hip injury/surgery	Problems within the hip joint, Tends to result in pain on the inside of your hip or your groin.	Physical injury or surgery after a hip replacement.	Surgery Physical therapy	800 000 people 2-3 months
Elbow	Elbow injuries symptoms such as pain, swelling, numbness, tingling, weakness, or decreased range of motion	Direct blow, penetrating injury, fall or by twisting, jerking, or bending abnormally.	Physical therapy	Weeks - 12 months 1 million (USA)
Broken bones	After a fracture, your bone will be set, or reduced, by a doctor. Reduction of the bone can be done manually. For more serious fractures, a surgical may be necessary	Trauma or physical force caused damage to one of the bones and cracked/broke it.	Surgery Therapy	6,8 million (USA) 6-8 weeks
Wrist fracture	Some fractures are more severe than others. Fractures that break apart the smooth joint surface or fractures that shatter into many pieces (committed fractures) may make the bone unstable. These require surgery.	Wrist fracture occurs from an injury such as falling down onto an outstretched hand, car accidents or falls from a ladder cause more severe injuries.	Surgery Therapy Pack of ice	8 weeks - 6 months 640 000 (USA)

NOKIA I ASSISTED REHABILITATION Why - Assisted rehabilitation

CHOSEN DIRECTION

As shown in this chapter, there are a lot of opportunities in the physical rehabilitation segment that Nokia can focus on to innovate for. To generate a successful thesis project and a concept that will be most beneficial for the company, it is important to explore one direction in depth to see what its true potentials are.

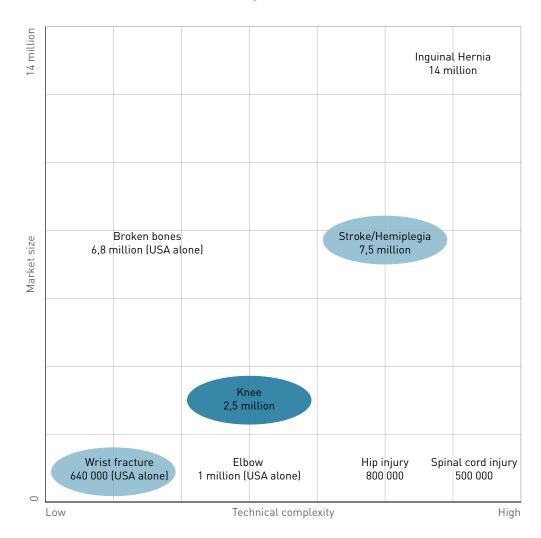
On the left is a mapping of the different opportunities in terms of market size and technical complexity. This means how much will Nokia have to invest, in comparison to how much outcome there is expected to be from potential clients.

For this thesis it is important to explore a specific topic in depth. This is why it makes sense to set the area of broken bones aside (since we have many bones we can break and it won't be feasible to explore them all in this project). The area of wrist fractures is relatively small but will be quite easy to achieve, for example Nokia could think here of a smart cast system that will monitor how the fracture heals and stimulates the muscles so they won't deteriorate.

The area of knee injuries is already a lot bigger but will also be more technically complex. Another benefit of this injury is that I have access in Umeå to one of the top leading specialists on this area. Furthermore it is an area with a lot of opportunities in terms of assistance with the long rehabilitation and potential prevention.

The area of stroke/hemiplegia is definitely an interesting topic because of its size and this is a target group that truly needs our help. However since I have done a previous project in this area, it was decided to leave this one for now so I have a topic I can look at with fresh eyes.

For these reasons the topic will be on the prevention and rehabilitation of knee injuries.





NOKIA

How - Abstract

ABSTRACT

The majority of sports injuries involve the lower body, particularly knee injuries where roughly 2,5 million²⁴ people each year get injured. Most of us have had a minor knee problem or know someone who has had one. Through sudden harsh movements the knee can get damaged and in time the injuries will get more serious. However the injury will never truly heal. Once the knee is weakened the risk of injuries increases and in many cases the functioning will never go back to the way it used to be.

As can be seen from the research there is a problem with the interaction between the therapist and the patients. The outcome of the treatment is too much determined by the capabilities of the therapist who does not have enough information to generate a personalized treatment for each individual. Another big problem is the fact that patients lose their motivation since they feel that they are not improving, and are alone in the overall process. We need to empower them and let them know that the outcome of the rehabilitation is mainly in their own hands.

By providing more data and communication between therapists and patients we can generate a system that will inform and educate each patient individually how to deal with their unique situation, whilst giving therapist the information they need to take human and data driven decisions, which in turn will result in a better outcome.

The system nowadays is too standardized and focuses on the recovery of symptoms and not the treating and prevention of the injury itself. By giving control back to the patient we can teach them how to reduce the effects of the injury in the long run (such as compensation), whilst teaching them how to prevent the injury from happening again, concluding in a more personalized and optimized rehabilitation plan.

For the concept this means that the primary users are the ACL patients and physiotherapists who will use the solution to be more in control of the rehabilitation, and recieve feedback on how to improve and if they are doing okay. Through increased

amount of insights the practitioner can take data and human driven decisions, which in turn will generate a more customized rehabilitation plan that will empower and motivate the patient.

Secondary users are clinicians who could use their patients' adherence and outcomes data to review the effectiveness of their care plans.

The primary focus of the concept should be to assist with the rehabilitation of ACL injured patients. To innovate for patients to recover their health in a faster and easier way through a personalized and humanized rehabilitation plan. The secondary focus will be on preventing the injury from happening in the first case; "To create and maintain sustainable health systems, there needs to be a shift in focus from treatment to prevention". Test has shown that focusing on preventive measure the risk of injury can be reduced between 50 to 70 %²⁵. This leads to the following vision:

- **WHY** To empower ACL patients to recover their health in a faster and easier way through personalized and humanized rehabilitation plan.
- Through constant sensing we provide an increased amount of insights for the practitioner to take humanized and data driven decisions. This will result in a more informed, easier, faster and reassured rehabilitation experience for the patient.
- **WHAT** A tool that will empower and enable both patient and practitioners to deliver data driven and a personalized outcome for the patient.

How - Knee injuries

KNEE INJURIES

Two of the main knee injuries are to the Anterior Cruciate Ligament (ACL) and the Medial Collateral Ligament (MCL). The ACL is one of the major stabilizing ligaments of the knee. The most common cause of sports injuries for an ACL strain is slowing down and trying to cut, pivot or change directions. When this part of the knee is injured the patients most likely will need to undergo surgery to restore the ACL and requires an intensive 9 months (on average) of rehabilitation. The recovery for MCL can usually be done without surgery and takes between 3 to 6 months. The rehabilitation is in collaboration with therapists and doctors but most of it has to be done by the patients themselves. Existing solutions give directions or recommendations but do not motivate or assist the patient in their recovery in a personalized way. This can lead to mis-performed exercises.

Smart consumer health products are getting more capable/powerful every day. Through technologies like IoT, deep learning/artificial intelligence and exoskeletons it is believable that soon we can sense injuries better and perhaps even see them before they arise. Therefore exoskeletons cannot only focus on the recovery of current injuries but also on the prevention of new ones. This project explored two areas:

The first one focuses on how we might assist in the treatment of existing knee injuries such as ACL and MCL. Surgery is usually followed by physical therapy over a period from 6 to 12 months, depending on the tear. How can we make the most of this period of recovery and make the overall experience as pleasant as possible? The second phase will be about prevention: The ACL will tear more often under certain circumstances such as cold muscles or not stretching²⁶. Can we detect and support to prevent and reduce the occasions in the future? This leads me to the question I wish to answer for this topic: How can assistive devices improve the recovery process of knee injuries and help not only with the recovery process but also with the prevention of future cases.

RELEVANCE OF THE PROJECT

Of the 2,5 million people suffer from knee injuries each year. These will have to start with a long and tiring rehabilitation process. In the USA, the average lifetime cost to society for a patient undergoing ACL reconstruction is \$38,121²⁷. This shows that the costs for society are substantial, and resources should be directed to developing innovations for injury prevention, and optimizing the treatment.

Next to the costs for society we also have to consider the impact injuries like this have on the overall quality of life of the patients and how we can improve this. There is no simple answer to this question, but we can at least say that it involves maintaining a long and high quality of human life. The main question of my thesis is to see if and how so-called "assistive devices" can help us to achieve these goals in the healthcare area (particularly for knee rehabilitation)?

I intent to explore how assistive devices can improve the treatment and rehabilitation process in the professional environment, and what impacts these devices can have on the overall experience (life improvement) of the patient.

The findings of this exploration will be used to establish a concept that shows what role a technological driven global player such as Nokia can play in the healthcare environment. In terms of how a product/service can be developed and implemented in this market segment.



How - Research

ACL INJURIES

Anterior cruciate ligament (ACL) injuries occur when the bones of the leg twist in opposite directions under the full body weight and place stress on the ligaments. In this case the ACL is stretched, partially torn or completely torn (see image on page 39). The most common of these injuries is for the ACL to be completely torn. When the incident happens there is usually a loud "popping" sound and after a couple of hours the joint starts swelling up. The most common symptoms include pain and instability of the knee. Injured ligaments are considered "sprains" and are graded on a severity scale²⁸.

GRADE 1 SPRAINS

The ligament is mildly damaged in a Grade 1 Sprain. It has been slightly stretched, but is still able to help keep the knee joint stable.

GRADE 2 SPRAINS

A Grade 2 Sprain stretches the ligament to the point where it becomes loose. This is often referred to as a partial tear of the ligament.

GRADE 3 SPRAINS

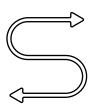
This type of sprain is most commonly referred to as a complete tear of the ligament. The ligament has been split into two pieces, and the knee joint is unstable.

About half of all injuries to the ACL occur along with damage to other structures in the knee, such as articular cartilage, meniscus, or other ligaments. The ACL is responsible for providing stability in knee rotation, as it prevents the tibia from shifting in front of the femur.

The policy after an injury depends on the severity of the injury, the type of activity/ sport in which the incident happened, and the amount of active lifestyle the injured

individual wishes to continue with. Some doctors choose to initially 'train' the knee, and wait to see if the knee can function properly after an initial rehabilitation process. Unfortunately it often goes wrong again after a period of time, and the surgery will still need to be performed. An additional danger to this is that when the patient 'goes through the knee' again, is that more damage might occur to the knee, in the form of injury to the meniscus and/or the cartilage. According to current insights, it seems more sensible to immediately think about placing a new anterior cruciate ligament if the person wishes to continue with an active lifestyle.

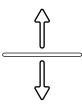
In most cases (roughly 70%²⁹) ACL injury's are a non-contact injury which occurs when an individual suddenly shifts their weight in a different direction, through which the knee rotates in an unnatural manner. The most common causes are:



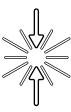
Suddenly/rapidly changing direction.



Overextending the limb, for example when landing from a jump incorrectly.

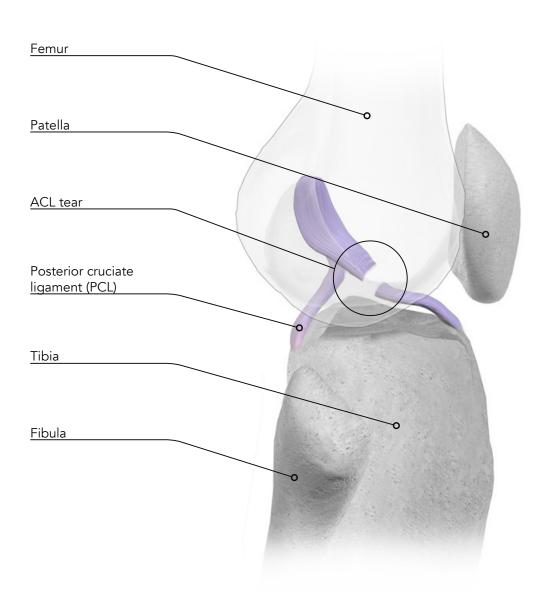


Suddenly stopping for example when running.



Direct contact or collision, such as a football tackle or accident.

How - Research



GENDER INEQUALITY

The highest rate of ACL injuries occur in sports like gymnastics, basketball, football and American football. Whilst ACL injuries most commonly occur in men, this is because they are more likely to play high risk sports, a recent study has shown that female athletes are two to eight times³⁰ more likely to strain their ACL in sports that involve cutting and jumping compared to men who play the same particular sport.



Potential causes for this are the difference in the active muscular protection of the knee joint and the greater Q-angle putting more medial torque on the knee joint. Q-angle is an abbreviation for the quadriceps femoris muscle angle. In a standing position. This angle is derived by measuring from the center line of the patella to the tibial tubercycle. The average angle in males is 13 degrees but 18 degrees³¹ in females. This angle is increased in females due to their wider pelvis.

How - Research

ACL DIAGNOSIS

When an ACL injury occurs, you need to go to a physician and other medical professionals who will then make an assessment of the situation, based on some physical tests and an interview:

PATIENT INTERVIEW

A doctor will ask the patient about how the accident or injury happened, symptoms, the pattern of knee pain, and how symptoms affect lifestyle.

PHYSICAL EXAM

A doctor will examine the patient's knee, noting any swelling, tenderness and pain points and range of motion.

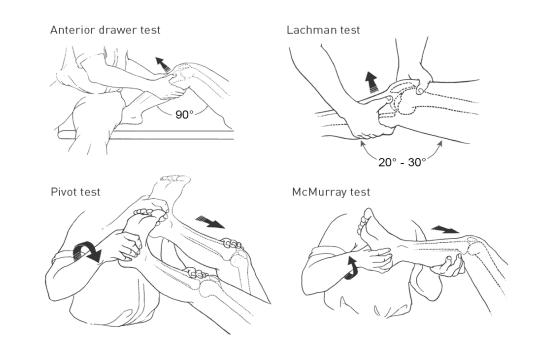
Since the injury does not always come with pain and the cause of the tear is not always noticed, it often takes a while for people to realize they might need to have a checkup. People often think it will pass in time, thus putting more stress on the injury by not having it treated. Even when patients go for their exam, quite often they will be sent back home and told to let the swelling decrease before the doctor is able to perform the diagnosis.

LACHMAN TEST

A person with an ACL tear will have difficulty bearing weight on the affected leg and the knee will show swelling within the joint. Physical examination tests specifically designed to test for ACL injuries are performed to see if the ACL is intact. This is most commonly done by testing the difference in motion/movement of the affected knee in comparison to the healthy one. One of the most accurate and common used tests for this is the Lachman's test. The Lachman's test is performed with the athlete on his or her back with the affected leg relaxed. The examiner holds the affected leg

with the knee bent at 30 degrees of flexion. With one hand on the thigh for stabilization, a pull forward on the calf will show an increase in motion and soft endpoint compared to the other knee if the ACL is ruptured. This is then also done on the healthy knee to see how great the difference is between them.

Other tests for the ACL diagnosis include the pivot-shift and the anterior drawer tests. Caution must be exercised if the examination occurs after significant swelling has occurred, because this may reduce their accuracy. This is because the swelling gives more stiffness to the impaired leg, which makes it more difficult to properly detect the real movement of the joints in comparison to one another.



IMAGING TEST

After the physical exam an initial diagnosis can be made. After this it is common to get a referral to the hospital to rule out other causes and to determine the severity of the injury. These tests may include:

X-RAYS

X-rays may be needed to rule out a bone fracture. However, X-rays can't visualize soft tissues, such as ligaments and tendons.

MAGNETIC RESONANCE IMAGING (MRI).

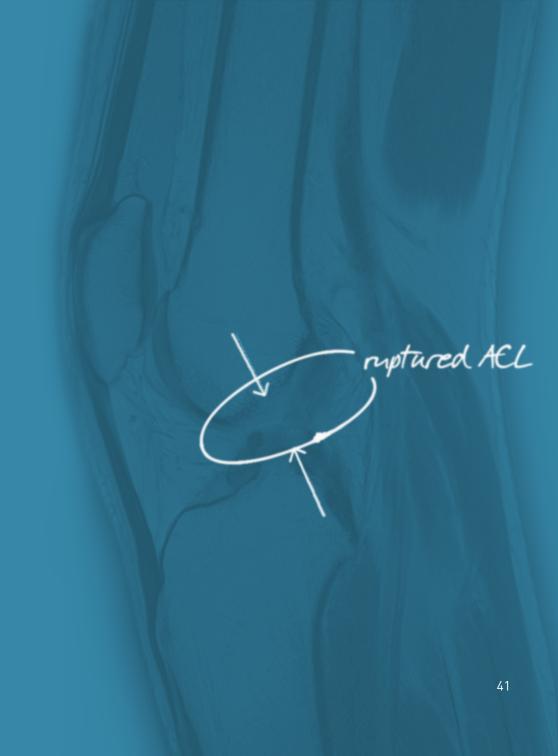
An MRI uses radio waves and a strong magnetic field to create images of both hard and soft tissues in your body. An MRI can show the extent of an ACL injury and signs of damage to other tissues in the knee (example of an MRI scan shown on the right).

ULTRASOUND

Using sound waves to visualize internal structures, ultrasound may be used to check for injuries in the ligaments, tendons and muscles of the knee.

MISDIAGNOSE

Unfortunately even though we have all these tests and technologies the injury is often misdiagnosed. "Roughly 40% of the injuries are missed during the first exam, and roughly 40% have to wait for the swelling to go down first before the doctors want to give a conclusive examination. Only in 20% of the cases is the injury immediately diagnosed³²". This comes because of inexperience from the doctors who do the test, who look more for fractures, for example with the X-ray machine and the stiffening of the leg which makes it more difficult (but certainly possible if well trained) to do the physical tests.



How - Research

ACL TREATMENT

Treatment for ACL injuries varies upon the patient's individual needs. For example, a young athlete involved in agile sports will most likely require surgery to safely return to their sports whilst a less active, older, individual may be able to return to a quieter lifestyle without surgery. In most cases however surgery is required. Prompt first-aid care can reduce pain and swelling immediately after an injury to the knee. This is usually done in accordance to the RICE³³ treatment model:

REST: Necessary for healing and limits weight bearing on the knee. **ICE:** When awake at least every two hours for 20 minutes at a time. **COMPRESSION:** Wrap an elastic bandage or wrap around the knee. **ELEVATION:** Lie down with the knee propped up for example by pillows.

NONSURGICAL TREATMENT

A torn ACL will not heal without surgery. But nonsurgical treatment may be effective for patients who are elderly or have low activity level. If the overall stability of the knee is intact. The doctor may recommend simple, nonsurgical options however, many people who choose not to have surgery may experience secondary injury to the knee due to repetitive instability episodes:

BRACING

A brace to protect the knee from instability. To further protect the knee, crutches may be given to keep from putting weight on the leg.

PHYSICAL THERAPY

As the swelling goes down, a careful rehabilitation program is started. Specific exercises will restore function to the knee and strengthen the leg muscles that support it.

SURGICAL TREATMENT

Most ACL tears cannot be put back together. To surgically repair the ACL and restore knee stability, the ligament must be reconstructed. Surgeons will replace the torn ligament with a tissue graft (for example a piece of the hamstring or donor ACL). This graft acts as a scaffolding for a new ligament to grow on.

Because the regrowth takes time, it may be six months or more before an athlete can return to sports after surgery. Surgery to rebuild an anterior cruciate ligament is done with an arthroscope using small incisions. Arthroscopic surgery is less invasive. The benefits of less invasive techniques include less pain from surgery, less time spent in the hospital, and quicker recovery times.

Recovery after ACL surgery is a slow process, taking averagely 9-12 months. The overall outcome is very positive with reconstruction surgery having a success rate of approximately 90% ³⁴. However, problems can occur both in the short term and long term. The chances of developing problems are greatly reduced by following a strict rehab program and having realistic expectations about the recovery process.

Problems often occur because the patients have an active lifestyle and wish to rush through the rehabilitation process in 6-9 months. Following are the most common short term problems that can occur:

SWELLING: Can last up to 3 months. This can be eased by appropriate rest, ice therapy, elevation and compression.

DIFFICULTY KNEELING: Kneeling often causes pain after surgery initially, but with gradual progression through rehabilitation exercises and a lot of stretching this will improve.

PAIN: Some pain is common both at the knee and around the new graft area.

How - Research

BRUISING: Bruising often appears down the heel and can last 4-6 weeks. It makes the lower leg sore. Keeping the leg elevated helps the recovery.

NUMBNESS: Numbness around the scars is common due to damage to the small nerves around the knee from the incisions.

Whilst the outcome of ACL reconstruction surgery is usually extremely positive, occasionally longer term problems do occur. The main risks are:

LACK OF STABILITY: Sometimes the new ACL graft does not provide enough stability to allow return to full sporting activities. Usually due to either the ligament not healing in a tight enough position or from associated damage inside the knee. Tailored rehab programs and wearing an ACL brace helps.

PATELLA PAIN: Anterior knee pain with activities such as squatting and sitting can develop in 10-20% of patients.

PATELLAR TENDIONITIS: Inflammation of the patellar tendon can occur. Strictly following the rehab program is the best cure.

KNEE STIFFNESS OR WEAKNESS: Stiffness is a common problem particularly extension (straightening the leg) but the chances of developing this are greatly reduced by starting exercises as soon as possible.

RE-RUPTURE: ACL can re-rupture in 1-2% of cases. The new ligament is most vulnerable 6-12 weeks after surgery. Wearing a brace minimizes the risk.

ARTHRITIS: Recent studies are suggesting an increased risk of developing arthritis later in life after ACL surgery. The most important factor in reducing the risk of developing arthritis is to regain full stability and strength at the knee.

MINIMIZING PROBLEMS

"These problems often stem from problems with the rehab program, either from a poorly designed rehabilitation program or poor patient compliance. It is important for the patients to follow the advice of their surgeon and physio and to rigidly stick to their rehab and recovery program." 35

As can be seen the outcome of the treatment and therapy is not completely controlled by the doctors and therapist, but also very much linked to the goals and commitment of the patients. If the patients wishes to push the rehabilitation to quick and short, risks increase of them injuring again.

If the patients are not motivated they risk never completely recovering at all and will lose certain amount of the functioning in their impaired leg. For professional and semi-professional athletes it is therefore more important to focus on prevention instead of treatment of the injury.

Research by the Oslo sports trauma center between 1998 and 2011 has shown that by focusing on the prevention of ACL injuries, they were able to cut down the injuries by fifty percent ³⁶. The Norwegian studies indicate that the ACL injury rate can be kept low through nationwide preventive initiatives and by focusing on the coach as a key partner. The coaches were trained by therapists and specialists in the field to explain what to look out for and which preventive exercises to perform.

This shows that sporting programs should include preventive exercises in their warm-up, a tailored exercise program specific to the sport/activities and a focus on education of the coach as a key factor.

How - Current rehabilitation

CURRENT REHABILITATION

After the injury happened, and the injury is diagnosed through an initial primary test, the patient will go to the ER to get an MRI and meet with a consultant how to proceed till the results get back. Roughly two weeks later the results come in and it becomes clear whether surgery is required, together with an advice from the doctor and therapist in the form of a consultancy. A decision will be made after which the rehabilitation or surgery is planned. Often after a few weeks/months the surgery will be performed, and a consultancy about how to reduce the swelling and the usage of pain medication. After this the rehabilitation phase starts:

INITIAL RECOVERY (Week 1 & 2). Recovering from the surgery, try to minimize stress on the injury/knee and range of motion (get leg straight).

RESTORE RANGE OF MOTION (Month 1 & 2). Recover initial range of motion, extend the leg to become straight and try to flex the leg at least 90 degrees.

RESTORE INITIAL FUNCTIONING (Month 2 & 3). Easy jogging, slight jumping. Begin to train for some strength and some resistance to impact.

REGAIN FUNCTIONING (Month 4 & 5). Start with some running and multitasking, some precise functioning, and sport specific exercises.

HEALTHY FUNCTIONING (month 6 & 7). Training to return to sport, first time returning to practice, test the progress through jump, stress, pain, endurance tests. More specific rehabilitation exercises.

EFFICIENT FUNCTIONING (month 8 & 9). Tests are performed, if acceptable able to return to play partially, like only perform 2/3 of the usual. Perform to regain endurance, people are under-trained.

RETURN TO SPORT/LIFE (month 9 and onward). Patient eventually on their own, need to continue with the rehabilitation. Main focus is for the athlete to regain confidence and prevent future injury

After this the rehabilitation is over and the patient will be on their own again in the recovery of their injury. It usually takes around two full years from the surgery for the graft to be completely healed, and the rehabilitation process can usually from 9 to 12 months. After this the visits with physiotherapists are no longer covered by the insurance. It is in this period that the patient will truly need to learn to trust their limb again and hopefully return to do the activities which they like to do (such as the one that got them injured).

Nowadays only 60% of the patients will make a full recovery, and do the same activities as they did before. A major reason for this is that it is a tough rehabilitation process and the patients feel the activities (such as soccer) are just not worth to risk the injury again. Especially not since they are four times more likely to get an ACL injury again.

I ASSISTED REHABILITATION

How - Current rehabilitation

I	Ν	J	U	RY	



DIAGNOSIS



SURGERY

REHABILITATION

PREVENTION











Patient injures the knee.

Primary test performed.

Go to the ER for an MRI.

Visit to a specialst for consultance on initial injury.

Get a final report with referral.

Decision about treatment (surgery or just rehabilitation).

Waiting for surery - minimum two or three weeks after injury. Don't want to operate on a knee that is swollen/inflamed. Awaiting surgery in the hospital.

Anestesia administration

ACL graft surgery

Consultance with surgeon and anesthesiologist.

Initial recovery (week 1 and 2).

Restore range of motion (month 1 and 2).

Restore initial functioning (month 2 and 3).

Regain funtioning (month 4 and 5).

Healthy functioning (month 6 and 7).

Efficient functioning (month 8 and 9).

Return to sport/life (month 9 and onward).

Insurance company

Primary care physicion

Hospital ER

MRI Facility

Orthopedic surgeon

Radiologist

Orthopedic surgeon

Radiologist

Insurance company

Orthopedic surgeon

Anesthesiologist

Surgical center

Insurance company

Orthopedic surgeon

Physical therapist

Coach and trainer

Coach and trainer

How - Research

ASSISTIVE DEVICES

After having suffered from an ACL injury, the patient will usually have some sort of assistive devices either during the period of their rehabilitation or indefinite. The devices which will be used in the beginning of this process consist of crutches together with some sort of brace to compensate for the stability/strength lost in the knee. Usually after a few weeks the patients can function without the crutches, however the braces are for a longer period of time or indefinite. This is why for the market research I will focus on these products.

A knee brace can be used following ACL tears and ruptures either instead of surgery, whilst awaiting surgery, or once recovering from surgery. They are a great way to provide stability to the knee, give it time to heal and prevent further injury. They can make all the difference, allowing you to safely return to sports and other activities. ACL braces may only be needed for a short time while the patient is strengthening the knee or recovering from surgery, or they may become the long term solution.

There are a huge variety of braces out there, I focused on the most effective and popular ones, and devided them into the benefits they give to the wearers. These are the reasons to use a brace:

INSTABILITY AFTER INJURY

ACL injuries can cause knee instability. An ACL knee brace can help improve instability, reduce pain and protect from further injury. The ACL is the main stabilizer of the knee. When it is damaged, the stability of the knee is reduced and can lead to the knee giving way during normal daily activities or when playing sport. If the knee is repeatedly giving way, it can cause more damage to the knee, especially the cartilage. Some people can overcome the problem through strengthening and stability exercises, but many benefit from an ACL knee brace.

FOLLOWING SURGERY

Many surgeons will recommend that you wear a knee brace for a few weeks following ACL surgery. The reasons for this are:

- The ligament needs time to heal: weakest from 6-12 weeks after surgery.
- Caution: Helps provide a reminder to the patient and those around.
- Peace of Mind: For the patient and the surgeon.

PREVENT INJURIES

Lots of sports people are starting to wear knee braces to reduce their risk of injury. Approximately 80% of ACL injuries are non-contact and are due to too much stress and force going through the ACL. By changing the way the forces go through the ligament you can reduce the risk of injury.

TYPE OF BRACES

There are many different options of knee braces. Usually the decision for which brace is made on the amount of support required, manufacturer, what condition and what style of knee brace is required. Following are the three main types of braces:

PULL UP SLEEVES: Simple pull up supports that provide warmth, compression and basic support. Great for minor injuries and pain reduction.

WRAP AROUND: Adjustable with Velcro straps allowing a perfect fit to your knee. Especially good if swelling comes and goes.

HINGED BRACES: Provide support to the knee using a range of hinges to support and offload the knee joint. For moderate/severe instability and pain.

How - Research

USAGE

ACL knee braces have different ways they work, for example with the wrap around braces they divide the energy that would be placed in the knee over a bigger area of the leg, whilst a hinged knee brace works by gently applying pressure to the unaffected side of the knee to relief compressive forces in the affected area. This is better shown in the illustration below.



In general we can say that the function of the brace is to divide the forces which would go to the affected ACL tendon to different parts of the knee in order to reduce the stress and tension on the tendon. Historically surgeons have prescribed

knee braces, like the so-called hinged braces for patients mostly after ACL surgery. This to allow it during the first critical 10 weeks in which the ACL is healing and it is most fragile. More recently however, there has been increased scrutiny as to the effectiveness of the use of knee braces after surgery.

A study published in June of 2013³⁷ (by the German Cantonal Hospital Bruderholz) examined the long term effects of using a knee brace after ACL surgery versus not using one. Four years after surgery the researchers measured ACL ligament integrity, pain levels and x-ray pictures in each patient who had surgery. They found that there was no difference in ligament integrity between the groups.

There was one significant difference between the brace group when compared to the no-brace group. The patients who did not use a knee brace after surgery reported less pain during sports or heavy physical work activities. This shows that the use of a knee stabilizing (for example the hinged) brace after ACL reconstruction is not recommended. On the other hand having any type of brace on the knee will improve patient confidence and protect the knee from being re-injured. This suggests that braces should be used for their protective capabilities but should not limit the patients in their functioning, as happens with the use of rigid/hinged ACL braces.

How - Research

MARKET OVERVIEW (ACL BRACES)



Spring-loaded technology Levitation Severe instability €1650,-

Overview: The Levitation knee brace reduces muscle fatigue, by assisting the movement with an integrated spring. This system enhances strength and performance, and help protect the knees from injury. The hinge acts like a shock absorption system to increase stability and reduce impacts.



Donjoy FullForce ACL Knee Brace Severe instability €550,-

Overview: This Donjoy ACL knee brace is designed for use with severe-moderate ligament instabilities and is suitable for court and non-contact sports, or when recovering from ligament reconstruction. It combines Donjoy's proven Four Points of Leverage™ System with its patented FourcePoint hinge technology to protect the ACL. It has a sleek, low-profile design, and is exceptionally light-weight. It also has a short calf length. It is suitable for competitive and recreational athletes as well as everyday use.



Donjoy Legend ACL Brace Severe instability €500,-

Overview: This Donjoy ACL brace is for moderate / severe ligament injuries. It has a low-profile design so can be worn underneath most clothing. It has a 10 degree extension block fitted to prevent hyper-extension, a common cause of ACL injuries. It also combines the Four Points of LeverageTM System and Four-cePoint hinge technology. It is also suitable for salt and fresh-water activities.

How - Research



McDavid Pro Stabilizer II Hinged Knee Brace Moderate/Severe instability €55,-

Overview: This McDavid brace is suitable for moderate/severe knee instability and pain. It has two side hinges that prevent hyper-extension, and rigid uprights providing additional sideways support whilst allowing freedom of movement. It is made of lightweight materials including aircraft grade aluminum gears that accommodate the natural gliding action of the knee. It has a sewn in patellar support buttress which helps improve patellar tracking. The fully adjustable Velcro straps ensure a perfect fit for the knee.



McDavid Patella Knee Support Mild/Moderate Instability €63,-

Overview: This brace has special supportive steel springs that strengthen the brace on either side of the knee joint to improve stability and support knee ligaments. It also has a supporting padded buttress around the kneecap to improve patellar tracking. The neoprene material provides soothing heat and compression which relieves knee pain and knee swelling and promotes recovery.



Donjoy Drytex Playmaker Mild/Moderate Instability €150,-

Overview: This Donjoy ACL brace is for mild/moderate knee instability following partial or complete ligament tears. It has a hi-tech, simple to use pin system that allows control of how much the knee bends and straightens by locking the brace at one of nine possible positions between 0 and 90 degrees. This is helps to block specific knee movements to provide protection e.g. following.

How - Research

INTERVIEW SURGEONS

"When we are rehabilitating the knee the most important thing is not the surgeon, he or she can perform a semi correct job or a really good one and it won't matter too much on the final result. The most important thing is the physiotherapist. Unfortunately there are big differences between therapists."

Markus Bohlin, Orthopedic surgeon, Umeå, Jan 2018

"Is the therapy therapists describe personalized for each patient (good) or is it a standardized procedure. Is the person motivating and really involving the patient? All these things are of great importance."

Magnus Hagstrom, Orthopedic surgeon, Umeå, Jan 2018

A big problem is that the injury is often misdiagnosed, 40% of the people who turn up for the initial test get misdiagnosed, another 40% of the cases need to wait several weeks for the swelling to go down, and only in 20% of the cases the doctors get it right. Another issue is that it is difficult to diagnose the knee when injured, since it is swollen, which gives extra stability and stiffness to the knee. This is mainly because they search for bone fractures and the therapists are not properly trained to recognize the injury straight away. By directly using an MRI there is a 95% success rate of detecting the injury.

Patients will come in as soon as they realize they have an injury, but it is often misdiagnosed or the patient thinks it will heal on its own, it is also common that other parts of the knee are injured. Just an ACL injury is easier to fix then when it is complicated with other issues. Whether it is through the injury or the surgery, it all complicates the overall rehabilitation process for the patient. For example when the surgeons take the graft from the hamstring, the issue becomes the rehabilitation of the hamstring itself, since most therapists just focus on the ACL, these usually stay very weak.

It is important for the patient to get control of the workload they place on the knee. Too much body weight, incorrect movement, or making mistakes because of tiredness are all of great importance to ensure the injury won't happen again. When people or their muscles are really tired, the risks gets really high, this usually happens because the patient then make more mistakes in their movement, for example not jumping/landing properly.

During the rehabilitation it is important to keep the patient motivated and keep reminding them of their goals so they have something to work for. "It is you who are in control of your own rehabilitation", It is important for them to be involved, because the outcome will be less successful if they are not.

Another issue is to know when the patient is ready to return to sport, especially if he/she has done rehabilitation with different therapists, this since there is no standard way to test the values, the rehabilitation centers check and because of this the data between different methods can not be checked or compared.

When the patient finally reaches the moment when they can return to sport, they should focus on prevention of future injuries. Especially for younger patients since patients younger than 15 years have a 25% change of re-rupturing the ACL. This is why the surgeons usually advice them to get a knee brace like the Donjooy Orthosis, which prevents against hyper-extensions. The big problem with these braces however is that they are not usable for soccer and floor-ball, where there are small motions that will still cause the injury. The brace helps a lot but unfortunately not in the sports that need it the most, where a lot of pivoting motions are taking place.

Luckily there is now a trend going on were knee control exercises are part of the training in Scandinavia. These sport clubs have been able to reduce the amount of ACL injuries by 60% in recent years.

"When we are rehabilitating the knee the most important thing is not the surgeon, he or she can perform a semi correct job or a really good on and it won't matter too much on the result.

The most important thing is the physiotherapist.
Unfortunately there are big differences between therapists."

Markus Bohlin, Orthopedic surgeon, Umeå, Jan 2018



3 surgeons interviews

How - Research

INTERVIEW THERAPISTS

When the therapists get a new patient it is important for them to create a bond and motivate the patient. Therapists often start explaining how the knee functions and what needs to be done for it to recover. The biggest problem they face is that the patient get scared of repeating the exercise that hurt or damaged their leg. They simply feel that it is not worth the risk.

"The biggest challenge you face as a physiotherapist is to be involved and motivate the people. The people need to move as soon as possible otherwise there can be more complications like thrombosis. I want to let the people move the day after surgery or the same day if possible... The problem is that they are sick of the medication they have been given."

Viktoria Aktell, Rehabilitation therapist, Umeå, Jan 2018

It is important for therapists to measure the bend and flexion/extension of the knee. The last degrees are of big importance, because that activates the middle quadriceps. If these are not stimulated the patient risks to lose a lot of muscle strength. That is why you see so many patients who have thin legs after getting an ACL surgery. If they can't fully extend the therapist teaches them how to assist the extension manually to stimulate the muscles.

In the first weeks it is important for the patient to do many short sessions of exercise, at least 5 a day. When they have the flexing and bending under control they move on to strength training and then it will be a different plan.

The wish is for the patient to already start with rehabilitation exercises before undergoing surgery. This since it will help with the recovery after surgery and the muscles won't weaken in the time they wait. It is important to adapt the surgery to each individual patient. For example when the surgery is done with graft from the hamstring

this weakens the hamstring so it also needs to be rehabilitated. In the end we want a maximum difference of ten percent between the legs. After six months of rehabilitation tests are performed to see if the patient can return to sport. But often it is 9 to 12 months before the patient is ready. After this the therapists don't see them anymore and they can start again with some basic training. People have to be careful with the return, for example when running it is three times the body weight on the knee when hitting the ground. People need to work out for the rest of their lives to rehabilitate. Roughly 50% of the people who have had an ACL injury will develop arthritis within 10-20 years.

Arthritis develop because of the trauma and swelling which has happened in the knee. The loading of the knee is another important factor, don't put too much weight/force on it, and have a proper balance between them, could help reduce the symptoms of arthritis. The problem however is that the patients often don't have any feeling in the injured knee after surgery, which makes it more difficult to balance. One promising study which is mentioned by all the therapists I met, is the practice of "Knee control", which is now performed in Sweden and Norway. It has overall very promising results and with the teams where it has been implemented, the amount of injuries dropped drastically.

It would be useful to have a tool to measure the strength the muscles are using and how. It could help answer questions like, how close the patient is to the maximum during the exercises, how are the muscles behaving, what is the maximum bend and stretch angle, how is it with the pain, what is the difference between the legs, how is the hamstring holding up, how is the full range of motion, use the patient using their full capacity? It is very troublesome that the rehabilitation between therapists is not the same... We cannot relate results and rehabilitation practices. Use totally different methods and goals, or even reliable data from the other one? By measuring these values you know for sure what the patient did, nowadays you have to take their word for it, so often we send them off to the next step in rehab when they are not ready,



How - Research

INTERVIEW PATIENTS

A total of six patients have been interviewed about their experiences with ACL recovery. One of the mayor problems is that with almost all of the people the injury was initially misdiagnosed, and because of this the injury only got more severe. From the beginning it got clear how important it is for these people to have friends, family or team that has been through the same since they will recognize the symptoms and support the patient in any way they can.

When deciding to go for surgery or not it is important that the doctors and surgeons are very clear and honest about the consequences. Without surgery the lifestyle will change dramatically since you can not perform the same active lifestyle as you might have been used to. It needs to be clear why they are performing certain tasks of the rehabilitation process, for example almost none of the patients wanted to do the rehabilitation before the surgery, since they would lose all the function they regained afterwards again. It was not clear that it would help them recover quicker in the second round of rehab. In general all patients look forward to having the surgery, since they see it as the beginning of the end of the injury. Because of the long waiting time (can take months) they do feel that their lives are on hold and they can't wait to get back to it.

"People don't realize how hard it is to not go to work or be able to do what you want to. Doing those activities that was me! You feel like your life is suddenly on hold when you go from five times training a week to none"

Amanda, ACL patient, Umeå, Jan 2018

Once the surgery is done, the rehabilitation can start, and since most patients were passionate athletes they started off with much motivation! Because of the pain and the swelling in the knee however the fear started to enter. They did not know how far they should stretch or bend their leg if it would start to hurt. Having the "am I

doing this right moments." Luckily in this phase the result will show rather quickly and can perform some initial exercises that will keep them motivated to perform the rehabilitation exercises. The risk however is that the patients are too motivated and will overdo it, risking a set back. Another big issue is that because of the limitation in the knee, they start to compensate. Four out of six interviewed patients have had some other injury/damage following their ACL injury.

After the first few months the improvement start to get less visible. This means that their motivation to do the exercises also drops and they are starting to doubt if they will ever come back to their normal functioning. This can have a bad influence on the final result. It is important to have someone or something that motivates them, this can be friends, family or a good therapist.

Another thing that helps is to focus on a goal to reach. For example one patient was no longer able to play soccer afterwards. But by focusing on going on a skiing trip, she managed to motivate herself enough to continue with her exercises and every time she managed to get closer to one goal (cross country turned into skiing) she pushed herself and her abilities further and further.

Another problem is the fear of being re-injured. People feel it is not worth it to go through this process once again, since they felt alone, and like their life was on hold. They did not feel in control of the process and did not know how long it was going to last. By empowering them and giving them control of their own rehabilitation they think this might have been improved.

They wish to know how to prevent the injuries from happening again, so they are prepared when they return. Even though they are all happy to be done with the therapy now, most admit that they do not do the exercises afterwards anymore to strengthen the knee.



How - Patient journey

REHABILITATION PHASES

In what phase of the rehabilitation are we?





Patient sustains injury

DIAGNOSIS



Diagnose severity of injury.

REFERAL



Decide how to treat the injury

SURGERY



Initial recovery (week 1 and 2).

Initial recovery (week 1 and 2).

PAINPOINT MAPPING

How did the patient experience the overall rehabilitation, what was positive and what was negative? Where were things unclear and help was required? What was good and what would he/she like to see differently? ACL is often misdiagnosed, people don't realize they have the injury and hope the injury will heal by it self, or the Doctors and physiotherapists often mistake the injured ligament because they check for bone fractures and are inexperienced to check for an ACL injury. Since the injury is common in sport, the teams know what to watch out for.

It often takes several weeks to get the MRI (wait for the swelling to go down), in this time the patient is still not sure about their injury. When deciding to have surgery or not, the needs of the patient are the most important.

People often have to wait for several months for surgery. In the mean time they are supposed to do initial rehabilitation. The motivation to do this however is really low.

One reason to skip surgery is because patients can be scared of it. In this case they will advice general rehabilitation without. The other choice is to go for surgery.

Patients are looking forward to it, just want to get it over with and back to their normal life. In this phase the patient is often in much pain, and limited in the actions. It is important for them to know the severeness of what they are facing and take enough rest. A good therapist is all the difference to keep a patient motivated.

NEEDS

What else would the patient have needed in this time? Was there something missing?

A quick and precise way to determine whether or not the ACL is torn. For example professional NFL teams have an MRI in the locker room.

Knowledge about the injury and mental support. Luckily it is quite common so there is often a friend/family member that can support them. A clear understanding of how the option of surgery or rehabilitation without surgery will influence the patients life. Motivation to get through the first rehabilitation phase. Help to make a choice.

A non fixed brace would make it easier for the patient to move around. It is also very limiting with the exercises. An app that would guide the patient through the process.

How - Research

REHABILITATION



Restore range of motion (month 1 and 2).

For the patient it feels that their life is on hold, they realize the severeness and that they might not return to sports. It is important to keep the patient motivated in this phase and make sure they do their exercises.

Keep the patient motivated. They feel left out, and like their life is on hold.



Restore initial functioning (month 2 and 3).



Something to stop the com-

pensation. Because of the in-

jury and pain, people tend to

compensate and risk injury.

Furthermore show the prog-

ress of the patient.



Regain funtioning (month 4 and 5).

Important for the patient to realize that it is all up to them. They should stay motivated, through the therapist, family and friends.

Because they don't trust the impaired knee there is still a lot of compensation in this phase.



Healthy functioning (month 6 and 7).

Getting closer to the goals keeps the patient motivated. The therapist should adapt the training to more specific exercises for these goals. However since there is no direct improvement visible, the motivation is quite low with most patients. They will realize that it will probably never be the same again as before.



Efficient functioning (month 8 and 9).

First time returning to the thing they love to do. This stimulates them to take the exercises serious.

Still a lot of compensation since they do not trust the knee yet and feel it might not be worth the risk of re-injury. PREVENTION



Return to sport/life (month 9 and onward).

Returning to sports. Having to continue with the rehabilitation themselves for at least two years. Problem is the patients neglect the exercises since they don't want to be reminded of the injury.

app would help to guide through the recovery process. Help the patient understand the exercises they need to do, so they do not too much or lit-

tle, and also correct.

Keep the patient motivated by letting them focus on a goal. Make sure they don't give up or settle for anything less. Get them to trust the knee again. Only 60% return to former levels, many afraid and feel like it just isn't worth it to return to previous levels.

Show how the legs and knees are doing. Focus on prevention. Need to stop the compensation and train to reduce further injury, by teaching the propper techniques.

How - Research

INTERVIEW COACHES

It is important to do preventive training, as a couch you wish to make sure your athletes are in their best shape and the risk of injury is as little as possible. Usually every third training is on technique and preventive training, but with younger athletes in Scandinavia they practice this at least once a week.

The preventive training focuses on technique, impact and balancing, so they are able to correct quickly when something happens during a match. In general the preventive training is done for all the limbs in the same training. These trainings are tweaked for each sport individually.

As a trainer you try to figure out what the physical needs are of the athlete and the sport and how this should affect the rehabilitation of the athlete. We try to get in touch with the physiotherapist but nowadays this is very difficult, and we get the information from the athletes themselves. But is this the correct information? As a coach you need to know how to get the most out of the athlete, and the understanding of the athlete can be different from what we would hear if we talk to the therapist ourselves.

When an athlete returns usually he/she has a program prescribed by the therapist, but quite often they don't really understand how this sport impacts the player. Every sport is different on how it affects the players.

It is important for the coaches to know that their athletes are in good shape and where they should focus on to improve, is the balance between the legs good? Are they equally as strong? How are the muscles working? How is the technique when they land? These are all questions of importance for them to take care of the athletes. Unfortunately they can't do these tests since they are too expensive for a small club. Don't have the same budget as the big clubs do. There they have the equipment and therapists to adjust the training to each individual athelete.

SHADOWING KNÄKONTROLL SESSION

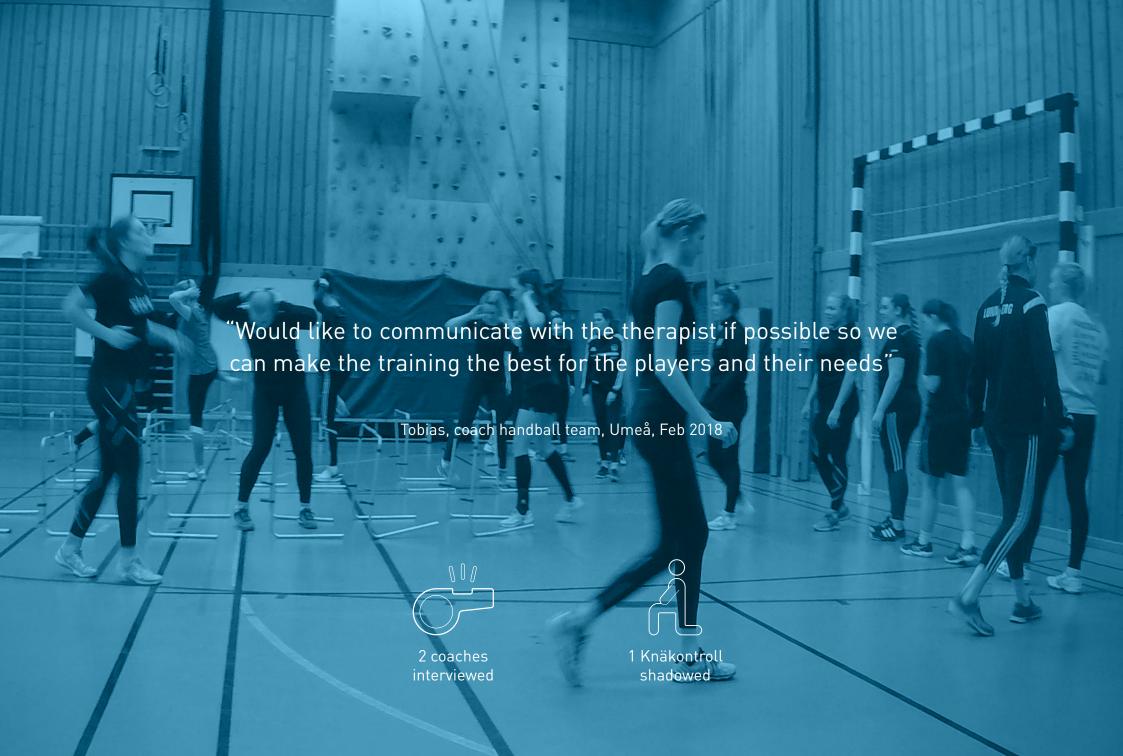
Since recent years injury specific preventive exercise programs have come into existence. A growing number of these programs have been developed to reduce the risk of knee injuries in general and ACL injuries in particular. One of these is the Knäkontroll program which is used in Scandinavia. The initial results show that they can roughly reduce the risk of injury by 50%.

Typically, these programs consist of exercises focusing on core stability, balance, dynamic stabilization and muscle strength of the lower extremities. The exercises are often designed as structured warm-up programs to ensure that all players use the program regularly.

A recent study focused on these training programs to reduce injury risk in football players, has shown that the trainings appears to be effective in reducing ACL injury risk and that lower extremity strength and balance exercises, in combination with core and trunk control, seem to the key factors in their success. This was also the main focus of the training that was shadowed. One of the most important factors of the training was the coach who would show the athletes how to perform the exercises and would correct them in case they made mistakes. Another important factor was that the athletes performed these exercises in groups since they pushed each other to perform them the best they could.

Unfortunately these Knäkontroll sessions still have some problems, for example when people perform them at home, it is in most cases ineffective since they don't get proper instructions and feedback on their technique.

Another important challenge is to convince coaches and athletes to use the programs. "Are the exercises really worth doing?" This is a common questions, and although the result is proven, it is not widely used yet.



How - Problem analysis

2 000 000 +

People suffer from an ACL Injury worldwide each year

20%

of ACL injuries are correctly diagnosed

THERAPISTS

"The most important thing is the physiotherapist. Unfortunately there are big differenes between therapists. Rehabilitation should be unique for each individual."











INJURY

Lack of accessibility preventive training.

Lack of knowledge to propperly recognize the injury

Women are 4 to 6 times more likely to injure their ACL

INJURY

Injury often misdiagnosed, do to lack of knowledge.

Have to wait for swelling to go down.

Can't get an MRI without an referral.

REFERRAL

Knowledge about the injury, what are the consequenses of surgery or no surgery.

Mental support.

Motivate patient to start with rehabilitation.§

SURGERY

Patients need to do as much rehab before surgery as possible.

Motivation to do rehab low.

Patients are scared of surgery.

INITIAL REHAB

Patients need to move ASAP.

Still sick from medication.

Lot of pain and swelling.

I ASSISTED REHABILITATION

How - Problem analysis

MOTIVATION

Patients tend to do too much or too little. Both put the outcome of rehabilitation at risk.



of patients will make a full recovery

50%

of patients will develop arthritis in the following 10 to 20 years.













MONTH 1 & 2

Patients are aftraid,

Lot of swelling, limiting the functioning.

Am I doing this right?

MONTH 2 & 3

Patients lose their motivation.

Don't see result.

MONTH 4 & 5

Patients might get too motivated and by doing to much reinjure.

Because of limitations start to compensate.

Is the patient ready for the next step? How do we know?

MONTH 6 & 7

Keep patients motivated through their goals.

Patients tend to settle for less.

Lot of compensation, increases risk of future injury.

How to measure the status of the patient? There is no standard.

RETURN TO SPORT

Is the patient ready to return? how do you know?

Afraid and feel it is not worth the risk of reinjury.

Patients too motivated to return. Do to much in too short time.

Hamstring often too weak.

PREVENTION

Risk increased four times to injure knee again.

Patients dont trust their knee.

Have to continue working out to strengthen and prevent.

> Compensation leads to future injury.

How - Research

DATA TO COLLECT

When we are looking to make a solution for the rehabilitation of ACL injuries, we first need to better understand what data needs to be gathered, to judge the rehabilitation upon. In general we can say that when a patient goes through rehabilitation, the therapists and surgeons will judge the current status of the recovering knee before letting the patient continue with the next phase. In general we can say there are three major area's in which data needs to be collected to see how the patient is performing³⁸:

MOBILITY RECOVERY

After a knee surgery, patients lose mobility on their knees. Recovering a certain range of motion (RoM) is required before patients can continue with the rehabilitation program. During the first weeks after surgery, patients need to know the degree of flexion and extension of their knees.

STRENGTH RECOVERY

After the injury and during the mobility recovery phase, patients suffer from muscular atrophy on the injured leg. Therefore, the second phase of the rehabilitation focuses on muscle building. A commonly performed exercise for strength recovery are one-leg squats and different variations of it. During a one-leg squat, patients stand on the injured leg, bend it as much as they can and then go back up into their initial position without deviating their knees from the line between the ankles and hips.

Currently, orthopedists and physiotherapists lack convenient ways to measure the angle of flexion of the leg during a squat. Therefore, the performance metric currently being used is the amount of squat repetitions. It would be convenient to have an objective way to measure shaking and bending of the leg during a squat. Unfortunately since different orthopedics and physiotherapists use different methods, the data can also not relate when being shared.

RETURN TO SPORT ASSESSMENT

Towards the end of the rehabilitation, orthopedists should assess whether patients are ready to start doing sports again. In order to do this, orthopedists compare the performance of the injured and healthy legs while executing different exercises, such as one-leg hops.

When the therapists and surgeons want to judge the patient on these stages they will measure how well the knee/muscles perform on the following factors:

PAIN. How much pain is the patient feeling performing the exercises?

BEND AND FLEXION. How far can the patient extend, bend and flex the knee? It should be at least 90 degrees backwards and a straight leg.

STRENGTH. How much force can the knee produce, and how much in comparison to the other one?

BALANCE. How is the balance between the legs? Are both legs carrying the same weight, or is one compensating for the other?

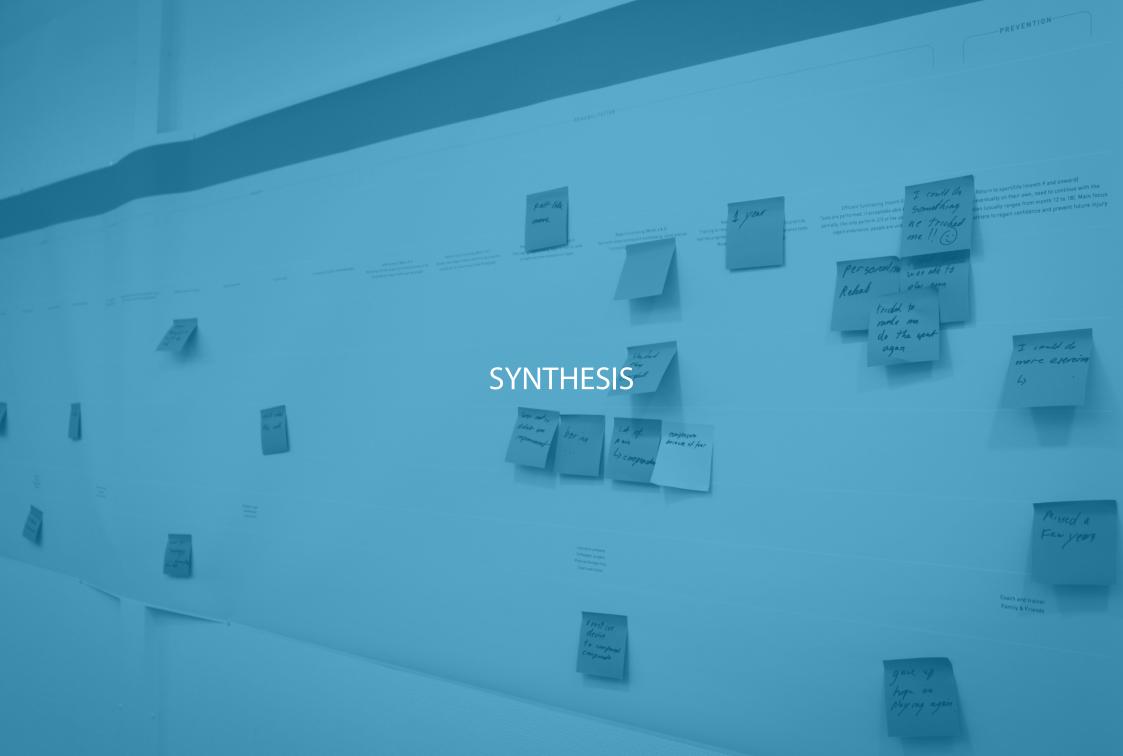
ENDURANCE. How long can the patient perform exercises?

To reduce the risk of reinjury the following information can be used to tell when a patient needs to take a break:

ACTIVITY. How active are the muscles? How close to the maximum of their capabilities are the people performing the exercises?

TIREDNESS. How tired are the muscles? When the muscles are tired or the patient distracted the risk of injuries is really high.







How - Synthesis



"I felt it was just not worth it, I already lost two years of my live."

Amanda, ACL patient, Umeå, Jan 2018

PRACTICAL & FUNCTIONAL NEEDS

EMPOWER the patient. Knowledge about the injury, how will this affect them if they don't take surgery? What to expect? Let them take control.

AM I DOING THIS RIGHT? How to perform the exercises? Because of pain/difficulties people tend to compensate or not perform them correctly.

NON-FIXED SOLUTIONS. Solutions like braces make it difficult for the patient to move around and they are not beneficial for the recovery.

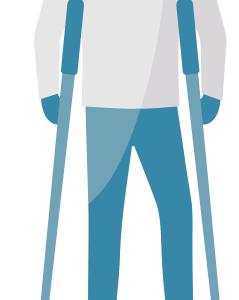
PERSONALIZATION. Every rehabilitation is different, what else is damaged? Do we need to train the hamstring as well?

COMPENSATION. People tend to compensate and risk future injury.

EMOTIONAL NEEDS

MOTIVATION. Stimulate patients to do the exercises so they don't do too much or too little. People tend to over or under train the injury.

TRUST. People need to trust the knee again.



How - Synthesis

NEEDS FOR SURGEONS & THERAPISTS

"The most important thing is the physiotherapist. Unfortunately there are big differences between therapists. Has the therapy they described personalized or standardized. Are they motivating and really involved?"

Markus Bohlin, Orthopedic surgeon, Umeå, Jan 2018

PRACTICAL & FUNCTIONAL NEEDS

MEASURE. Need for an easy and precise way to measure the bend, flexion, strength and endurance of the knee.

WHAT STAGE? Is the patient ready for the next stage? Have they done the training, you have to take their word for it.

RELATE RESULTS. Rehabilitation between therapists is not the same. Because of different methods results can not be compared.

TAILORED PROGRAMS. Often ACL complicated with other injuries, or from surgery. Need to take this into account.

RETURN TO SPORT. Is the patient ready to return to sporting? Should continue their exercises, no more contact with patients.

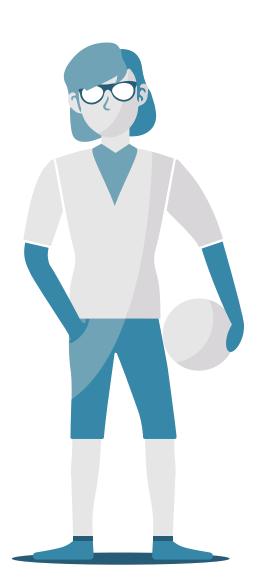
EMOTIONAL NEEDS

INVOLVE AND MOTIVATE. The biggest challenge as a physiotherapist is to be involved and motivate the people.





How - Synthesis



NEEDS FOR PREVENTION

"Eventually they are on their own, need to create confidence, to no longer be scared of what got them injured, so they are able to return to sport/activity."

Magnus Hogstrom, Orthopedic surgeon, Sports Medicine, Umeå, Jan 2018

PRACTICAL & FUNCTIONAL NEEDS

CONSISTENCY. Continue with the exercises to keep strengthening the knee. It is still weak for the first two years.

KNEE CONTROL. Teach the patients how to use the knee properly, how to land, how to run, etc... Exercises to reduce the risk.

TIREDNESS. When you are really tired, the risk of injury is really high.

BALANCE. How is the weight balance distribution, overuse of one leg can lead to future injuries, and also increases the risk of arthritis.

FOLLOW UP. When returning to sport in the professional sector, the patients meet with therapists for the first few months to monitor how they have recovered and how to improve from there.

EMOTIONAL NEEDS

TRUST. The biggest problem is that patients get scared of repeating the exercises that damaged their leg.

How - Insights



PERSONALIZATION

Rehabilitation is a very broad topic, every injury has its own rehabilitation program and every person has their specific needs. Unfortunately often the rehabilitation is still standardized.



MOTIVATION

Because of the injury, it can feel that life is on hold for the patient, and since they will see little to no improvement over longer periods they can lose the motivation to do the exercises.



COMPENSATION

Because of pain and not performing the exercises in the correct way, the patients often create the habit of compensation in which they overuse the other leg and risk injuring it in the long run.



DIAGNOSIS

Unfortunately the injury is often missed during initial diagnosis, or the patient thinks its just a swelling and hopes it will go away. This will often cause even more damage to the surrounding body parts.

How - Insights



PREVENTION

The focus today is on recovering from the injury, which is expensive and after getting the injury, patients are four times more likely to tear the ACL again. There should be more focus on prevention, especially since it is proven to work!



EMPOWER

Patients do not feel in charge of their own rehabilitation. Adapt the process to their specific need.



RETURN TO SPORT

Most critical moment. Difficult to test. Patients need to continue rehabilitation on their own.



FEAR

It's just not worth it... People fear re-injuring the knee, stop doing what they love.

How - Scenario 1: empower patient

EMPOWER

Provide the patient with a tool to get total control of his/her own rehabilitation process. Monitors the injury and adjust the therapy accordingly.

CONTROL

By providing the patient with their personal rehabilitaiton plan, we enable them to take complete control of their own rehab and motivate them.

PREVENTION

The tool will be used to teach the patient how to properly return to sport and reduce the risk of future injury.









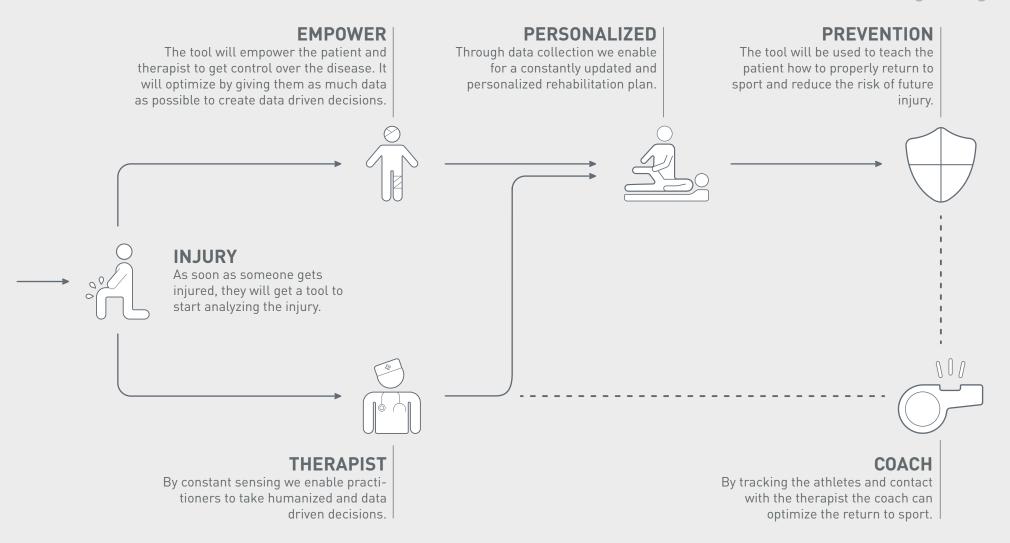
INJURY

As soon as someone gets injured, they will get a tool to start analyzing the injury.

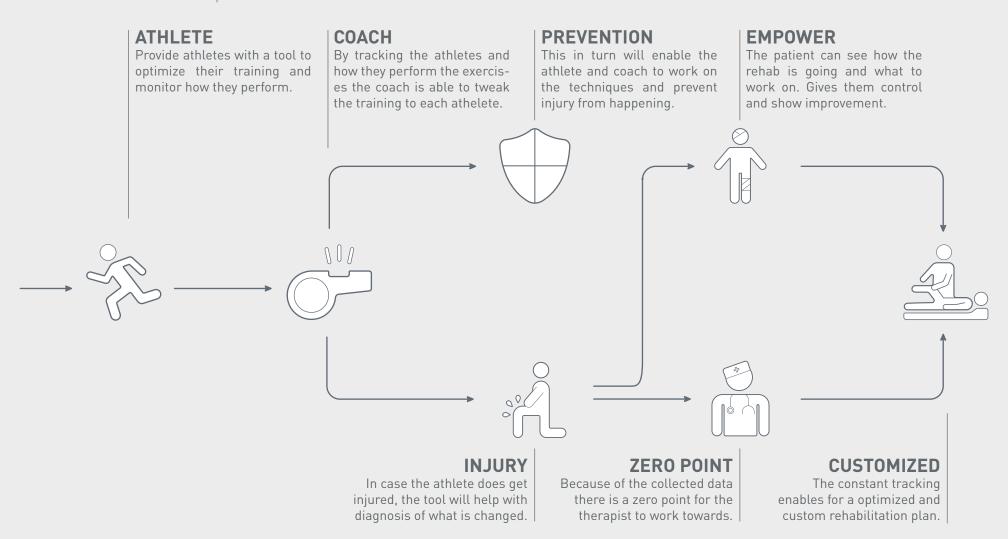


In this case the therapist will play a supportive role and most communication is done through tele-health solutions and physical checkups.

How - Scenario 2: stronger together



How - Scenario 3: prevention





CHOSEN SCENARIO 2:





REHAB

HOME





PRIMARY: REHABILITATION

The primary focus of the concept should be to assist with the rehabilitation of ACL injured patients. To innovate for patients to recover their health in a faster and easier way through a personalized and humanized rehabilitation plan.



"To create and maintain sustainable health systems, there needs to be a shift in focus from treatment to prevention". Test has shown that focusing on preventive measure the risk of injury can be reduced by 50 %.

Due to the stronger need, bigger human impact and healthcare focus, scenario two has been chosen with the main focus on empowering the patient and therapist in the rehabilitation process.

Even though the primary focus is on rehabilitation the device might be able to empower the patient to reduce the risk of re-injury with little to no adaptation.

How - Design opportunity

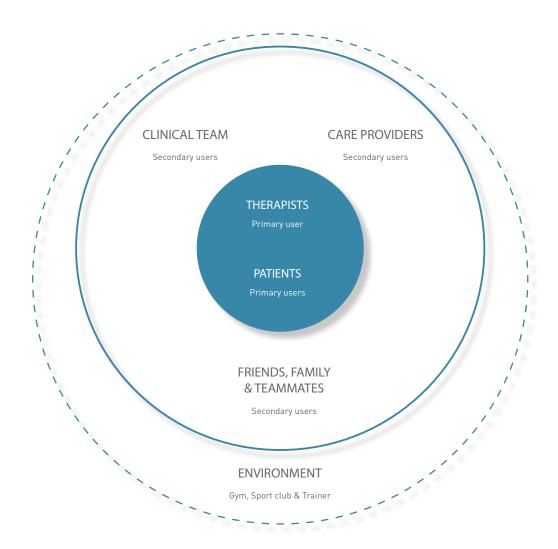
PROBLEM STATEMENT PATIENTS

How might we empower ACL patients to recover their health in a faster and easier way through a personalized and humanized rehabilitation plan?

PROBLEM STATEMENT THERAPIST

How might we provide an increased amount of insights for the practitioner to take humanized and data-driven decisions?

NOKIA I ASSISTED REHABILITATION How - Design opportunity



PROJECT FRAME

The primary users are the ACL patients and physiotherapists who will use the concept to be more in control of their own rehabilitation, and get feedback on how to improve and if they are doing ok. Through increased amount of insights the practitioner can take data and human driven decisions, which in turn will generate a more customized rehabilitation plan that will empower and motivate the patient.

Secondary users are clinicians who could use their patients' adherence and outcomes data to review the effectiveness of their care plans.

Also the friends, family and teammates are considered as secondary users, since they will play a big role in the emotional and motivational part of rehabilitation. For patients who are active in team sports, it is helpful to know they have the support of their team, and they would like to know how their team-member is doing with the rehab.

The customer of the concept will be the Care Providers who's main focus it is to reduce the costs of rehabilitation with better health outcomes and can optimize how to spend the money they have for rehabilitation the best between the most promising patients.

Finally the last user groups are the Sport club and the Coach/trainer, who wish to stay up to date on how the rehabilitation is going, and see how they can help in the end with the return to sport when the patient no longer has the support from the therapist.

Furthermore the gym and sport club might also wish to use the concept to reduce the overall risk of getting an injury if it manages to assist with the prevention.

How - Design opportunity

CONCLUSION

As can be seen from the research there is a problem with the rehabilitation between the therapist and the patients. The outcome of the treatment is too much determined by the capabilities of the therapist, who does not have enough information to generate a personalized treatment for each individual. Another big problem is the fact that patients lose their motivation since they feel that they are not improving, and feel alone in the overall process. We need to empower them and let them know that the outcome of the rehabilitation is completely in their hands.

By providing more data and communication between therapists and patients we can generate a system that will inform and educate each patient individually how to deal with their unique situation whilst giving therapists the information they need to take human and data driven decisions, which in turn will result to a better outcome. The system nowadays is too standardized and focuses on the recovery of symptoms and not the treating and prevention of the injury itself. By giving control back to the patient we can teach them how to reduce the effects of the injury in the long run (such as compensation), whilst teaching them how to prevent the injury from happening again, concluding in a more personalized and optimized rehabilitation plan.

WHY To empower ACL patients to recover their health in a faster and easier way through a personalized and humanized rehabilitation plan.

HOW Through constant sensing we provide an increased amount of insights for the practitioner to take humanized and data driven decisions. This will result in a more informed, easier, faster and reassured rehabilitation experience for the patient.

WHAT A tool that will empower and enable both patient and practitioners to deliver data driven and a personalized outcome for the patient.



PRIMARY FOCUS: REHABILITATION

The primary focus of the concept should be to assist with the rehabilitation of ACL injured patients. To innovate for patients to recover their health in a faster and easier way through a personalized and humanized rehabilitation plan.



SECONDARY FOCUS: PREVENTION

"To create and maintain sustainable health systems, there needs to be a shift in focus from treatment to prevention". Test has shown that focusing on preventive measure the risk of injury can be reduced by 50 %.

How - Design opportunity

GOALS



EMPOWER patient to take control of their own rehabilitation.



Increase the patients MOTIVATION to perform the rehabilitation.



PERSONALIZE the rehabilitation plan to each individuals personalized needs.



Reduce the amount of reinjury by teaching patients about **PREVENTION** which in turn will help reduce the long term risks of the injury by reducing the amount of **COMPENSATION**.



Optimize the **RETURN TO SPORT**, make it easier for practitioners to test and for patients to continue their rehabilitation afterwards.



Improve the **OVERALL OUTCOME** and let more people return to their original functioning.

WISHES



Enable **SHARING OF INFORMATION** between all stakeholders.



Create a system that will make the patient more **CONFIDENT** in their functioning and trust in their knee again.



Have a design that test the rules set for design in the **CIRCULAR ECONOMY** (see report "preparing for a circular economy").



Have a concept that will be of **RELEVANCE** for Nokia to explore how they can enter the professional healthcare market.



NOKIA

What - Abstract

ABSTRACT

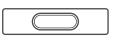
After the research phase the ideation started to find a way to tackle the problems and opportunities related to the injury. These were eventually put into three concept directions which were then prototyped and validated with both patients and healthcare professionals. After several rounds of refinement the ecosystem for the concept was put together and a new case created of how the injury will be tackled by the concept:

As soon as a individual gets injured, he or she receives a tool from the hospital/ therapist that start to analyze the injury and creates a zero point for the therapists and patients.

This in turn will empower the patient by creating a better understanding of their injury and also informing them about the consequences. Through constant sensing the concept will provide an increased amount of insights for the therapists to take data an human driven decisions that in turn will result in a more informed, easier and reassured personalized rehabilitation experience for the patients.

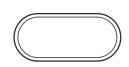
The concept will collect data throughout the entire rehabilitation process and adapt it along the way accordingly to the patients current capabilities and measure how the muscles are reacting to the exercises. For example if the knee starts to swell it will tell him to take a break or adjust the exercises to a lower level for next time. In the long run this will also enable the patients to better focus on the preventive side of the rehabilitation since the exercises will be adjusted accordingly and they will receive life feedback.

When the patients are able to return to their previous activities, for example a team sport, the data can also be shared with the coaches/trainers so they also know what to watch out for in the first year with this individual and where he or she should focus more on during the exercises.



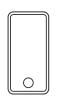
BRACELET

The sensor technology is integrated inside the bracelets. These will be washable by hand and chargeable over night via induction charging. The internal components consist of Blue-tooth. Battery, IMU position sensors, a printed circuit board, LED's (multi color) and a vibration engine.



CHARGING DOCK

The charing dock is used to charge the bracelets over night, via induction charging.



APP

The app will be used to communicate the data with the user and make it understandable via an app. There will be three different types of app's, one for the patient to monitor the injury and therapy, one for the therapist for telehealth and one for athletes to be used for performance enhancing.

The above described ecosystem come together into a concept called Ara, which will be delivered by Nokia in the form of a service towards healthcare providers. The result can be seen from page 120.

APPROACHING THE CHALLENGE

DEFINING A DESIGN STRATEGY

To approach the challenge effectively we need to develop a design strategy for the design process and development. The initial goal is to rethink and challenge the current rehabilitation process, and start designing a new experience with the human centered experience in mind, before the functional and technical standpoint.

RETHINKING REHABILITATION FUNCTIONALLY

Having gained knowledge of the issues therapists and patients face during the current rehabilitation process, the first step is to tackle how the process could be done in a better way.

DEFINE THE EXPERIENCE AND CONCEPT ECOSYSTEM

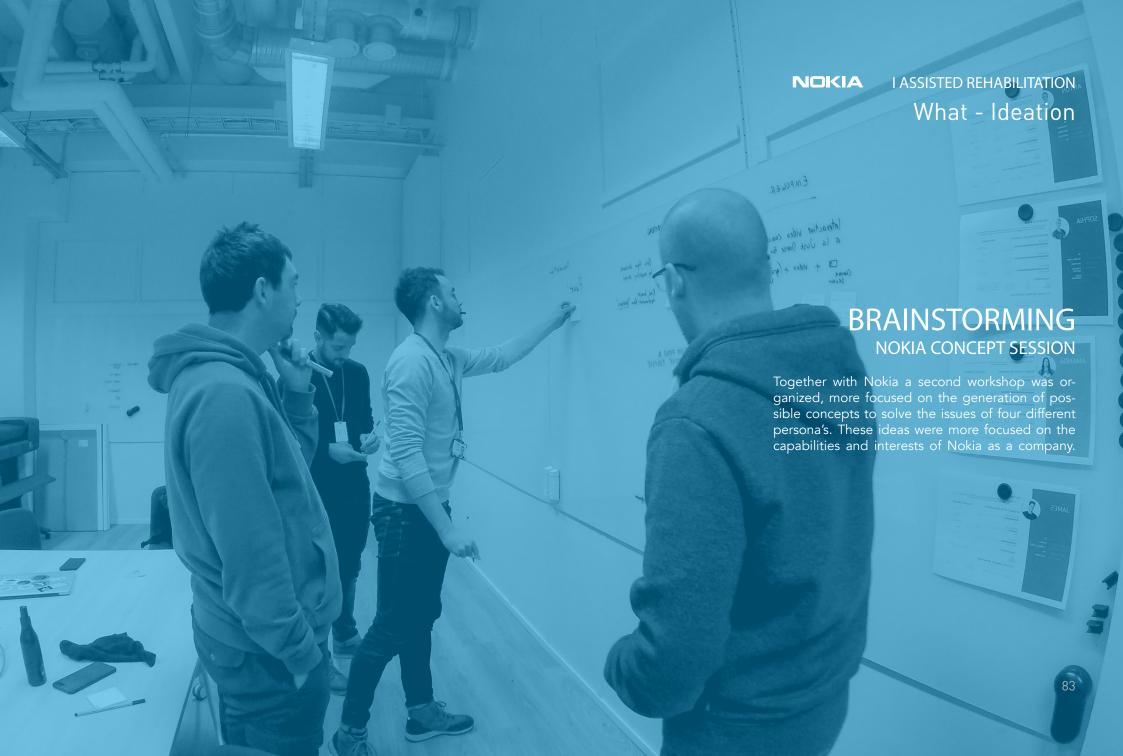
To ensure the patients feel involved and empowered in their own rehabilitation there is a need to explore the entire experience, from the moment they get the initial diagnosis to the moment they are able to return to sports.

DESIGN WITH THE PATIENT CENTERED

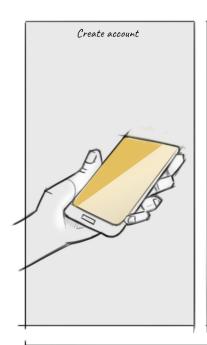
A big challenge with current assistive devices in rehabilitation is that they are not designed with the human centered. Patient almost become robots when they are hanged in these big bulky machines. How can Nokia provide the benefits of technology without making it intrusive?

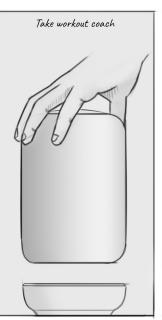


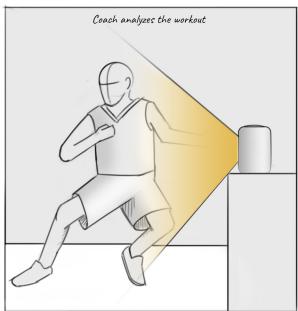


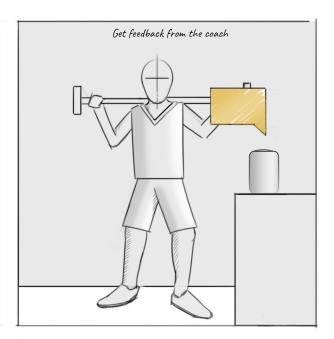


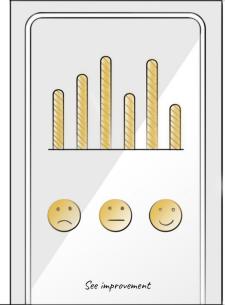


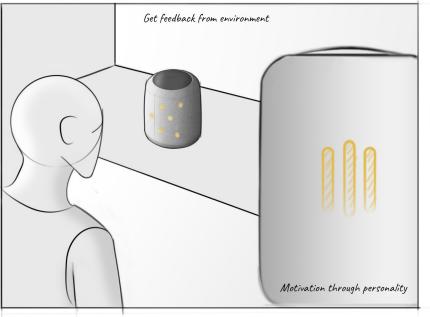


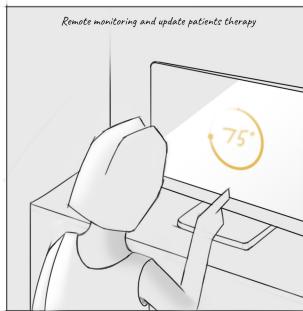


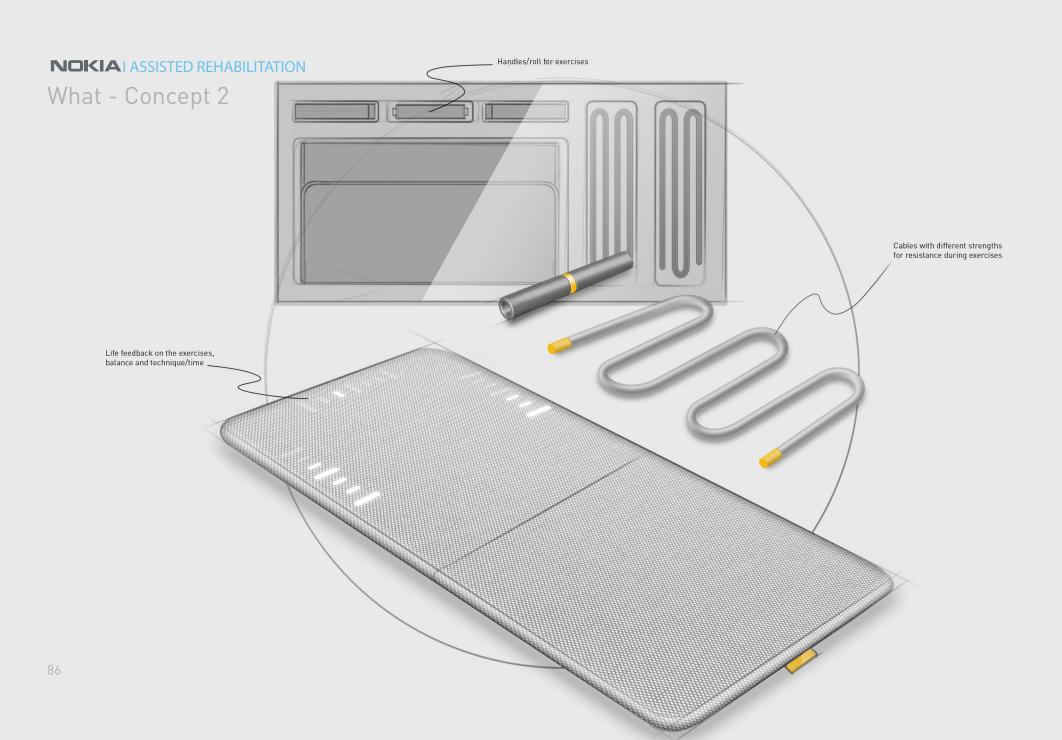


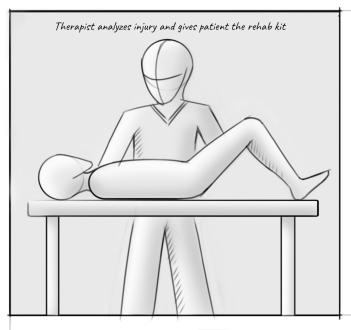




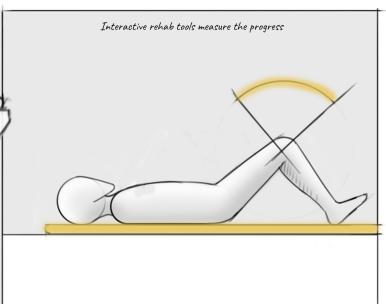


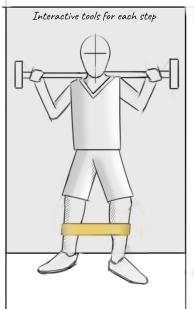


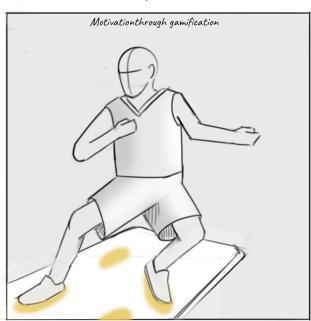




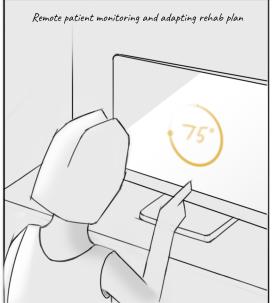


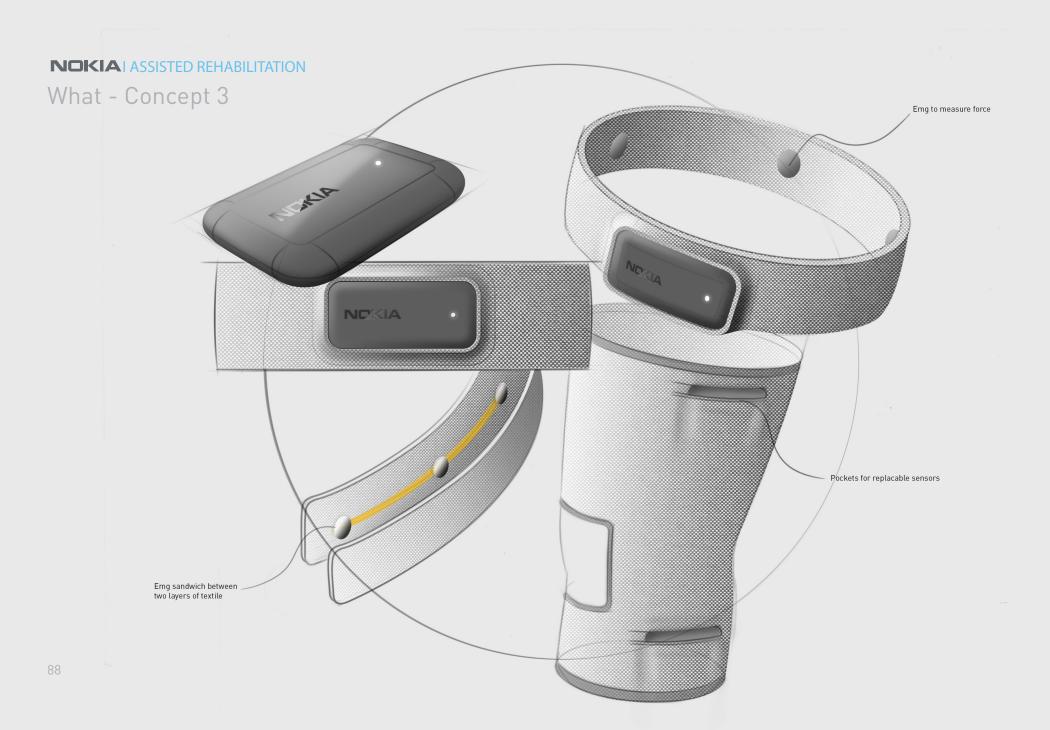




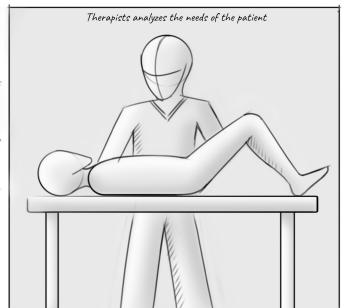


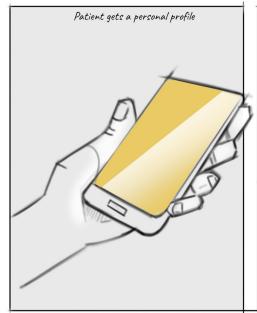


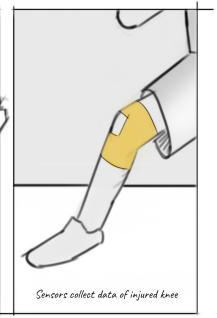


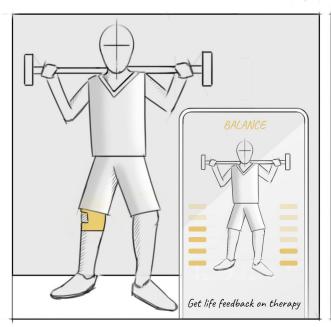


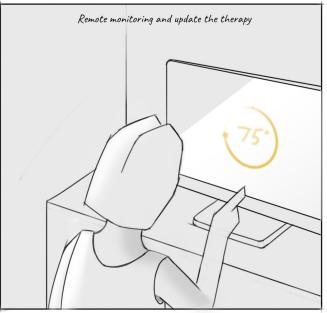


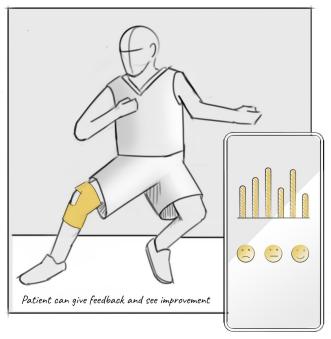












What - Validation

CONCEPT 1

The benefits of concept one is that it is easy to use, and the least intrusive of all the concepts. Through it's personality the tool can be used as a great motivator to perform the exercises. It was seen by the surgeons and therapists as a new type of rehabilitation tool with great potential. Because of how it analyzes the patients it will open up for a broad segment of rehabilitation, from broken arms to knee injuries.

The downside however is that there is no deep data analyzed by the concept, since it is mostly visual. You can't monitor how the knee is reacting to certain exercises, for example whether it starts swelling. From all the concepts this is the one that collects the least amount of information for the therapists.

CONCEPT 2

Concept two appealed because of the elements of gamification. It was the idea to turn the exercises into fun games and would collect more data than concept one because of the interactive workout tools. It would motivate through the use of games and by showing live feedback on the exercises and improvement.

The downside is that the data collected was still not deep enough, for example it can not analyze the reaction/status of the knee during the exercises and would also be more work to set up. You would not take the devices with you to the gym, etc.

CONCEPT 3

What appealed the most about concept three was the ease of use. You could just strap it on around the knee and you are good to go. The concept will give a good holistic view of the injury and will collect all the data that is required to personalize the treatment. It was described as the "Doctors and Physiotherapists best friend". It will analyze the knee continuously and can analyze the return to sport which is not able with any other device yet. The other benefit was the potential of using this device for preventive training.

The downside of the concept was that it was the least motivational of the three. There needs to be an element implemented that would make the therapy fun and stimulate by showing improvement, for example through an app.

The validation was done with the Orthopedic specialist Marcus Bohlin from the Umeå hospital (who is also the head surgeon and therapist for the Swedish female Volleyball and floorball team), as well with two users, of which one is currently going through rehabilitation.

What - Chosen direction



WEARABLE SENSORS

Data collection to empower patients and therapist to take human driven decisions.

MOTIVATION

Motivation through personification of the therapy to stimulate the patient, by device or an app.

What - Refining the scenario

ZERO POINT

Because of the collected data there is a zero point to work towards in case of injury, and a more personalized and focussed plan for the athlete and their sport.



PREVENTION

PERSONALIZED

This in turn will enable the athlete and coach to work on the techniques and prevent injury from happening.



ATHLETE

The tool in turn can also be used to do regular checkups on healthy athletes.





EMPOWER

The tool will empower the patient and therapist to get control over the disease. It will optimize by giving them as much data as possible to create data driven decisions.



OWER

Through data collection we enable for a constantly updated and personalized rehabilitation plan.



The tool will be used to teach the patient how to properly return to sport and reduce the risk of future injury.



INJURY

As soon as someone gets injured, they will get a tool to start analyzing the injury.



THERAPIST

By constant sensing we enable practitioners to take humanized and data driven decisions.





COACH

By tracking the athletes and contact with the therapist the coach can optimize the return to sport.

NOKIA I ASSISTED REHABILITATION What - Refining the scenario

REFINING THE SCENARIO

After validating the concepts with users and specialists it became clear the proposed scenario could be expanded to include the preventive side of the injury as well. In the new case the patient journey will be as follows:

As soon as an individual gets injured, he or she receives a tool from the hospital/ therapist that start to analyze the injury and creates a zero point for the therapists and patients.

This in turn will empower the patient by creating a better understanding of their injury and also informing them about the consequences. Through constant sensing the concept will provide an increased amount of insights for the therapists to take data an human driven decisions that in turn will result in a more informed, easier and reassured personalized rehabilitation experience for the patients.

The concept will collect data throughout the entire rehabilitation process and adapt it along the way accordingly to the patients' current capabilities and measure how the muscles are reacting to the exercises. For example if the knee starts to swell it will tell the patient to take a break or adjust the exercises to a lower level for next time. In the long run this will also enable the patients to better focus on the preventive side of the rehabilitation since the exercises will be adjusted accordingly and they will receive live feedback.

When the patients are able to return to their previous activities, for example a team sport, the data can also be shared with the coaches/trainers so they also know what to watch out for in the first year with this individual and where he or she should focus more on during the exercises.

Additionally this device can be used by athletes and sport clubs to enhance their capabilities and prevent the injury from happening in the first place. An athlete will

use the bracelets during their normal training exercises and get feedback on their technique such as balancing and speed and will learn what the high risk factors are and how to minimize an injury from happening. In case they do get an injury in the end, the devices have established a precise zero point of the athlete what they should be aiming for.

By collecting this data of healthy athletes Nokia also creates a library of different types of sports and what the affects are on the athletes. For example it can tell how soccer on average will affect a male, who is 165 cm tall and weighs 65 kilograms. This can then be used as a reference to further personalize the rehabilitation process and create more precise preventive exercises.

What - The ecosystem

DEFINING THE ECOSYSTEM

After the initial feedback session of the Orthopedic specialists, patients, Nokia's design team, and the tutors from the design institute, a decision was made to continue with concept three, since this concept has the highest relevance for ACL injuries. It will provide the most in depth information for both professionals and patients about the status of the knee and what needs to be done to improve the conditions.

Furthermore it was noted that during the feedback sessions with the patients that there was little trust in the first two concepts and the data they collected, since the data would not be collected from sensors in touch with the body. They trusted the idea of a protective brace with integrated sensors and wished for it to be linked to devices like their phone and smart watches to give live feedback on their therapy/ exercises.

Further research has also noted that although the idea of gamification is appealing, it only works for a certain type of user, and does not appeal to a target audience as large as we are trying to tackle in this case (Jenni Torrisova, March 2018).

It is for these reasons that I decided to continue with the concept of sensors on the body with the motivational part done by an app instead of the earlier proposed physical product. This will make the overall ecosystem easier to produce and won't create extra products which is in line with the rules defined for the circular economy. The sensors will also be able to be placed in a smart bracelet for healthy athletes. By doing so it will open up the business model even further and allow for the service to be provided to athletes and sport clubs who would want to use the product to enhance their performance.

The general ecosystem will look as follows: It will consist of two sensors which will be placed on the injured knee of the patient to monitor the activity, exercises and capabilities of the body part throughout the entire rehabilitation. During the first two

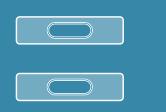
months when it is the most important to control the swelling, the brace will be worn throughout most of the day, and later on in the rehabilitation process it can be used less and less.

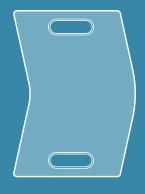
The sensors are placed in an textile knee brace, which has EMG's embedded in between the fabric. By doing so it can track the growth and activity/tiredness of the muscles throughout the workouts and show progress over time. Since the main sensors are removable from the brace, it can be put into the washing machine at the end of the day, so they can be put into a fresh set of braces at the beginning of every morning.

The sensors will communicate the collected data with an app on the patients smart-phone through bluetooth, which will process the data and send it to the cloud where it will be processed and analyzed by Nokia before being send to the therapist, who then can analyze the data themselves and give feedback and remotely change the therapy to each individual their needs.

NOKIA I ASSISTED REHABILITATION What - Ecosystem









SENSORS

The sensors are used to measure the movement of the knee and give direct feedback when needed.

- Bluetooth.
- Battery (Induction).
- IMU, position sensors.
- Printed circuit board.
- LED's (multi color).
- Vibration engine.

BRACELET

The bracelets will be used by healthy athletes who will use the tool to enhance their performance.

- EMG's.
- Dock for sensors.

BRACE

The brace will be used by patients who are recovering from an ACL injury, for them its more of a protective tool.

- EMG's.
- Dock for sensors.

CHARGING DOCK

The charing dock is used to charge the sensors over night (induction charging).

• Induction plate.

APP

The app will be used to communicate the data with the user and enable communication.

- app for therapists.
- app for athletes.
- app for patients.



What - Refining the ecosystem

REFINING THE ECOSYSTEM

Sacrificial prototypes were made to test the chosen concept direction. These were validated with two patients, two athletes and a knee surgeon from University Hospital of Umeå. In general the feedback was positive and the idea of wearing the sensors on the body was appreciated by all since it would be a more reliable way of collecting all the required data.

However in knee rehabilitation a big discussion is going on whether or not bracing the knee is good in the first place. It helps with getting the swelling of the knee down but otherwise increases the risk of future injury.

For this reason the designed brace would only have a light compressing ability and no additional benefits for stability. After hearing this and expressing the fact that during therapy they would need to wear the device for most of the day, the benefits of the brace in contrast to just the bracelet were challenged.

Performance enhancing athletes are still required to wear two bracelets, only just one on each leg. For rehabilitation it would then be necessary to wear both the bracelets on the same leg. This turned out to be the preferred direction to go for all the participants. It also had the additional benefit that instead of making two product that compromise in functioning to fit the removable sensor, I would be able to develop a single bracelet for both functions. This will result in a cheaper product for Nokia to produce.

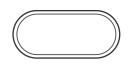
The only major benefit the brace has in contract to the use of two bracelets on the same leg is to issue of positioning the sensors. With the bracelets the test subjects were sliding them around first when they had no explanation whilst the brace was put on correctly straight away. This issue was however solved after explaining how they work but do need to be considered in the final design concept. Because of these insights the new Ecosystem looks as follows:





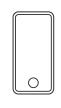
BRACELET

The sensor technology is integrated inside the bracelets. These will be washable by hand and chargeable over night via induction charging. The internal components consist of Bluetooth. Battery, IMU position sensors, a printed circuit board, LED's (multi color) and a vibration engine.



CHARGING DOCK

The charging dock is used to charge the bracelets over night, via induction charging.



APP

The app will be used to communicate the data with the user and make it understandable via the app. There will be three different types of app's, one for the patient to monitor the injury and therapy, one for the therapist for telehealth and one for athletes to be used for performance enhancing.



NOKIA

What - Guidelines

DESIGN GUIDELINES NOKIA

Nokia does not have styling guidelines that identify the brand of the product in a tangible way. With this they mean, to avoid identifying the brand with visual icons. By doing so, Nokia does their best effort so that the products are recognized by abstract values like, usability, reliability, quality, sustainability, performance and efficiency. This approach has many clear benefits. Each product/solution can be designed to perform the best without forcing tangible icons that are no longer relevant (squircle) and it gives designers, the tools to move freely and design the best without compromises. To manifest these values there are the following rules³⁹:

BRAND VALUE

Nokia believes that the solutions they design are not meant to create profit. The goal of a solution is to create Brand value. This is something that takes years to build and that requires an extensive strategy.

GOLDEN TRIANGLE

A solution is the outcome of three different perspectives, not one. User, Technology and Business. All of them are equally important since without one of them, the solution will not be holistic.

THE USER Design with the user experience centered. They will use the product so create experiences that satisfies customers, to create brand value.

TECHNOLOGY Design inside out. Do not style it. Make beautiful engineering. Work with R&D (with the same objectives) to make the production more efficient, the usability more reliable and the quality unbeatable.

BUSINESS If you met the first two you are supporting a business and will do your best to get a return for the investment. Consider the markets, segmentations and build a business on real user needs.

Having a User Centered Design approach is not enough these days. The Nokia design team work together on all the levels of the organization to elevate their values. This to become a critical part in the company.

SUSTAINABILITY

Nokia design, believes that being sustainable (not referring to green washing) is a great business. In their opinion, the hardest of all rules since it involves companies, individuals and political entities to achieve holistically.

SIMPLIFY, SIMPLIFY AND SIMPLIFY

Simplicity is a win win situation where everybody wins. By doing so you are potentiating the other goals. For example, by reducing parts or assemblies, companies will be able to refocus the production costs into what really matters (eg. better software or better surface finish) or simply saving costs (eg. removing UI components), while elevating the business case by building more margin for profitability.

Simplicity is about subtracting the obvious and adding the meaningful. Remove what is not needed and invest on what brings value, meaning and purpose.

APPROACHABLE

Nokia wishes for their product solutions to be approachable and not intimidating. This is achieved by extreme simplification and avoiding the styling. Try to design as little as possible.

HONEST

Don't try to cheat the user. Don't make things look like something they are not. For this reason Nokia's products try to get the best out of what they have and be honest about it. When it comes to hardware, this point is deeply connected to simplicity. If you simplify extensively, you will be able to afford more and focus on key aspects that will elevate the value.

What - Guidelines

DESIGN GUIDELINES FOR SUSTAINABILITY

One of the challenges I set out during this thesis was to explore how a company such as Nokia could create and sell sustainable products. This has been explored and documented in the report sustainability report⁴⁰. The ultimate aim of this thesis is to test and validate these principles that have been formulated over the last year and create a product that contributes to a sustainable society, and the best way to achieve a sustainable world is to start at the beginning. It means at the design of products, and to define guidelines for making a sustainable design. Following are the five main guidelines that have to be considered to make a design sustainable:



MODULARITY

Modular design combines the benefits of mass production with the benefits of customization, it has the potential to be more sustainable since you no longer need to make several different products to adapt to your customer needs and gives the possibility to easily have your products up to date with the latest technology. It requires a different way of design thinking and will deliver more expensive products in the short run, but since the products can be updated in the long run it might actually be cheaper for both the client and producer. Attention points in a modular design are:

Independence. By ensuring all parts of a product are independent of one another, they are more easy to sort and separate for recycling.

Multi-functional/Repurposing. Each component should be used in multiple products, so that they can be reused and the development costs remain low.

Ease of pairing. Ensure that different components are easily attachable to each other.

UPGRADABILITY

A product that is long lasting and future resistant, depends a lot on the degree up to which a product is upgradeable. This can be done on aesthetically, but also on technological level to improve/maintain a product. In order to design a product so that it can be upgraded in the future, it is important to know what is possible and needed in the future and what technological possibilities there will be. Monitoring trends and developments are therefore very important, and companies should come to agreements which technologies will be standardized. Some factors to keep in mind are:

Operating stability. Ensure the device can keep its core functions through time (e.g. ensuring that there is support for the operating software, etc).

Life extension advice. Keep user informed about product performance and provide advice according to functional needs.

Functional upgradability. Both in hardware and software upgrades to increase/maintain performance (e.g. accessing memory through the cloud).

NOKIA

What - Guidelines

MAINTENANCE

To ensure the product can last long, it must have the possibility to be maintained if something fails. To keep the costs of serviceability as low as possible, it is in the interest of both the company and the user to make the maintenance as easy and accessible as possible to reduce parts that need to be replaced and the time it takes, especially if the product is delivered as a service and the maintenance costs are for the manufacturer. The maintenance can be performed by the users themselves, by designated service providers or by so-called repair shops.

DISASSEMBLE

In order to easily repair and recycle a product, it is important that it is easy to disassemble. Attention points are:

Reversibility connections. A connection must always be reversible, otherwise repair or replacement of parts is not possible.

Single piece. Make sure that recyclable parts such as a circuit board can be removed as a single unit.

Equal parts. If a product is separated it is usually shredded, it is most beneficial if small parts are roughly the same size (preferably larger than 1 mm).

Stiffness. Avoid that materials/parts fold/move during disassembly by choosing the stiffness properly. That can be done in the part itself as well as surrounding parts.

Connections. Avoid fixed connections as much as possible. By doing so the components will separate themselves from the other parts when for example going through the shredder.

MATERIAL CHOICES

By choosing the best material for the best function whilst keeping recycling in mind, companies can create products which are much better in their function whilst reducing the amount of material that is down-cycled. Materials should be chosen that are fit for multiple cycles and phase out toxicity. The following factors are of importance:

Material type. Some materials are better recyclable than others. For example, some types of aluminum are relatively cheap but hardly recyclable. In general, it is better to choose "pure" materials, so materials that consist of only one raw material so it is not contaminated.

The amount of materials. The less materials, the better. Therefore, aim for the lowest possible weight of the entire product.

Pure materials. The less different materials are used, the easier it is to recycle a product, because it will reduce the time needed to separate all parts.

Surface finishes. Coatings protect a material, but also make recycling more difficult. Thus, durability and appearance of the product must be weighed against recyclability. There are coatings that are compatible with the materials used and thus facilitate recycling, for example the aluminum body of a car that is spray painted is contaminated and can only be down cycled, by anodizing however the material stays pure and no contamination happens.

Recycled materials. Increase percentage of recycled material input. Why delve for new materials when we can reuse old ones.

Responsibly sourced. Maximize percentage of material that are responsibly sourced (e.g. conflict mineral free and renewable materials).

What - Defining the experience

MATERIAL PASSPORT

By giving materials an identity for example through a material passport (document that describes all the materials used in a product or construction and where they are located), you ensure that materials receive and keep a value both during the time of their use as well as at the end of their product life cycle. A material passport allows the owner of a product/construction to know exactly what it is made of. This is of importance at the end of its useful life, to enable the most effective re-use of the materials. It allows the owner to view a product/construct as a material bank of valuable materials. Furthermore, the process of creating a material passport also helped to shape the design. The easier the materials can be extracted and re-used, the better. This will lead to an increase of recyclable/reusable materials. Another possibility is that a material passport enables the owner to get a better overview of the value of the product/construct. Besides the value of the location and of the space, it can now also improve the valuation of the materials used. A higher, or more accurate, valuation of the product/construct can be made possible.

The biggest advantage of using a material passport with the product is that it can close the information loop in the supply chain, and solves the lack of quality assurance. The material passport helps prepare the way for products and project to fit within the circular economy. Material passports can be used by a broad range of stakeholders: from product manufacturers (knowhow the product is made and where everything is located), building/system owners and users (knowhow of what you own, how much the product is actually worth), to disassembly companies (how to recycle and disassemble), and material suppliers (how to use materials to enable them to up cycle). Different levels of information allow a safe sharing of information along the supply chain during their period of use and when a relevant stakeholder gets into contact he or she can collect the necessary information via an app, so they will have access to the information that they require to best reuse and recycle all the materials and components available.

DEFINING THE EXPERIENCE

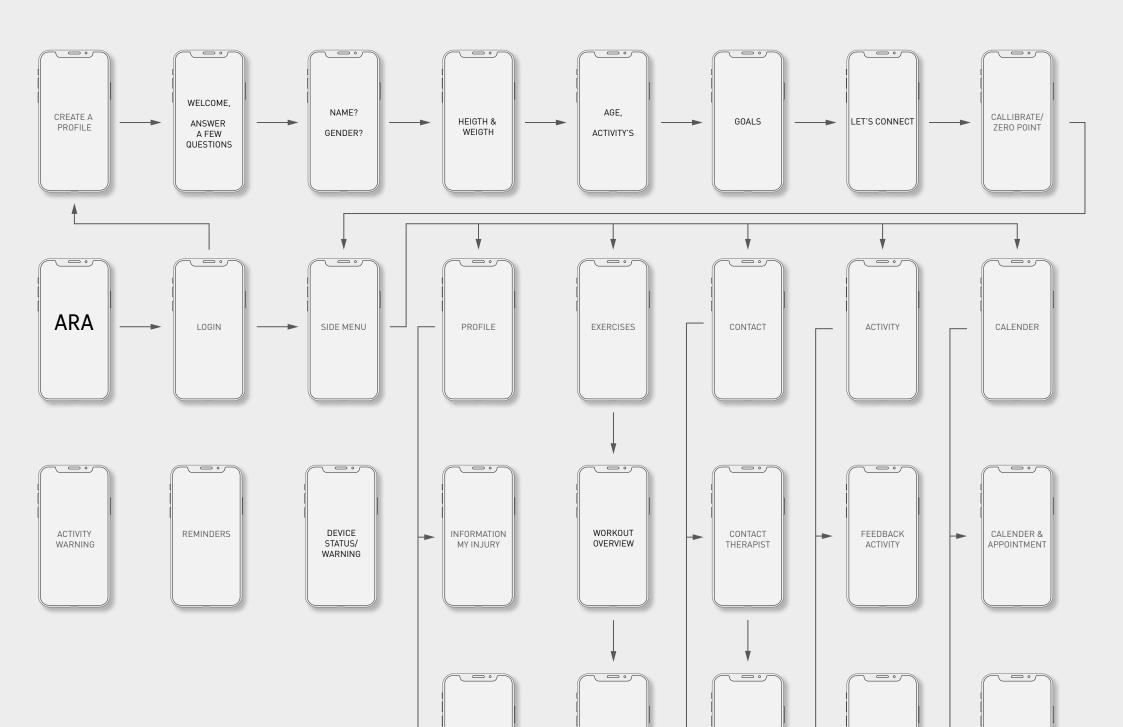
Following the painpoint mapping workshop it was time to start exploring the overall rehabilitation experience. This meant exploring all the touch-points that will happen between the therapist, the patient and the solution. This was done by an exercise called roadmapping (see in the appendices). What it comes down to, for each step of the rehabilitation process, the key pain point was identified and what the purpose of the concept should be to solve it and which concrete actions needed to follow to fulfill this purpose.

For example in the referral phase the motivation of the patient is really low, he or she just wants to get the rehabilitation over with, and is waiting for the rehabilitation or surgery to start. The purpose of the concept in this phase is to make the options understandable for the patient, what happens if they don't do the exercises now, what if they don't do the surgery? The key actions that the design then would need to fulfill is to explain the injury, what the options are and inform about the facts (personalized for their case).

Then the exploration started to see who is responsible for the actions to be taken (the patient, the surgeon, therapist, app or bracelet), and how they will fulfill these needs.

The result was a flowchart of the different steps each component of the ecosystem should fulfill, as well as a initial overview of the key wire frames that are needed to be made for the different app's to fulfill the patients, athletes and therapist their specific needs.

This would then be used as the starting point to further define the app.

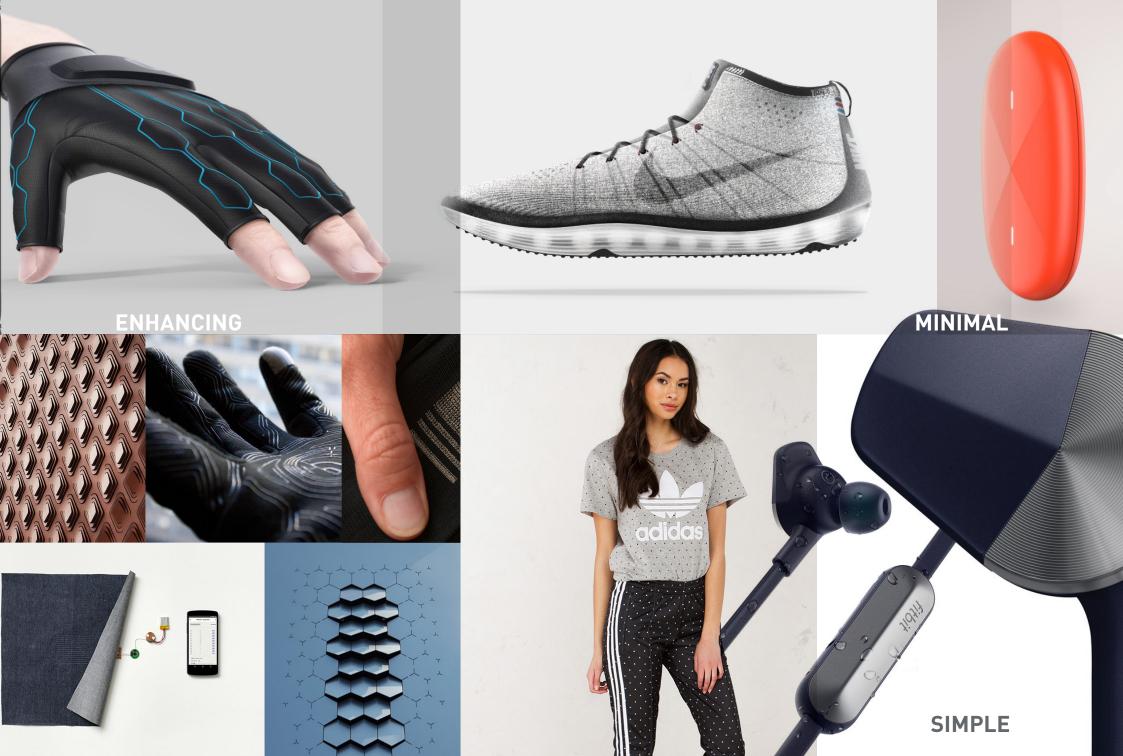


What - Moodboard

MOODBOARD PATIENT & ATHLETE

In order to inform and stimulate the design process, visual moodboards was created for both patients who are in rehabilitation as well as athletes who are looking for enhancing capabilities. The moodboards contains interesting and inspiring objects, mainly focused on protection and enhancing, whilst honoring the Nokia values.



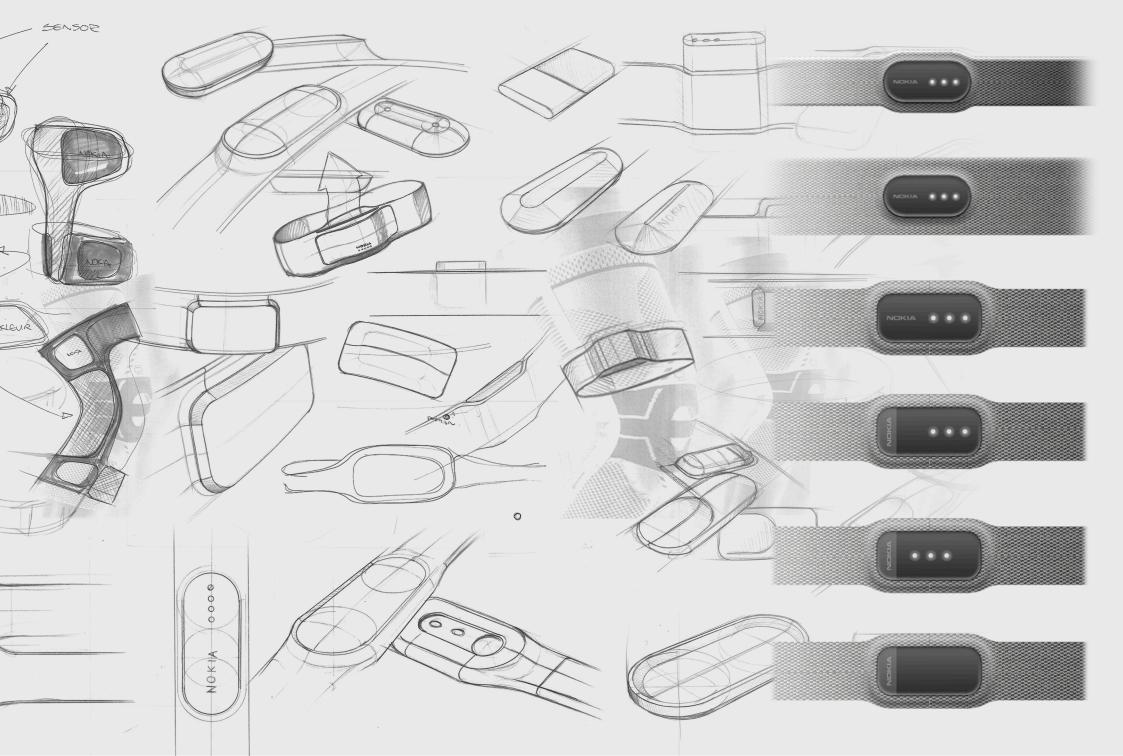


What - 2D Exploration

2D CONCEPT EXPLORATION

After having narrowed down the direction of the concept and its ecosystem, the 2D (mainly sketch) exploration began to define the usage and visual experience of the bracelet and charging dock, that would honour both the Nokia design guidelines and the rules for sustainability. From this the most promising direction was visualized in Illustrator and used as an underlay for the 3D exploration in CAD.



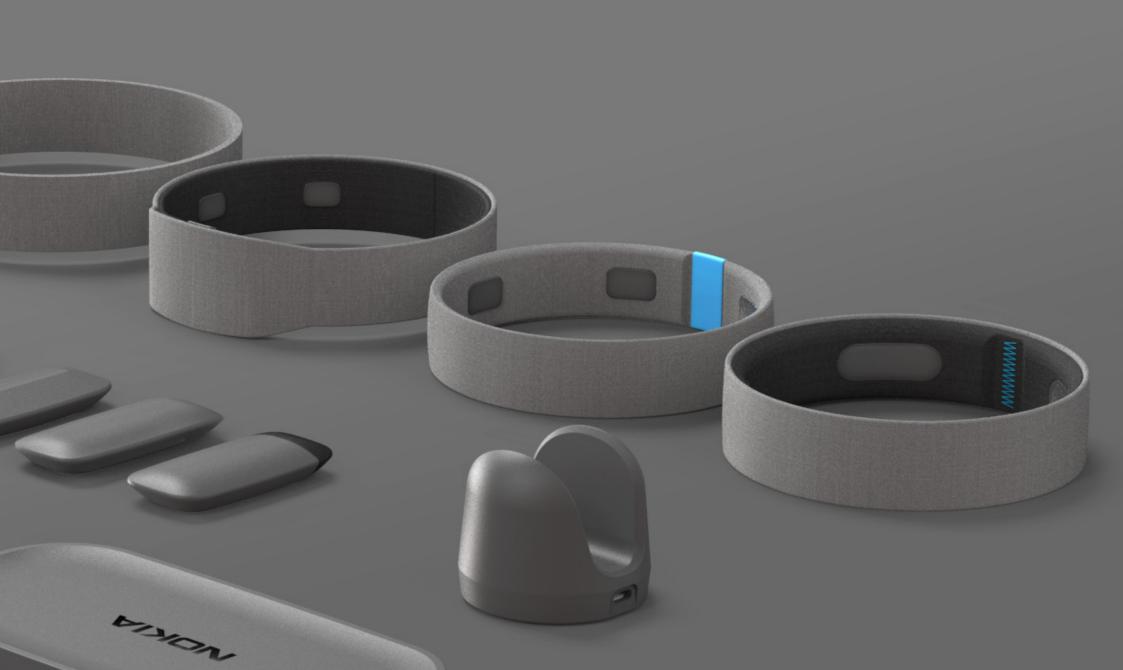


What - 3D Exploration

3D CONCEPT EXPLORATION

After having defined the 2D direction to continue with, the shape was explored in 3D Solidworks and refined. This was because of technical developments such as the change to integrating the sensors inside the textile, switching to a flexible PCB and eventually the flexible battery. This enabled the design to be simplified as much as possible. The final result is as simple as possible from the outside to give the user the benefits of technology, without visually wearing a stigmatising product.





What - Prototyping

PROTOTYPING AND TESTING

Mockups were made simultaneously to the 3D CAD process to judge the designs physically and feel how the design would be on the skin. The prototypes were tested and validated while performing exercises in the gym and iterations were made to improve the overall comfort and make the overall design as simple and understandable as possible. Tests were done on the stretchability of the band and if it would feel comfortable but still secure on both the upper and lower leg when wearing two bracelets.

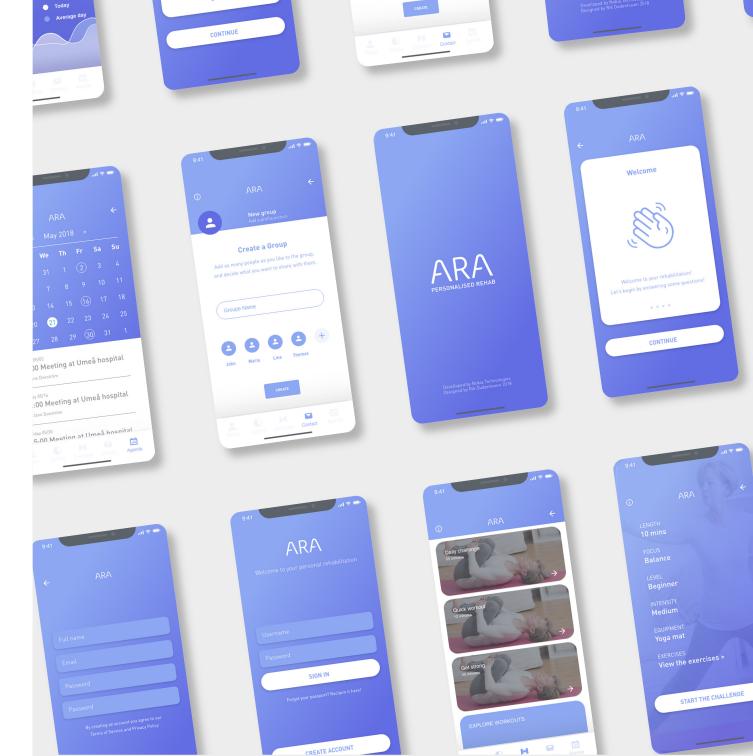




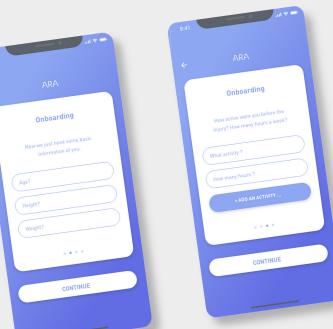
What - UI Exploration

UI EXPLORATION

A mockup of the patient and therapist app was made to validate with fellow students and professionals from the hospital. This was done in several iterations to ensure that the app was as simple as possible. A big learning was to enable the sharing of visual data between the patient and therapist, since this will allow them to more precise feedback in between meeting sessions. Simultaneously the branding of the concept was developed. The final name of the concept was chosen: ARA. This is a Hindi word meaning: Alter, sanctuary, home, refuge, shelter, protection. Since this device will be used to enhance an athletes performance or guide a patient through an optimized (safe) rehabilitation I thought this was a suitable name.

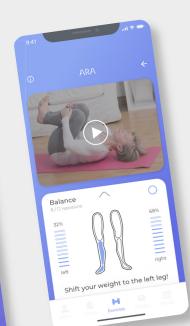


























The injury seems to be healing quite well, the swelling is gone down, and the flexation of the knee seems to be good From next week your constitutional the channel in the aversion. Schedule will be changed to fit exercises ... READ MORE

ABOUT ACL INJURIES

- To go skiing with my Fiance in 6 months.
- To be able to go running again for 10K.
- To have the freedom to be active!
- + ADD ANOTHER GOAL....

ACCESS DEVICES

- Gym membership with standard equipment
- AVA Knee brace
- Yoga matt
- Medicine ball







NOKIAI ASSISTED REHABILITATION What - Validation

VALIDATION OF CONCEPT

The final validation was eventually done with Marcus Bohlin, from the Orthopedic department of the University Hospital of Umeå. He has been involved with the project from the beginning and is the expert who was consulted the most. He was really impressed with the overall design and would like to assist with the possible continuation and testing after the thesis has ended. He believes the concept can solve the biggest issues that patients and therapists are faced with this injury and described it as "the next big thing in





What - Sustainability in design

SUSTAINABILITY EXPLORATION

To show the influence of sustainability on the design a cutting detail was added towards the ring. This detail shows where the product should be separated so no components are damaged in the process, yet it will also be used to keep the technology in place. The idea is that the technical components are mounted on a flexible PCB and then enveloped with the same flexible plastic as the PCB. This makes a flexible "slab" where all the technical components are protected inside. For the recycling, all Nokia has to do is to heat up the slab and the flexible plastic will be separated from the rest, leaving the intact components to be re-

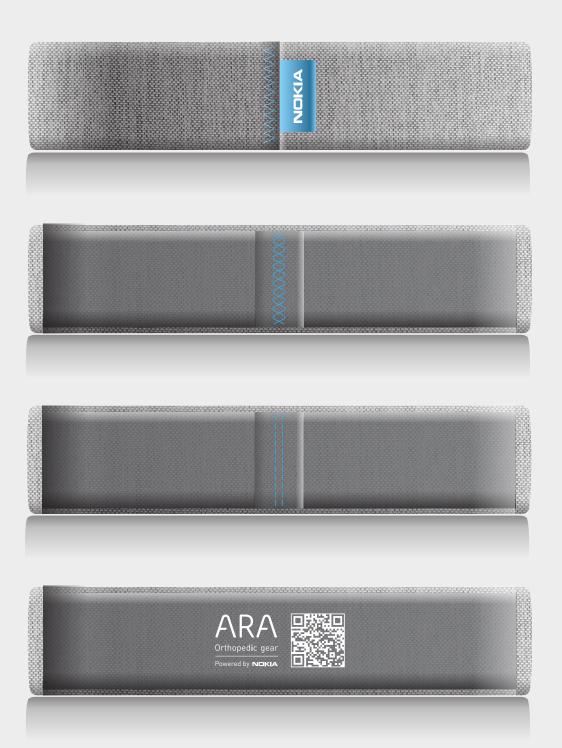




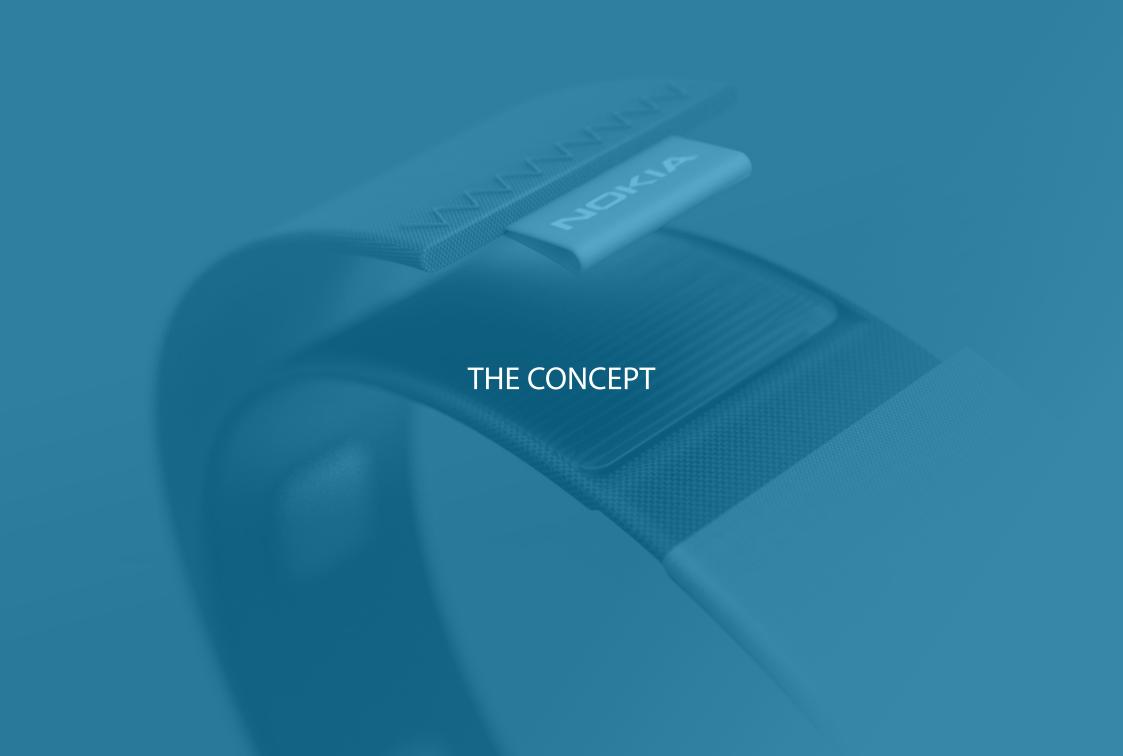
What - Detailing

DETAILING

Following the feedback sessions, the details were studied further to give both the best visual design as well as the most understandable in function. It was decided to highlight the splitting detail by a stitch that would need to be cut to open for recycling, highlighted by a Nokia branded label which can be used to remove the technology from the textile shell. The final details were the branding on the inside, showing the QR code referring to the ARA product passport.









What - Components

COMPONENTS

The ARA bracelet analyses the functioning of the knee in terms of balancing, strength, fatigue, muscle growth, endurance, flexing and swelling. It can compare this to the statistics of the healthy knee. But how exactly does it do this? To understand we first need to know what are the most important components inside the bracelets?

FLEXIBLE PCB

The flexible PCB is the biggest component inside the bracelet. It is a piece of PLA on which a conductive ink is printed that forms the circuit board for the device. After this the individual compenents are "glued" on by a robot and the entire piece is encasted by another layer of flexible and stretchable PLA to make the entire structure water proof and give shape to the overall core of the product. The benefits of using the flexilbe PCB is that the overall structure is still able to form a stretchable elastic band.

FLEXIBLE BATTERY

To ensure that there are no hard pieces pressing against the skin, it was decided to use a flexible battery that will be placed inside the PLA layer.

ECG SENSORS

Electromyography is an electro-diagnostic medicine technique for evaluating and recording the electrical activity produced by skeletal muscles. An EMG detects the electric potential generated by muscle cells. The signals can be analyzed to detect medical abnormalities, activation level, or to analyze the biomechanics of human movement which means the fatigue of the knee and how the muscles are improving.

IMU POSITION SENSOR

An IMU is an electronic device that measures and reports a body's specific force, angular rate, and sometimes the magnetic field surrounding the body, using a combination of accelerometers and gyroscopes, sometimes also magnetometers. In this

case they are used to measure and monitor the precise movement of the knee, and provide a reliable overview of the patients gait.

BLUETOOTH

Through the combination of a microprocessor and bluetooth unit we are able to process the collected data and share it with nearby devices such as smartphones. By doing this we can generate a much simpler unit since most of the processing power will be used from the phone to make sense of the data.

VIBRATION ENGINE

The vibration engines are small cylindrical motors, placed behind the ECG sensors. They will vibrate when communication is required with the wearer of the bracelets, for example when there is an issue with the product, acknowledging that it is turned on correctly or when it is time to charge.

POSITIONING

Through the use of the IMU sensors the ARA bracelet is able to recognize which muscles it is sensing. It works through the use of triangulation, since we know already how the movement of the leg is, and we know the position of the IMU sensors we can calculate where they are located on the leg (the knee functions as the third point for in this triangulation). This means that no matter how ARA is positioned on the leg, it is able to calibrate itself.



What - Onboarding

RECIEVING ARA

The patient recieves the ARA bracelet from the therapist during their first meeting. The therapist will setup the goals and the calibration during this session and explain how the device works. During the calibration the device is first mounted on the healthy knee to get a reference for what the capabilities of the knee should be after rehabilitation. After this the bracelets are placed on the injured knee and the rehabilitation can begin.





NOKIA I ASSISTED REHABILITATION
What - Onboarding

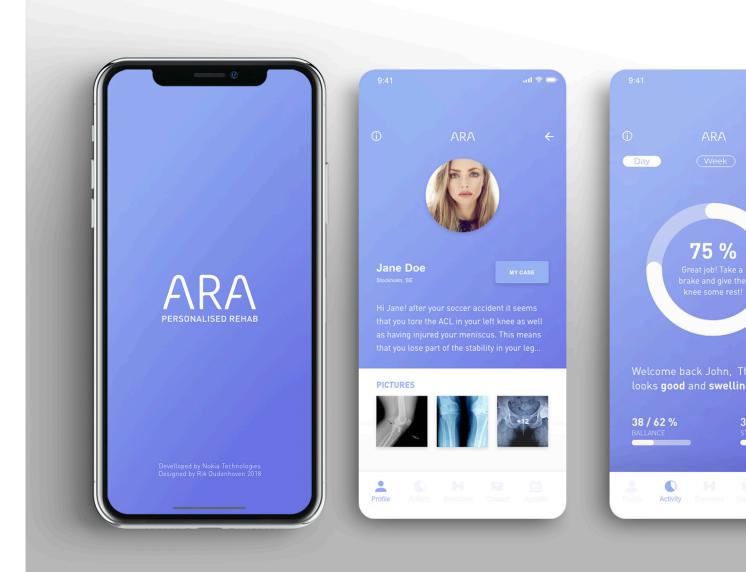
VIBRATION FEEDBACK

Through the integrated vibration engines, the bracelets are capable of communicating with the patient if necissary. This will be done as little as possible, for example when the patient is in risk of re-injury or needs to take a brake. Or needs to shift weight during an exercise.

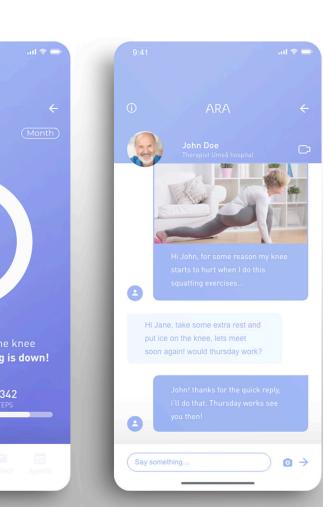
What - Patient app

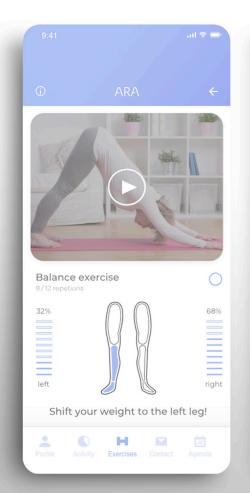
EMPOWERING PATIENTS

The patient app empowers patients to take an active role into their own rehabilitation. It will show users their medical information, such as the facts about their injury, and how it has evolved over time. It will show the activities of the day and warn them if they should let the knee rest for a while, or stimulate them to do more, to make sure the knee doesn't turn stiff. Through the contact page patients and therapists are able to communicate about the injury in a secure way and also share photos and videos when they would like more precise feedback. By showing the improvement over time patients will be motivated to continue their training and the app will allow patients to celebrate and share achievements with their environment.











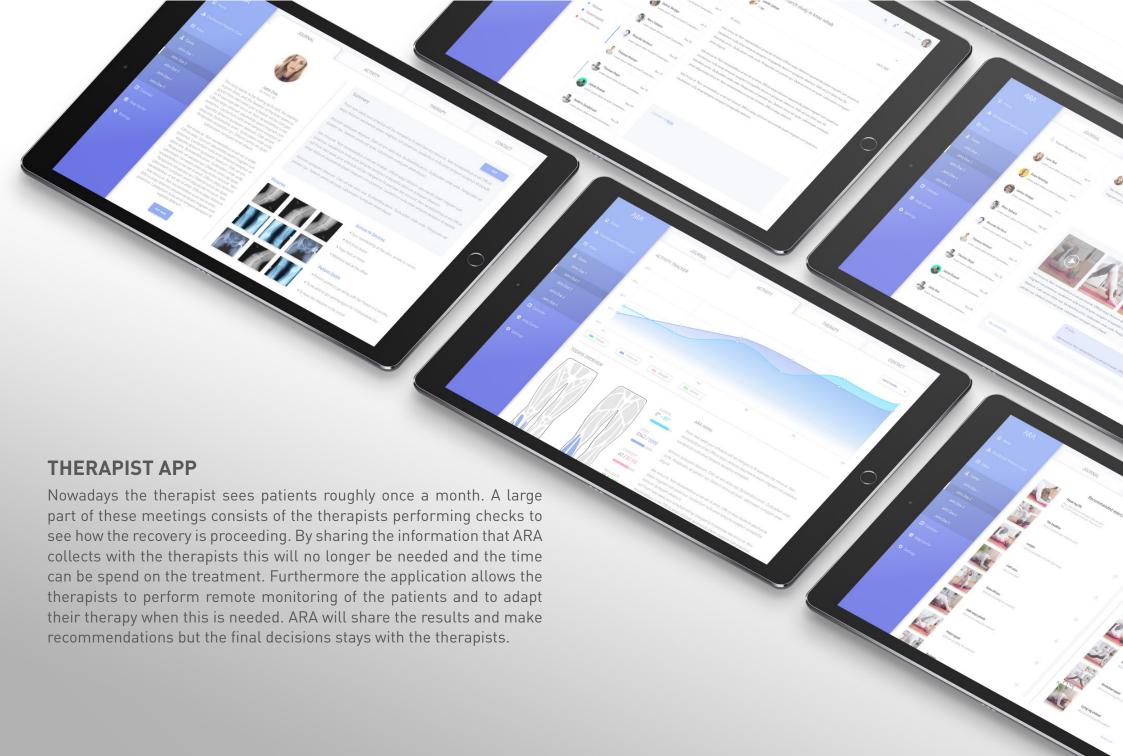


What - Patient app

LIVE FEEDBACK

One of the biggest problems with rehabilitation is to know when you have done enough exercises for the day. If patients push themselves too far, they risk further injuring the knee, instead of rehabilitating it. To ensure that patients don't push themselves too far ARA has several vibration engines integrated into the bracelet. These will vibrate when direct feedback is needed, for example when they need to take a break. ARA comes with an app that will give live feedback to patients when performing these exercises and will serve as their personal rehabilitation coach.



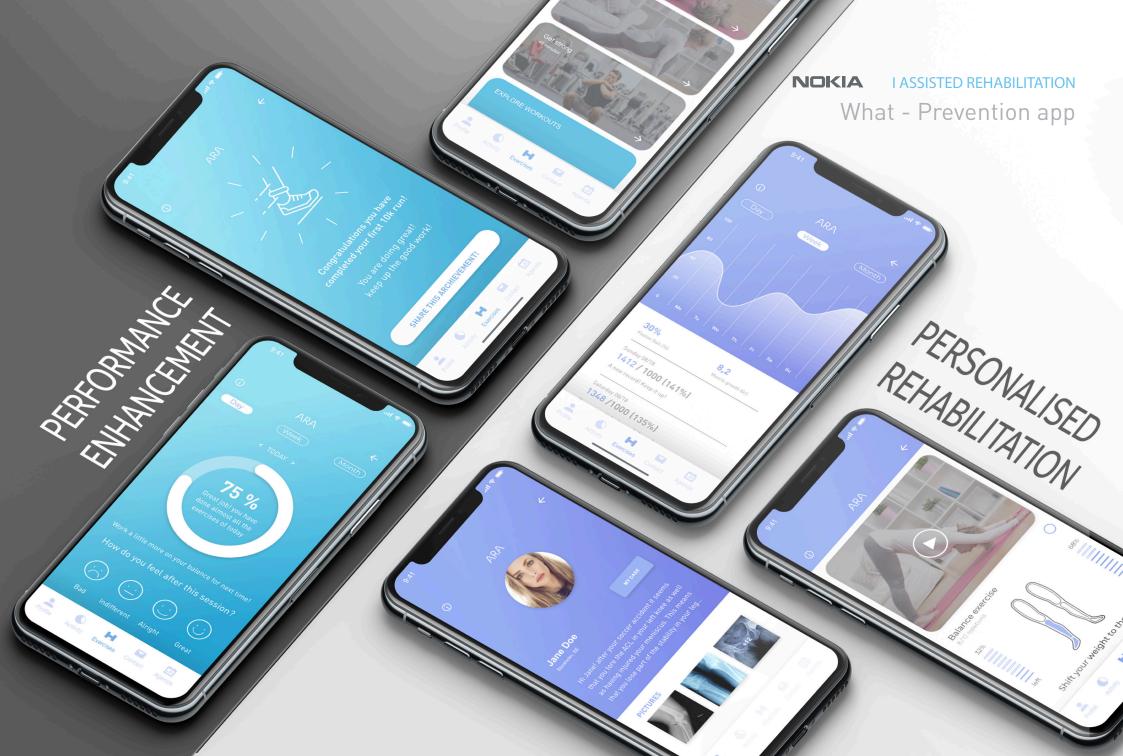


NOKIAI ASSISTED REHABILITATION
What - Prevention

PERFORMANCE ENHANCING

ARA can also be used by individuals who wish to reduce the risk of injuries from happening in the first place. This is done by using one bracelet on each leg when doing exercises. This since the balance and motion of the legs in comparison is more important then to get precise data of the knee. The performance app will teach people the proper techniques and methods adapted to their desired activities and built. For example when you are a basketball player it will focus more on your technique of landing whilst for soccer a quicker reaction time of the muscles is more important.





What - Charging

THE CHARGING STATION

Since ARA is worn throughout the day, and also during sporting exercises, they are washable by hand. After this they can dry and charge at the same time when placed on the induction charging station. This station is made of a bend piece of aluminum with LED's integrated to communicate the status of the battery. The bracelets will be positioned correctly above the coils through the use of an integrated magnet in both the charging station and the ARA bracelets.





What - Packaging

THE REHAB KIT

ARA gets delivered to the users as a kit. This kit includes two ARA bracelets, a charging station, a user manual and the charging cable.

The user manual is a quick guide into how to set up the product for first use and explains where to get more information.

The overall packaging is made of a cardboard structure with simple Nokia branding on the outside. The inner-structure is made from a material called paperfoam, which is an injection molded paper pulp. This to ensure that the packaging is completely recyclable.





What - Sustainability

DESIGN FOR SUSTAINABILITY

By acknowledging products and their materials, in the case of ARA, through the use of a QR code on the inside of the product, we are able to link products to a product passport which shares information accross the stakeholders. For example how best to recycle/repurpose a product after users are done with it.

By thinking and designing how ARA would be dissassembled, in this case by simply cutting the blue thread at the top of the product and pulling on the Nokia branded tag, a product was created whose components are easily disassembled and sorted.



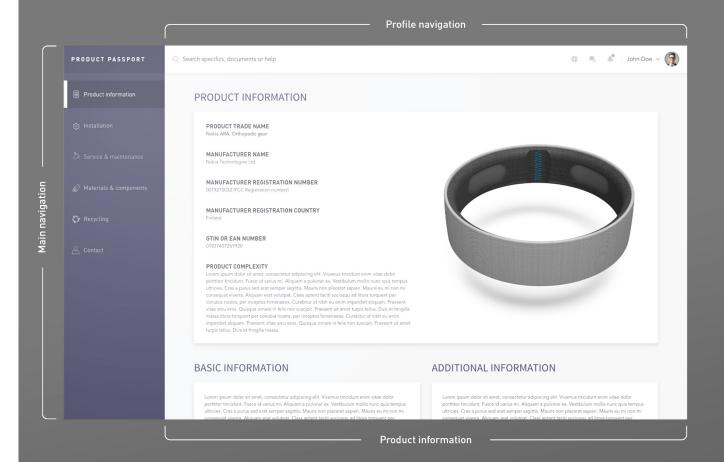


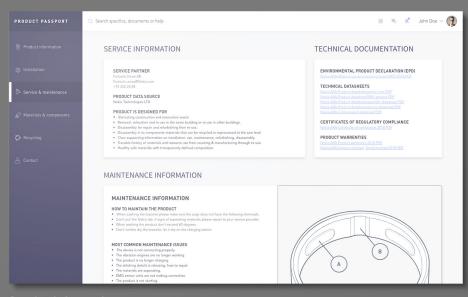
What - Sustainability

PRODUCT PASSPORT

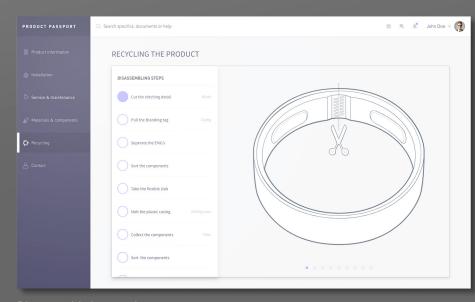
The biggest advantage of using a material passport with the product is that we can close the information loop in the supply chain, and the lack of quality assurance. The material passport helps to prepare the way for products and projects to fit within the circular economy. Material passports can be used by a broad range of stakeholders: from product manufacturers (knowledge of how the product is made and where everything is located), building/system owners and users (knowhow of what you own, how much the product is actually worth), to disassembly companies (how to recycle and disassemble), and material suppliers (how to use materials to enable them to up-cycle).

In the case of ARA, the product passport shares the general information such as who is responsible for maintenance and who produced it. How to do service to the product, what materials and components are in there and how best to dissasemble it, to gain back the most value.

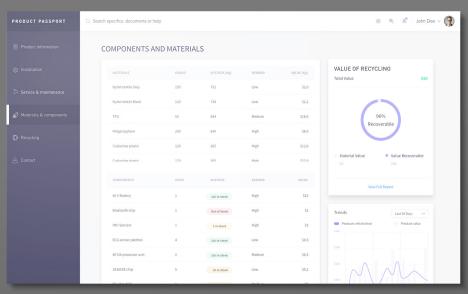




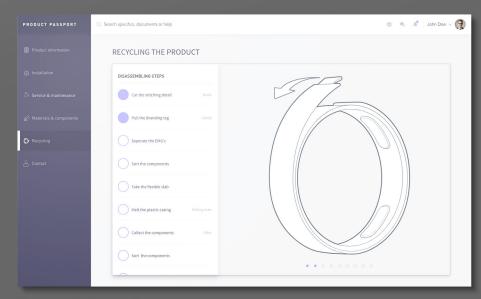
Service information



Disassembly instructions



Components & Materials



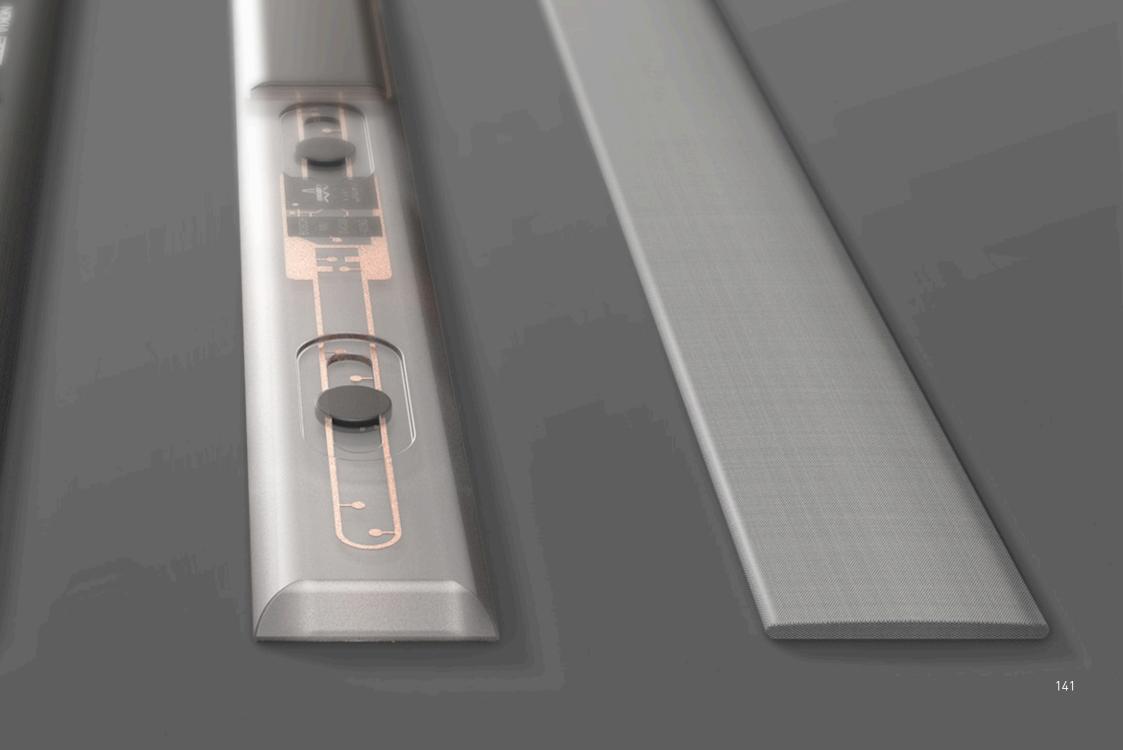
Disassembly instructions

What - Sustainability

SUSTAINABILITY = PROFITABILITY

By embracing new technologies and challenging their possibilities, the Nokia design team and I were able to come up with a new way to produce electronical components in a protected and easily recyclable way. The starting point was the technology of a flexible PCB which enabled users to wear technology without the stigmatising image of a bulky technical compartment. However by encasing this plastic PCB with all the components again with the same material we protect it in such a way that the entire PCB is water tight, flexible, stretchable, yet it can be recycled by simple heating up the plastic, after which all the components are exposed and ready to be used again.





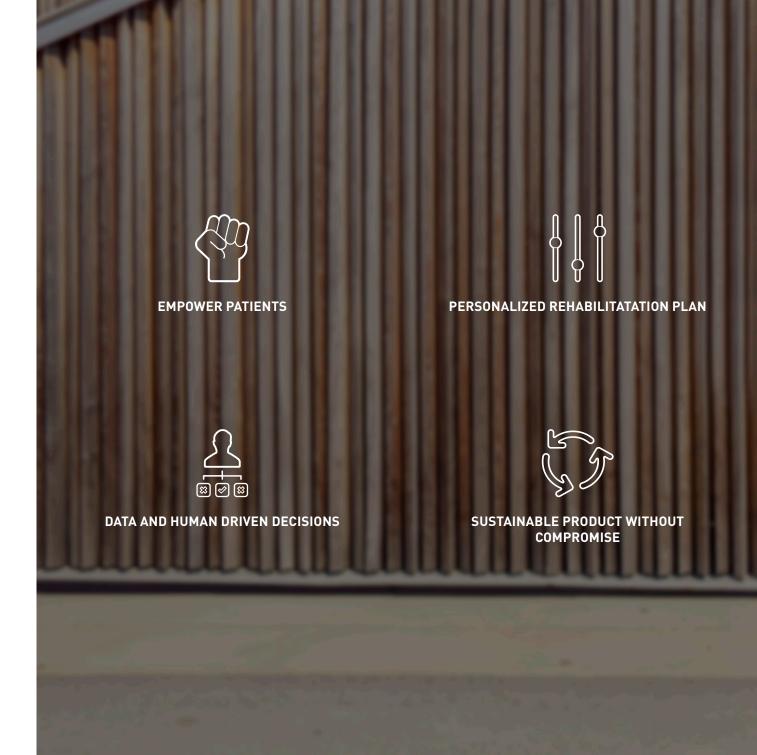
What - Conclusions

SO WHAT DO WE GET?

Traditionally when we think of sustainability, we consider that these products will be more expensive for companies to produce. With ARA we have shown that it is in fact profitable to be sustainable. By thinking of sustainability from the very beginning we have optimised the assembly and recovery process of the product, and since Nokia will be able to reuse all the materials and components they will gain back value from what otherwise would be considered waste.

Because of this performance based economy the responsibility of the products no longer lies with the consumer but with the company, and they become unburdened. Furthermore by staying owner of the product it becomes important for the producer to create high quality to reduce the maintenance costs and regain the highest quality of material from the returned products.

So what we get is a product whose performance is enhanced for users, enables practitioners to take data and human driven decisions, which results in a personalized rehabilitation plan and is completely sustainable without compromising on the benefits they give to mankind.







Appendices - Reflections

REFLECTIONS AND RECCOMENDATIONS

During this project I had two main focuses, to find a pathway to create sustainable products, without compromising on the benefits they give to mankind, and to find a way to improve the outcome of ACL rehabilitation by personalizing the rehabilitation therapy plan for each individual, and empower the therapist with more and precise data collection.

Looking back at the work that has been done and the overall outcome I'm pleased to say that in my opinion I have managed to do both these things up to a level that can be expected as a student. In truth I think I will never be able to prove that I have tackled the issues, unless the product and service I have developed are produced and used for a longer period of time. But in all fairness, the concept looks promising. For example the healthcare professionals that I have been talking to believe in the concept and wish to develop it further. And from the sustainability perspective, I have manged to convince both Nokia and experts in the fields of materials and recycling up to a point that they would like to explore the sustainability rules further.

There are things however that I have not explored as in depth as I would have liked, for example the case of performance enhancing, in which the ARA concept can be used by athletes to prevent the injury from happening in the first place. For this case more research needs to be done to find out how the athletes want to receive the information and the feedback for example. This is since the project was only 20 weeks and my main focus has been on the rehabilitation side. With this thesis I believe I have proven that this case, even though not fully explored yet, is at least of interest to explore further to enlarge the possible target group of the product.

What I learned from the sustainable side, and implementing the design rules is that although the five rules of sustainable design are valuable, they should always be seen as guidelines and not as laws, because otherwise you might restrict yourself in

functions that might not be necessary. For example with the ARA concept the maintenance rules did not really apply since it would be easier and probably cheaper to just recycle the product and make a new one for the customer. However the thinking of this was most valuable since one is forced to truly design the entire journey of each component and material in this lifecylce and the next.

By thinking about these things the result of the thesis is a product that is sustainable, doesn't harm the environment, without compromising in any way on the benefits it gives to human life. The idea of a material passport will need to be further explored since in the current concept it is only visible on the outside but if the QR code gets damaged how will it then be identified? It would make sense to experiment with infrared QR codes to see how well these would perform in large recycling plants or other ways of identification which are not costly and durable.

In general my recommendation to Nokia would be to continue with the concept in the way it is, and also see the benefits sustainable design can give, whilst doing additional research on the preventive case to find out the true needs and desires of the athletes that might purchase this product.

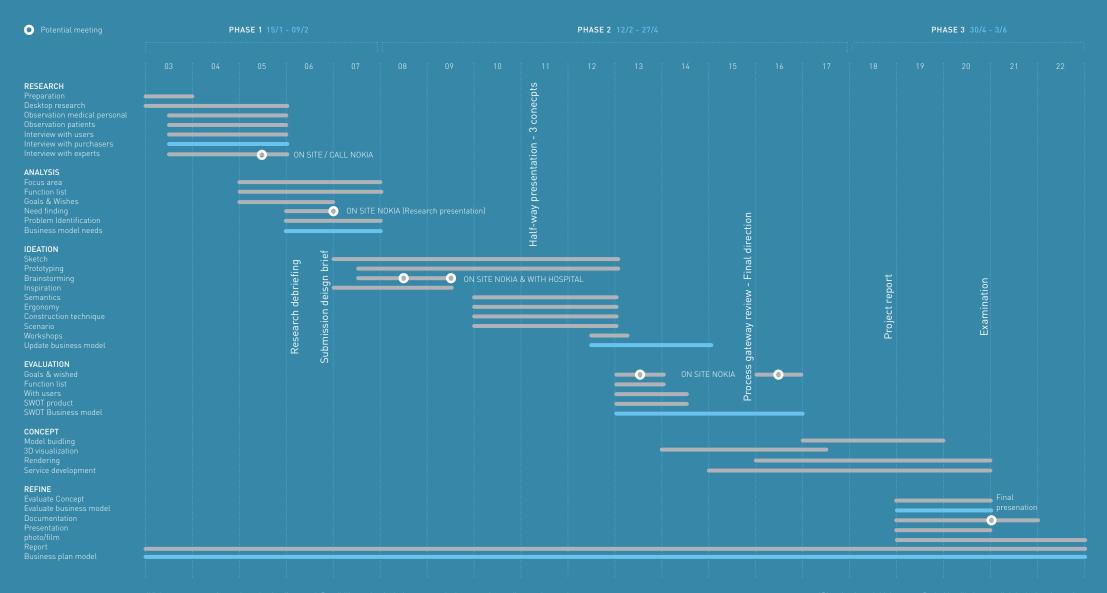
Appendices - References

1	Nokia, 2018 Q1 Earnings, 2018, www.nokia.com
2	Nokia, People & Planet Report, 2017, www.nokia.com
3	World Health Organisation, Constitution of WHO: principles, www.who.int
4	Nokia, Digital health - mission statement, 2016, www.nokia.com
5	Tara Mullaney, Thinking beyond the cure, Umeå Institute of Design, 2016
6	Sackett, Rosenberg, Gray, Hayns & Richardson, 1996
7	D. Norman, The way I see it: A fetish for numbers. 2008
8	Tara Mullaney, Thinking beyond the cure, Umeå Institute of Design, 2016
9	Brenda Holmes, Lecture on rehabilitaiton nursing, 2009
10	Philips, Future health index, www.futurehealthindex.com, 2017
11	Interview R. Forsgren & M. Hagstrom, Umeå sports medicine, 2018
12	Societal and economic impact of anterior cruciate ligament tears.
13	Richard Whitehall, Smart design, The power of personalization in health and wellness, www.smartdesign.com, 2017
14	Philips, Future health index, www.futurehealthindex.com, 2016
15	Philips, Future health index, www.futurehealthindex.com, 2016
16	The telegraph, Connected healthcare what's it all about, www.thetelegraph.co.uk/wellbeing, 2016
17	The telegraph, Connected healthcare what's it all about, www.thetelegraph.co.uk/wellbeing, 2016
18	The telegraph, Connected healthcare what's it all about, www.thetelegraph co.uk/wellbeing, 2016
19	Philips, Future health index, www.futurehealthindex.com, 2016
20	Scott Lachut, Smart design, The power of personalization in health and wellness, www.smartdesign.com, 2017
21	Nokia, People and planet report, www.nokia.com, 2016
22	ING, Financing the circular economy, www.ing.nl, 2015
23	Interview V. Eklund, Occupational Therapist, Rehab Center Umeå, 2017
24	Gage BE. Epidemiology of 6.6 million knee injuries, The Research Institute at Nationwide Children's Hospital, Columbus, OH, USA, 2012

25	ACL Injury: Prevention Is Better Than Cure, Physio-network.com, 2018
26	Interview R. Forsgren & M. Hagstrom, Umeå Sports Medicine, 2018
27	Richard C. Mather III, MD, and Lane Koenig, PhD. Cost-benefit data suppor
	reconstruction of ACL tears, www.ncbi.nlm.nih.gov, 2014
28	American academy of orthopaedic surgeons (AAAOS), Anterior Cruciate Ligament Injuries. orthoinfo.aaos.org, 2014
29	BR Sports med. Non-contact ACL injuries in female athletes an Internationa
	Olympic Committee current concepts statement, NCBI, 2014
80	Larry W. McDaniel, Reducing The Risk Of ACL Injury In Female Athletes,
	Dakota State University, USA, 2010
31	Sports injury clinic, Q Angle of the Knee Explained, 2018
32	M. Bohlin, interview Umeå University Hospital, Orthopedic department 2018
3	Mayo clinic, Diseases and conditions - ACL Injuries - Diagnosis & Treatment www.mayoclinic.org, 2018
34	Interview R. Forsgren & M. Hagstrom, Umeå sports medicine, 2018
35	Knee pain explained - take back control, Problems after ACL surgery, www.Knee-pain-explained.com, 2018
86	Myklebust G, Skjølberg A, ACL injury incidence in female handball 11 years
	after the Norwegian ACL prevention study, www.ncbi.nlm.nih.gov, 2013
37	Martinek V, Friederich NF, To brace or not to brace - How effective are knee
	braces in rehabilitation, www.ncbi.nlm.nih.gov, 1999
88	M. Bohlin, interview Umeå University Hospital, Orthopedic department 2018
39	Alejandro Sanguinetti, Nokia technologies, Design guidelines, 2018
10	Rik Oudenhoven, Towards a sustainable future, Umeå Institute of Design,

www.rikoudenhoven.com, 2018

Appendices - Planning



Appendices - Concept and product overview



LITHIUM BY MAJA HEDLUND

Lithium is a concept by Maja Hedlund, which consists of several small EMG sensors which are used to measure the growth and development of muscles over time. It will help assist female soccer players through their individual rehabilitation.



MOTEX, MONITORING TEXTILE

The Motex project is an intelligent textile which is capable of measuring knee angles of users during physical activities, such as sports or rehabilitation exercises. The smart textile is equipped with integrated sensors and corresponding embedded electronics. These electronics are placed on a stretchable circuit board. They condition the sensor signal and transmit the data wirelessly to a smart-phone app.



INTEGRATED TEXTILE SENSOR

The True Posture smart shirt trains and strengthens the back muscles and core for a good posture. It monitors the wearers positing over time and stimulated the user to sit correctly through localized vibrations which function as reminders.

NOKIA

I ASSISTED REHABILITATION

Appendices - Concept and product overview



ATHOS SMART SHIRT

The Athos' shirt offers 18 sensors. Fourteen are dedicated to electromyography (EMG) tracking, which allow athletes to understand how hard their muscles are working, if they are reaching certain muscle targets, including building, toning, and under training, and if they have muscle fatigue. Two of the remaining sensors track heart rate and heart rate variability and two track breathing patterns. Sensors are directly integrated in Lycra fabrics by using conductive elastomer (CE) sensors.



SENSORIA SOCKS

Sensoria socks are infused with proprietary 100% textile sensors. They are paired with a Blue-tooth Smart cool and detachable anklet that not only delivers superior accuracy in step counting, speed, calories, altitude and distance tracking, but goes well beyond that to track cadence, foot landing technique as you walk and run.



KNITTED MUSCLES

Researchers have coated normal fabric with an electro-active material, and in this way given it the ability to actuate in the same way as muscle fibers. The technology opens new opportunities to design "textile muscles" that could, for example, be incorporated into clothes, making it easier for people with disabilities to move.

Appendices - Technology overview







ELECTROMYOGRAPHY (EMG)

Electromyography is an electro-diagnostic medicine technique for evaluating and recording the electrical activity produced by skeletal muscles. An EMG detects the electric potential generated by muscle cells. The signals can be analyzed to detect medical abnormalities, activation level, or recruitment order, or to analyze the biomechanics of human or animal movement. In this case it could mean the fatigue of the knee and how the muscles are improving.

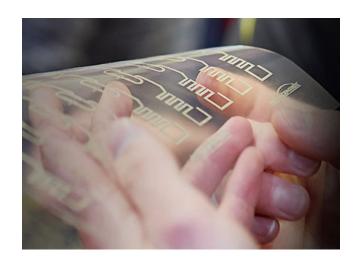
INERTIAL MEASUREMENT UNIT (IMU)

An IMU is an electronic device that measures and reports a body's specific force, angular rate, and sometimes the magnetic field surrounding the body, using a combination of accelerometers and gyroscopes, sometimes also magnetometers. In this case they could be used to measure and monitor the precise movement of the knee, and provide a reliable overview of the patients gait.

PRESSURE SENSORS

Pressure sensors can be used to measure the force being used by the knee, to help measure how the balance is being used and give feedback on how to correct it. Interest if it would be possible to embed these in to the smart textile or to measure from the knee instead of having to place something under the foot.

Appendices - Technology overview



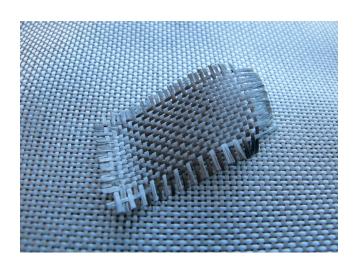
LAMINATED STRETCHABLE CIRCUIT BOARD

This technology makes it possible for the first time to really integrate high performance electronic circuits easily into textiles and so may be the building block for a totally new generation of wearable electronic systems.



MICROPROCESSOR AND BLUE-TOOTH

Through the combination of a microprocessor and blue-tooth unit we are able to process the collected data and share it with nearby devices such as smartphones. By doing this we can generate a much simpler unit since most of the processing power will be used form the phone to make sense of the data.



SMART TEXTILES

Smart textiles are often called electronic textiles or e-textiles. These are textiles with electronic and interconnections woven into them, making them intrinsics to the fabric, hence no external component is needed for them to function.

Passive smart textiles: only sense the environment/ user using sensors. Active smart textiles: sense and react to external stimuli. Very smart textiles: sense, react and adapt to the changing circumstances.

PHYSIOTHERAPIST

ANTON



AGE 58

FAMILY STATUS MARRIED

EDUCATION MASTERS

EMPLOYER HOSPITAL

SPECIALIST NO

DESCRIBING QUOTE

"Often rehabilitation is done by someone who has little to no experience with ACL injuries. Only treat the symptoms and not the injury itself. For example; after six weeks when the pain was gone he felt like the patient is cured."

REHABILITATION INF	LUENCERS	EXPERIENCE		
INSPIRING		VERY HIGH		
DISCOURAGING	MOTIVATING	HIGH		
ADAPTABLE		MEDIUM		
STANDARD	UNIQUE	LOW		
INVOLVED				
IMPERSONAL	PERSONAL	VERY LOW		
TOUCHPOINTS				
		TOTAL OF 8 TOUCH POINTS, DONE AFTER 6 MONTHS		

ATTITUDE TOWARDS TECHNOLOGY

INNOVATOR EARLY ADOPTER LATE ADOPTER LAGGARD

PHYSIOTHERAPIST

SOPHIA



AGE 32

AMILY STATUS IN RELATION

EDUCATION MASTERS

EMPLOYER PRIVATE SECTOR

SPECIALISM KNEE INJURIES

DESCRIBING QUOTE

"Every injury has its own rehabilitation, every person has their specific needs, every rehabilitation program is personalized. The biggest challenge is to be involved and motivate the people."

REHABILITATION INFLUENCERS **EXPERIENCE** INSPIRING VERY HIGH DISCOURAGING MOTIVATING HIGH ADAPTABLE MEDIUM UNIQUE STANDARD LOW INVOLVED VERY LOW IMPERSONAL PERSONAL **TOUCHPOINTS** TOTAL OF 10 VISITS, BUT ALWAYS TRY TO FOLLOW UP THROUGH ENTIRE PROCESS. AVERAGE 9 TO 12 MONTHS

ATTITUDE TOWARDS TECHNOLOGY

INNOVATOR EARLY ADOPTER LATE ADOPTER LAGGARD

JAMES



AGE 32

AMILY STATUS SINGLE

EXERCISE 2 TIMES A WEEK

PROFESSIONAL NO

PROFESSION DESIGNER

DESCRIBING QUOTE

"I quickly realized that I would never go back to the sport. I just felt that it was not worth it, lost already too much time of my life on one rehabilitation."

REHABILITATION INFLUENCERS **FOLLOWS THERAPY** MOTIVATION TOO MUCH LOW HIGH GOOD KNOWLEDGE MEDIUM LOW HIGH LOW SUPPORT VERY LOW IMPERSONAL PERSONAL **TOUCHPOINTS** TOTAL OF 8 TOUCH POINTS, DONE AFTER 6 MONTHS

ATTITUDE TOWARDS TECHNOLOGY

INNOVATOR EARLY ADOPTER LATE ADOPTER LAGGARD

PATIENT

AMANDA



AGE 22

FAMILY STATUS IN A RELATION

EXERCISE 5 TIMES A WEEK

SPORT FOOTBALL

PROFESSIONAL SEMI-PRO

PROFESSION STUDENT

DESCRIBING QUOTE

"People don't realize how hard it is to not go to work or be able to do what you want to. Doing those activities that was me!"

REHABILITATION INFLUENCERS **FOLLOWS THERAPY** MOTIVATION TOO MUCH LOW HIGH GOOD KNOWLEDGE MEDIUM LOW HIGH LOW SUPPORT VERY LOW IMPERSONAL PERSONAL **TOUCHPOINTS** TOTAL OF 10 VISITS, ABLE

ATTITUDE TOWARDS TECHNOLOGY

INNOVATOR EARLY ADOPTER LAGGARD

TO CONTACT THERAPIST, ADDITIONAL SUPPORT FROM COACH AND TEAM,

Appendices - Patient journeys

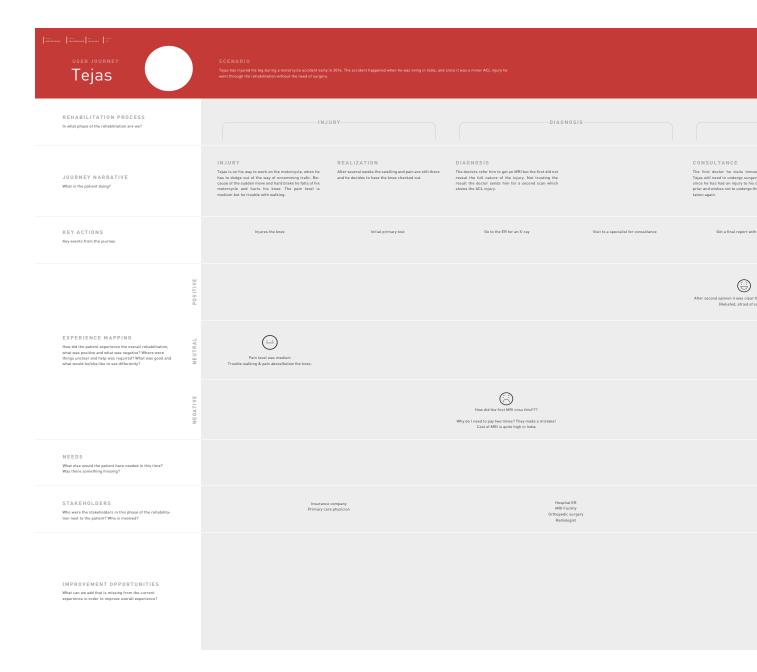
USER JOURNEYS

To gain better insights into the patients their experiences in the overall process (from injury, diagnosis, surgery, treatment, prevention till eventually the here and now), workshops were organized in which they could share their story.

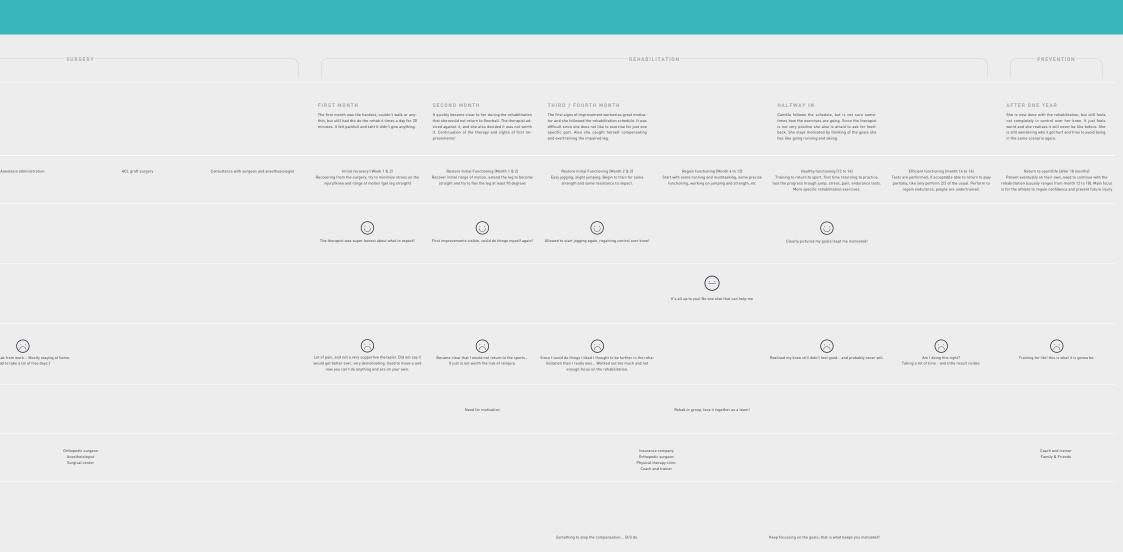
Together we mapped out how their journey went, what were the most important points and how were these experiences? What were the overall pain point, and what did they miss in general? What would have made their experiences more pleasurable, better outcome, etc.

This generated insights into what areas would be most interesting for Nokia to look into and where we could add value and how.

The area's of Diagnosis and rehabilitation were in general the ones were the most options for improvement were found, but since the patients in general also experienced problems in the long run because of compensation there was also a lot of interest in how to prevent this future damage, and even prevent the injury from happening in the first place or again.



REFERRAL -REHABILITATION--PREVENTION-SECOND OPINION BUYING THE BRACE FIRST SESSION CHECKING UP RETURN TO FUNCTIONING RETURN TO LIFE Changed to soft braces, used for a longer period of time, and still uses when the knee in pain. Is carefull for the rest of the period when in public that people cant bump into his knee. "sit at the back of the bus so people don't have to pass" diately suggest that y. This frightens him ther leg a few years Not sure about the first doctor, he asks for a second After recommendation from the doctor he buys a brace During first meeting with the chiropracter he hears he Had to stay home for the first month, everybode had to After the rehallitation. Telas has taken it easy on the leg Not sure about the first doctor, he asks for a second opinion from a doctor referred to by his family. This doctor takes another look and says that he can recover without surgery. [is a minor injury] Can heal without moving the knee for 1 or 2 moths. with metal frame so he can't move the knee and give it some rest to recover. should rest and take it easy at least the first six months. Also exercises are explained which he should perform. come visit him, his parents wouldn't let him go out the house. After 1.5 months another MRI and after two months he stopped using the metal brace. for more than 1,5 years before riding the motorcycle again. Occasionally he is still scared of injuring the knee again and is carefull with the exercises/activities he Restore Initial Functioning [Month 2 & 3] [month 9 and onward] Patient eventually on their Waiting for rehabilitation, first two weeks he was not Initial recovery [Week 1 & 2] Restore Initial Functioning (Month 1 & 2) Regain functioning (Month 4 & 5) Healthy functioning (month 6 to 7) Efficient functioning (month 8 to 9) allowed to place any pressure on the leg and had a stiff brace which made him unable to bend the leg. Recovering from the surgery, try to minimize stress on the injury/knee and range of motion (get leg straigth) Recover initial range of motion, extend the leg to become straight and try to flex the leg at least 90 degrees Easy jogging, slight jumping. Begin to train for some strength and some resistance to impact. Start with some running and multitasking, some precise functioning, and sport specific exercises. Training to return to sport, first time returning to prac-tice, test the progress brough jump, stress, pain, endur-ance tests. More specific rehabilitation exercises. Tests are performed, if acceptable able to return to play partially, like only perform 2/3 of the usual. Perform to regain endurance, people are undertrained. own, need to continue with the rehabilitation (usually ranges from month 12 to 18). Main focus to regain con-fidence and prevent future injury (Surgery or rehabilitation) () nat I did not surgery, rgery) Occasional exercises to improve knee movement. Loses motivation to perform the exercises. \bigcirc Scared of reiniury. Orthopedic surgeon Radiologist Insurance company Insurance company Orthopedic surgeon Physical therapy clinic Coach and trainer Coach and trainer Non fixed brace would make it easier for the patients to move around. The brace was also limiting with exercises. App would help to guide through the recovery process. Help me understand the exercises I would need to perform. Soft textile would make the comfort level a lot better, instead of



160

SURGERY				REHABI	ILITATION-			PREVENTION
		PREPARED After the surgery she felt prepared, and there was not much pain, so her initial rehabilitation was quite fast.	UNMOTIVATED Because of the initial rehabilitation she has lest a let of strongh in the tone. This together with the difficulty of serroring and teacing the leg makes her unmotivated to do the exercises.	FIRST RESULTS The first results finally started to show of. The therapiet teld that she would be able to run again fine football that all. This gave her a big boost of motivation to work harder.	STAYING MOTIVATED After reaching the first goal of going for other runs, again, now the focus has abilited fleareds, seembally hanged to the focus has abilited fleareds, seembally hanged the first goal in its leap farm or indirect the thermapist also changes the exercises to work towards these specific sports.	LITTLE IMPROVEMENT Because she saw little improvement from here on, the motivation was gone again, it is also difficult for her to perform exercises correctly since she has no feeling in her force.	RETURN TO REHAB After having little improvement for several months, and lialing the return to sport test coveral times, the is now driven to finish the rehabilitation.	RETURN TO SPORT She has one more meeting in which they will perform the final return to sport stack liver the still get the final recommendations of after that she will get the final recommendations of after that she will get the final spoint of the spo
Anestesia administration ACL graft surgery	Consultance with surgeon and anesthesiologist	Initial recovery (Week 1 & 2) Recovering from the surgery, try to minimize stress on the injury/knee and range of motion (get leg straigth)	Restore Initial Functioning (Month 1 & 2) Recover initial range of motion, extend the lag to become straight and try to flex the lag at least 90 degrees	Restore Initial Functioning (Month 2 & 2) Easy jogging, slight jumping. Begin to train for some strength and some resistance to impact.	Regain functioning (Month 4 & 5) Start with some running and multitasking, some precise functioning, and sport specific exercises.	Healthy functioning (month 6 to 14) Training to return to sport, first time returning to practice, test the progress brough jump, stress, pain, endurance tests. More specific rehabilitation exercises.	Efficient functioning (month 14 to 18) Tests are performed, if acceptable able to return to play partially, like only perform 72 of the usual. Perform to regain endurance, people are undertrained.	Return to sport/life (month 18 and onward) Patient eventually on their own, need to continue with the rehabilitation (assailly ranges from month 12 to 18). Main focus is for the athlete to regain confidence and prevent future injury
	Pleasent and good explanation about what to expect after the surgery and during schabilitation.	Felt prepared after the consultance. Because already had initial rehabilitation the beginning was faster and not so much pain.		First results started to showl felt strenger, begin running and became clear would be able to do more sports I liked!		Training adapted with every visit! Adapted towards my personal goals (sports) No pain anymeric		
								Don't do certain activities since I know the amount of work if it goes wrong.
		Knee was really swellen.	No motivation, didn't take the rehabilitation and its exercises serious			Motivation low, no direct change/improvement visible.		e. Den't trust my knee jet It's in my head, den't want to do this a rehabilitation another time already lost enough time.
						Continuously update the goals, This month it was to eventually learn the slalom!	Do exercises on one leg so I can't compensate. Don't know if I do since I can't feel in my knee. Difficult to balance the weight propperty	Sometime warm the knee so it's less stilf and also hurts less. Made a habit of compensation, need to be reminded not to do!
Orthopedic surgeon Anestheleidig it Surgical center				Orthop Physical	nce company edic surgeon therapy clinic and trainer			Cosch and trainer Family & Friends

Would like to know how my legs and knees are doing, so I don't get injured again. Need to be helped to stop the compensation and how to train properly.

	SURGERY				REHABI	ILITATION			PREVENTION
		CONSULTANCE Because of her education Jessie decided to move away to Sweden. After the consultance in Norway the rethabilitation was taken over by the Swedish rehabilitation centers.	 around with crutches (tried to stop using after 1 month) 	INITIAL REHAB She had to rest, and keep it witch stretching and some cycling, Initial rehab happened in the pool and she would meet once a week for the first five weeks. Because she is a very active person after three weeks the true weeks the standard of the standard strength of the strength of the standard strength of the strength of the standard strength of the stan	TOO MOTIVATED Since the rehabilitation was going slow, and she used to have a very size to lifestyle before, Jessis tries some jogging and overstretches the ACL quite often	LOSE MOTIVATION The entire rishab felt so impersonal and standardized, the didn't see any improvement and starts to lose her motivation, fearing she will never be able to play her fearounts sport angular. Luckly her francis west through the same thing at the time so she was not alone.	RETURN TO NORWAY On her refurn to Norway the decided to go to a thera- pist there a swall. He tricks her into doing certain ex- ercises more specialized and specific for her rughy rostinin, like decideopsing, and the got hope again that she could resum to the open take town.	She regains her stability and strength through the re- habilisation and is motivated to recover!	RETURN TO SPORT After 15, years the is finally ready to return to her- sport. Unfortunately because of compensation she does remain with a weakened knee and hip now she starts working an regaining her considence to get back into the sport.
Anestesia administration	ACL graft surgery	Consultance with surgeon and anesthesiologist	Initial recovery (Week 1 & 2) Recovering from the surgery, try to minimize stress on the injury/knee and range of motion (get leg straigth)	Restore Initial Functioning (Month 1 & 2) Recover Initial range of motion, extend the leg to become straight and try to flex the leg at least 90 degrees	Restore Initial Functioning (Month 2 & 3) Easy jogging, slight jumping, Begin to train for some strength and some resistance to impact.	Regain functioning (Month 4 to 12) Start with some running and mulitasking, some precise functioning, working en jumping and strength, etc	Healthy functioning (12 to 14) Training to return to sport, first time returning to practice, test the progress frough jump, stress, pain, endurance tests. More specific rehabilitation exercises.	partially, like only perform 2/3 of the usual. Perform to	Return to sport/life [after 18 months] Patient eventually on their own, need to continue with the rehabilitation (usually ranges from month 12 to 18). Main focus is for the athlete to regain confidence and prevent future injury
						Friends that go through the same; I'm not alone in this!	Therapist tricked me into specific exercises for rugbyl More personalized rehabilitation!	I could do something with the sport again! Didn't think I would be able to play again!	
		Did not realise how much work the rehab will be				Very carefull with the most standard things			Should focus more on the prevention, After the rehabilitation don't want to think of the injury again.
				Very boring, your life is on hold, can't do a thing. You lose motivation because you don't see improvement.	Lots of pain - leads to compensation. Wan't to do to much, overstretch the ACL a few times. Meant had to start over and over with the rehab.	Compensation because of fear.	People don't realise how hard it is to not go to work or be able do what you want to. Doing those activities, that was me!	10	Missed out on a few years of my life
						Going from exercising 6 to 7 times a week to nathing is difficult. Needed someone who would motivate me.		In Sweden they check you with a lot of jumping and balancing tests, you can compensate for those with your other knee The return to sport didn't work with this system. High risk of injuring the other log through compensation.	
	Orthopedic surgeon Anestheiologist Surgical center				Orthop Physical	ance company ance company the state of the			Coach and trainer Family & Friends

Assistive device to stop the compensation... I now have hip and knee trouble in the other leg because I used it too much...

Need to keep the patient motivated... I had given up on playing again, motivation improved again when it turned out I could!

SUR	RGERY				REHABILI	TATION			PREVENTION
			LETS START! Exited to have the surgery done, she is metivated to start directly and get back to the field ASAP Because she was using crutches for the first month however, she was slimited in what she could do, also socially Could not participate in activities she would have liked.	LOSING MOTIVATION She lost the metivation, and since she was also 1141 in the age of wanting to have fun, she decided to not be as active with the rehabilitation as she could.	COMPENSATING The exercises were not to challenging and gave her the feet the could ever one the injury! However because her knew sost liquides till and rost flexible, till was really difficult not to cheat/compensate with the exercises.		THE GOAL IN SIGHT When she was getting closer and closer to being able to play again, the motivation grew again!	THE GOAL IN SIGHT Altar just 8 months the was recovered from her injury, however through centrue of the knees 1,5 years later he would damage copyledy 40% her hermiscus. Some time after she would starge copyledy 40% her hermiscus. Some time after she would starge the ACL another time.	THE GOAL IN SIGHT After the rehabilitation she wanted to go back in 100% luckslift the training the first back as it. Unfortunately after all this elime he still this retooks with the firstallity and banding the knee. The injury never property healed.
Anestesia administration	ACL graft surgery	Consultance with surgeon and anesthesiologist	Initial recovery (Week 1 & 2) Recovering from the surgery, try to minimize stress on the injury/knee and range of motion (get leg straigth)	Restore Initial Functioning (Month 1 & 2) Recover initial range of motion, extend the lag to become straight and try to first the lag at least 90 degrees	Restore Initial Functioning (Month 2 & 3) Easy jagging, slight jumping, Begin to train for some strength and some resistance to impact.	Regain functioning [Month 4 & 5] Start with some running and multitasking, some precise functioning, and sport specific exercises.	Healthy functioning (month 4 to 7) Training to return is sport, first time returning to practice, text the progress brough jump, stress, pain texts. More specific rehabilitation exercises.	Efficient functioning (month 8) Tests are performed, if acceptable able to return to play partially, like only perform I/3 of the usual. Perform to regain endurance, people are undertrained.	Return to sport/life (month 9 and convard) Patient eventually on their own, need to continue with the rehabilitation (sexually ranges from month 12 to 18). Main focus is for the athlete to regain confidence and prevent future injury
	Could go home the same day!		Directly started with an exercise program. First did them together with the therapist. Adapted to my status		Got more balancing enercises for soccer. Not to demanding, casy to perform. One or two challenging ones, let) you can overcome this!		Getting closer to playing again! increased motivation!		
				General rehabilitation, not specialty for my needs as a soccer player.					Wanted to go back all in, luckly the coaches did not allow me.
			Crutches were very limiting. Could not participate in a lot of activities. Couldn't even sit down as a normal person.		Biking was tough, was constantly compensating. Couldn't not cheat! Get a set back 2/3 times so lost a few menths each time.				When it is cold, the leg is still and still feels weird. Trouble for a long time sitting on my knees, and swellen. Eventually more injury and compensation
			Wasn't getting motivated to perform the exercises.		Worst part is that you don't know how far you are, and don't know how much longer it will take.				
Anest	edic surgeon Itheiologist ical center				Insurance Orthopedic Physical Coach and	surgeon rapy clinic			Coach and trainer Family & Friends

If the cycling was not so fixed, change it so that it adapt to my capabilities so I don't have to cheat...

Not so fixed and not too demanding.

Show how far the patient is, % of rehab done...

Everyone has an smartphone nowadays, what if we could have a couch, for example like dualingo for the rehab?

Something to prevent me from getting arthritiz because of the injury? Is a common problem (roughly 50%)

REHABILITATION PHASES In what phase of the rehabilitation are we?	INJURY Patient sustains injury	DIAGNOSIS Diagnose severity of injury.	REFERAL Decide how to treat the injury	SURGERY Performing surgery, after this directly into rehab.	Initial recovery (week 1 and 2).
PAIN	MISDIAGNOSED	UNCERTAINTY	MOTIVATION	CHOICE	ACCEPTANCE
PURPOSE	PRECISION	KNOWLEDGE	UNDERSTANDING OPTIONS	DECIDING	ENCOURAGE
		SET UP	INTRODUCTION	PREPARING	INFORMING
ACTIONS		Medical data collected. Case/profile created.	Explain your injury what are the options Inform facts & figures	Explain what to come.	How is the status of the knee? How is the swelling going? Encourage motion.
INFORMATION		Medical history. How did the injury happen? How is the injury?	Basic information of patient. What is the status of the injury Measure the healthy knee vs injured on strength, flexion, endurance and swelling.	How is the treatment to be done? With or without surgery?	Flexion, extension Swelling
PATIENT			Patient meets therapist. Patient introduced to tool. Tweak personal profile. Inform about the injury.	Inform about treatment options. Define the desired result.	Start stretching exercises Compress the knee, Manage the swelling.
APP		Medical data collected Patient profile created	Profile updated by patient. Inform patient about injury.	Inform patient about treatment. Define desired goals.	Give feedback on exercises Motivate to perform. Inform about the effect. Feedback therapist. Share progress/data.
DEVICE			Measure the healthy knee. Fit to the injured knee.		Measure the swelling. Measure the flex & bend. Give feedback on exercises.

Inform patient about injury. Inform patient about treatment. Measure the zero point.

Consult in the decision.

Monitor swelling. Monitor flex & bend. Give feedback.

Fill in patient information. Create a profile/case.

THERAPIST

	REHABILITATION —						
Restore range of motion (month 1 and 2).	Restore initial functioning (month 2 and 3).	Regain funtioning (month 4 and 5).	Healthy functioning (month 6 and 7).	Efficient functioning (month 8 and 9).	Return to sport/life (month 9 and onward).		
REALITY	EXERCISE TOO MUCH OR TOO LITTLE	TRUST	ADAPTING	RISK OF RE-INJURY	NEGLECTION		
REWARD	EQUILIBRIUM	EVIDENCE	REFOCUS PERSONAL GOALS	BELIEF	CREATE AWARENESS		
PROGRESS	ACTIVITY TRACKING	ACCOMPLISHMENTS	MOTIVATING	ANALYZING	STIMULATION		
Explain what to expect, Show what the status is, Show improvement, How to perform the therapy	Daily goals for exercise. Show the progress. Warn if too much or too little	Show the improvement, Celebrate accomplishments	Set goals and show how close. Celebrate accomplishments.	Compare the knees. Work on technique. Show where and how to improve.	Remind of the exercises, Follow up in long term.		
Flexion, extension Swelling	Flexion, extension Swelling Strength	Flexion, extension Swelling Strength Endurance	Flexion, extension Swelling Strength Endurance Balance	Flexion, extension Strength Endurance Balance	Flexion, extension Strength Endurance Balance		
Perform exercises. Manage the swelling.	Perform exercises. Manage the activity.	Perform exercises. Share results. Manage the activity.	Perform exercises. Update the goals. Manage the activity.	Perform exercises. Inform environment Manage the activity.	Educate environment Perform preventive exersises. Continue with therapy.		
Motivate to perform. Give feedback on exercises. Reward by showing progress. Communication / feedback therapist. Share progress/data.	Give challenges. Show progress. Correct/warn about overuse. Share progress/data.	Celebrate accomplishment/share. Show progress. Give feedback on exercises. Enable communication.	Show how close to the goal. Celebrate accomplishments/share. Show progress. Give feedback on exercises. Enable communication.	Show how to improve. Inform about the risks. Show progress. Give feedback on exercises. Enable communication.	Send reminders. Feedback on progress. Show how to improve. Suggest exercises.		
Measure the swelling. Measure the flex & bend. Give feedback on exercises.	Measure the activity. Measure the flex & bend. Give feedback on exercises. Measure the strength.	Measure the activity. Measure the flex & bend. Give feedback on exercises. Measure the strength. Measure endurance.	Measure the activity. Measure the flex & bend. Give feedback on exercises. Measure the strength. Measure endurance.	Measure the activity. Measure the flex & bend. Give feedback on exercises. Measure the strength. Measure endurance.	Give feedback on exercises Measure the motion/technique		
Monitor swelling. Monitor flex & bend. Give feedback.	Analyze data. Give feedback Adapt therapy.	Analyze data. Give feedback Adapt therapy.	Analyze data. Give feedback Adapt therapy.	Analyze data. Give feedback Adapt therapy.	Follow up.		