Co-funded by the Horizon 2020

REACH

***Deliverable D5.1*: List of requirements and functions report**

Abstract: In REACH, WP5 focusses on identifying the requirements for the Personalized Interior Intelligent Units (PI²Us) and concrete functional elements that have to be integrated by the PI²Us based on the outcomes of WP1 (in particular the detailed analysis of the use-case). In order to simplify later on the modularization of the system where possible between different levels of relevance of both requirements and functions are distinguished. Furtherore, the selected requirements and functions are discussed with stakeholders, experts, care professionals and users. Chapter 1 introduces an overview of results of tasks and activities related to T5.1. In Chapter 2 and 3, requirements of care givers and elderly citizens from different social perspectives are described. Lastly, summery is presented.

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Participants:	DTU, KOP, TUM, NKBA, TU/e, ZuidZorg, HUG
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13.07.2016	Deliverable strategy ready	completed
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Tasks of the involved partners with respect to the deliverable (and respective tasks) presented in this report:

Partner	Short task description
DTU	• Responsible for deliverable and structure • Contribution on use cases and stakeholder summaries, early trials results and privacy issues, requirements summary • Detailing of overall T5.1 and task activities, roadmap
TUM	• Description and analysis of PI²U functions and derived requirements • Guidance on contents of report, review and feedback, on drafts and links to Touchpoints, Engine, and the resulting interfaces (
ZuidZorg	• Report and analysis of care giver requirements based on workshop results
Tu/e	• Collaboration with ZuidZorg on workshops and reporting
SK	• Contribution to Use Case and stakeholder analysis • Contribution to ethics issues in patient journey
HUG	• Composing and collecting ethics issues in patient journey

Please note: T5.1 is a task that continues and therefore the partners have not yet used all the allocated resources. Beyond this deliverable report, T5.1 (as a task that continues up to Month 48) will facilitate the uptake of the introduced guidelines, the subsequent detailing of interfaces and specifications by the implementation work teams (e.g. the Touchpoints/Engine associated work teams), and the monitoring of the technology maturation and integration processes. The outcome of this facilitation work will be laid down as updates to this deliverable report.

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Key expressions

Abbreviations for partners:

AH: ArjoHuntleigh

AM: Alreh Medical

BZN: Biozoon

CU: University of Copenhagen

DTU: Technical University of Denmark

EPFL: École Polytechnique Fédérale of Lausanne, Switzerland

FIAIS: Fraunhofer

HUG: Hôpitaux Universitaires Genève

SC: SmartCardia

SK: Schön Klinik

TU/e: Eindhoven University of Technology

TUM: Technical University of Munich

ZZ: ZuidZorg

Ambient sensors: sensors not worn on the body but integrated in environment, everyday objects, PI²Us, etc.), supply in REAC primarily context and labelling.

Annotation/ labelling of data: in the work carried out so far it was clarified that in each Touchpoint, in general, wearable sensors (which experience more and more acceptance among elderly and also increased recently significantly in terms of their practicability and usability) are used to obtain the physiological signals whereas ambient sensors are used to supply in an automatic manner context and labelling (e.g. add information to the physiological signals about the context, activity, person, environment etc. in context of which the physiological signal was obtained) .

Behavior Change: REACH extensively leverages state-of-the-art knowledge on the topics of motivation and behavior change to engage elderly to change efficiently the early-detected undesired behavior patterns of physical activity of specific elderly. More specifically, how to apply motivational strategies stemming from behavior change theories to create interventions that will be engaging and will have high levels of adoption amongst end users

D: Deliverable report.

Data Analytics: Two major types are distinguished in REACH. Analytics type 1 focusses based on machine learning algorithms on the detection and prediction of activities, trends, and behaviour profiles. Analytics type 2 allows based on clustering algorithms on the matching and optimization of behaviour profiles and personalized intervention profiles through clustering algorithms.

Data Management Plan (DMP): The consortium developed and presented as part of Deliverable T10.1/D43 on a voluntary basis a DMP.

Decomposition of testing approach: For each Touchpoint separate testing parts/instances (early detection, motivational techniques, and programmed interventions) were created and each of this testing instances represents a separate trial with an own hypothesis, own outcome measures, and an instance specific trial design.

Draft of Action (DoA): actual, updated REACH project proposal which is part of the Grant Agreement

Early warning and detection dimensions: The early warning and detection dimensions that were identified for being implemented in REAC are 1) one-off alarm regimes (e.g. detection of sudden deviations), 2) detection and prediction of short term and long term activities and patterns, 3) device integrated automatic early assessment (e.g. validation of an interaction or training with PI²Us or Playware tiles as an equivalent to 6-minute walk test), and 4) the early assignment and optimization of personalized interventions.

End users: the end users are the main target of the REACH system. They will interact with the REACH system primarily directly through the Touchpoints.

Engine: The “Engine” – in itself also modular with regard to its functionality – serves from the viewpoint of the end user as “invisible” back end system. In general, the end users (elderly) are supposed to interact with the “engine” primarily in an indirect way through the Touchpoints.

Interfaces: Three basic types of interfaces are distinguished in REACH: “human-system interfaces”, “system-system interfaces” (e.g. between “Touchpoints” and the ICT-system “Engine”), and “b to b interfaces” between the Engine and non-end users such as care professionals.

Interventions: Through the analytics section generated output is used in REACH to, to select develop, and or personalize interventions that react on the early detected trends, patterns, or deviations of physical activity with each PAD. In that context, sophisticated motivational techniques and engagement strategies are used and tailored towards PADs, individual users, and user profiles to create a highly efficient and long lasting behaviour change. Both programmed interventions and device interventions will be used in REACH.

Key Performance Indicators (KPI): As part of the DoA a set of selected KPIs was introduced allowing quantitative and qualitative assessment and monitoring of the progress of REACH in each reporting period

M: Project month within the project duration (e.g. M19 refers to project month 19, namely August 2017)

Motivational techniques: User engagement and interaction; the Touchpoints will embody and serve as mediators for a variety of motivational and engagement techniques that allow the Touchpoints to engage end users (elderly) in a way which is superior to conventional monitoring and intervention products.

Personalized Intelligent Interior Units (PI²Us)/ Smart Furniture are used to integrate the REACH concepts and functionality seamlessly into the different

REACH use case settings. Touchpoints will mainly materialize as “furniture” in a broader sense, i.e. elements that can be placed and moved within a certain environment or setting (e.g. beds, bath furniture, mobile walkers/standers, large scale interfaces, smart flooring tiles, smart tables, etc.) but also as ambient sensor add-on modules and wearables.

Physical Activity Dimension (PAD): in REACH the Touchpoints represent complementary dimensions or views of physical activity which partition the testing and data gathering space around the REACH physical activity data model core into four segments (TP1: general mobility; TP2: postures, ADLs, micro-mobility; TP3: socialising and nutrition; TP4: gaming and training).

Physical Activity: Target condition of REACH. The systemized early detection and intervention based prevention of physical inactivity and sedentary behavior in a variety care setting such as homes and everyday life, day care centers, and other geriatric facilities will not only reduce significantly the risk of LTC admissions and re-admissions (and thus as targeted by REACH reduce overall health care cost) but also increase the elderly’s functional performance, social participation, independence, and quality of life.

Platforms sides/ multisided platform: from a business viewpoint the REACH system shall state a “multisided” platform that allows for interactions between two or more “actor” sides. In REACH two basic sides can be distinguished, the “end user side” and the “professional side”. Both sides can be customers of the REACH system. For each side so called “key interactions” must be defined.

PM: Person-Month

Product-service-system (PSS): Product-service-systems can be defined as “a marketable set of products and services capable of jointly fulfilling a user’s need” (Goedkoop, van Halen, te Riele, & Rommens, 1999).

R: Reviewer Recommendation/Comment

REACH physical activity data model: this common data model will build the basis for the development, testing and application of various machine learning methods to early detect changes in physical activity levels and patterns, and to train clustering algorithms that help with the optimized and personalized assignment and recommendation of specific engagement strategies and interventions

REACH’s unique Sensing-Monitoring-Intervention (SMI) activity flow: The REACH consortium has based on its initially defined Sensing-Monitoring-Intervention concept outlined in the DoA, as part of the work carried out so far, detailed and took this concept further towards a unique Sensing-Monitoring-Intervention Activity Flow

Sensing: In REACH physical activity was further detailed as the target condition and categorized into Physical Activity Dimensions (PADs). Based on the PAD and the selected early detection regimes, a specific set of sensors, which is able to serve the selected condition, and detection regime can be selected in a target-oriented manner.

Stakeholders: In REACH the term “stakeholders” is refered to the entire network and the diversity of players, partners, shareholders, stakeholders, end users, organizations, companies, institutions, and others that relate to, act in, are impacted by, and/or are interested in the activities, developments, and goals of the project.

System architecture: fundamental concepts or properties of a system in its environment embodied in its elements; organization of a system and the relation of its parts and subsystems to each other (ISO/IEC/IEEE 42010:2011; IEEE standard 1471).

T: Task defined in the project proposal.

Testing Instance: Decomposition of the “testing approach”. For each Touchpoint (each equaling one PAD area) separate testing parts (=instances) were created following REACH’s sensing, monitoring, and intervention based professional areas. Each testing instance represents a separate trial with an own hypothesis, own outcome measures, and an instance-specific trial design.

Testing period: In REACH four testing periods are distinguished: Test Period 1: Early testing/early trials (M1 - M24); Test Period 2: Pre-testing 1 (end of year 2); Test Period 3: Pre-testing 2 (year 3); Test Period 4: Final testing / demonstration (year 4).

Touchpoints (TP): The “Touchpoints” will act as “graspable” front end towards the end users (elderly). The Touchpoints will serve as data gathering devices as well as mediator of services and interventions coordinated by the Engine towards the end user. Each Touchpoint is modular and made up of several subsystems which allow to adapt the system both for a certain person or setting as well as over time. Each Touchpoint reflects a Physical Activity Dimension (PAD).

Touchpoints/Engine concept: structures the envisioned REACH product-service-system architecture, into manageable research and development clusters.

Use case setting: Use case setting refers to the four solution operators and this report called them the use case setting since they reflect concrete application scenarios.

V-Model: in the first project phases requirements are developed and formalized, the overall problem is decomposed, and the high-level system architecture is developed. This architecture is in the subsequent development phases translated into concrete functionality, detailed and implemented on component level, integrated again to a system, and finally in a series of subsequent activities verified and validated.

Wearable sensor: worn on the body, obtain in REACH primarily uni- or multivariate physiological signals

Work teams/ clusters: The work teams around each Touchpoint were formed and re-confirmed with the consortium. The “Touchpoints and Engine concept” now structures the envisioned REACH product-service-system architecture, into manageable research and development clusters.

WP: Work package specified in the DoA.

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1 Overview of results of tasks and activities related to T5.1

In REACH, a sensing-monitoring-intervention system is being developed that can be placed in an unobtrusive manner in various care settings and living environments of elderly. The system will be able (1) to use a set of sensors to detect selected vital signs, behavioral and care patterns, and health states, (2) to predict - as early as possible - future health states, risks or events like the loss of function, frailty, stroke, etc., and (3) to provide and coordinate proactively a set of customized products and services that have the overall aim of supporting and promoting physical activity - including related social activities and serious games. The system's main task is preventing or delaying functional loss and reinforcing functional ability of the elderly to prolong independent living.

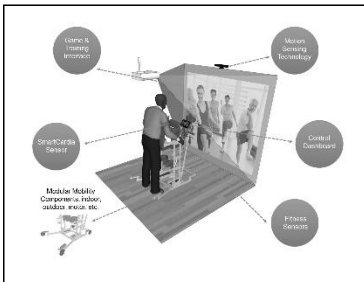
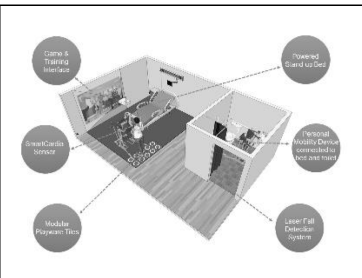
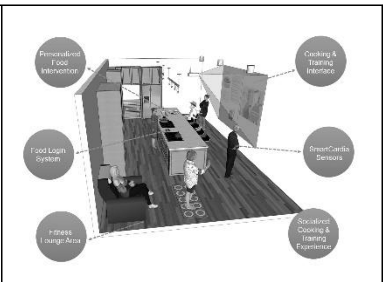
1.1 Touchpoint and Engine Concept

Stating a key achievement of the first project year, the REACH consortium has developed and detailed a holistic conceptual solution, the "Touchpoints and Engine concept" (**Figure 1-1**), based on an in-depth analysis of the four REACH use case settings, and the identification and inclusion of consortium internal and consortium external stakeholders (elderly, care personnel, insurances, etc.) in the system architecture development process. This conceptual solution fully reflects REACH's "Product-Service-System" value proposition. 5 physical touchpoints will function each as data gathering and intervention devices, which are bound together by cross-sectional, integrated engine (i.e. platform) functionality.

Touchpoints 1-4 not only state development an innovation clusters within the consortium, but

a) represent each a specific dimension of physical activity in general (REACH Physical Activity Dimensions, PADs)
b) and will each implement an instantiation REACH's unique Sensing-Monitoring-Intervention Activity Flow (see also **Section 1.2**).

Touchpoint 5 and the Engine state cross sectional development areas that serve these 4 PADs. A detailed description of the Touchpoint and Engine concept and the REACH partners and use case settings associated with each of its components are outlined in detail in **Deliverable T1.4/D4**.

		
Touchpoint 1: Personal Mobility Device	Touchpoint 2: Active Environment	Touchpoint 3: Socializing & Nutritional Intervention

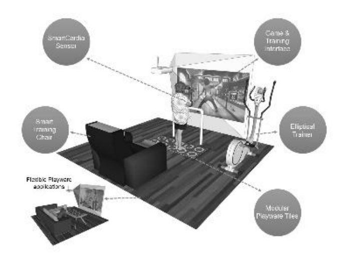
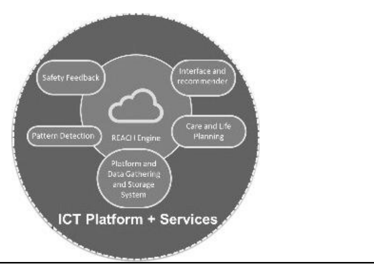
		
Touchpoint 4: Gaming & Training	Touchpoint 5: Wearables	Engine

Figure 1-1: Touchpoints not only state development an innovation clusters within the consortium, but represent each a specific dimension of physical activity in general and will each implement an instantiation REACH's unique Sensing-Monitoring-Intervention Activity Flow

"Touchpoints" will act as "graspable" front end towards the end users (elderly). Touchpoints will mainly materialize as "furniture/PI²Us" in a broader sense, i.e. elements that can be placed and moved within a certain environment or setting (e.g. beds, bath furniture, mobile walkers/standers, large scale interfaces, smart flooring tiles, smart tables, etc.; see also **Section 1.7**) but also as ambient sensor add-on modules and wearables. The Touchpoints will serve as data gathering devices as well as mediator of services and interventions coordinated by the Engine towards the end user. Each Touchpoint is modular in itself (thus also serving as a kind of physical product platform) and made up of several subsystems which allow to adapt the system both for a certain person or setting as well as over time. The "Engine" ICT platform - in itself also modular with regard to its functionality – serves from the viewpoint of the end user as "invisible" back end system. In general, the end users (elderly) are supposed to interact with the "engine" primarily in an indirect way through the Touchpoints.

1.2 REACH's target condition

In tune with the objectives defined in the DoA, REACH will in in the various Touchpoints address different instances of physical activity as the target condition to be early detected. Physical inactivity enhances the risk of, is associated with, and is and indicator for the development of a variety of secondary conditions, such as decline of functional ability, the onset of frailty, the risk of falls, the risk coronary artery disease, diabetes, hypertension, obesity, osteoporosis, and depression.

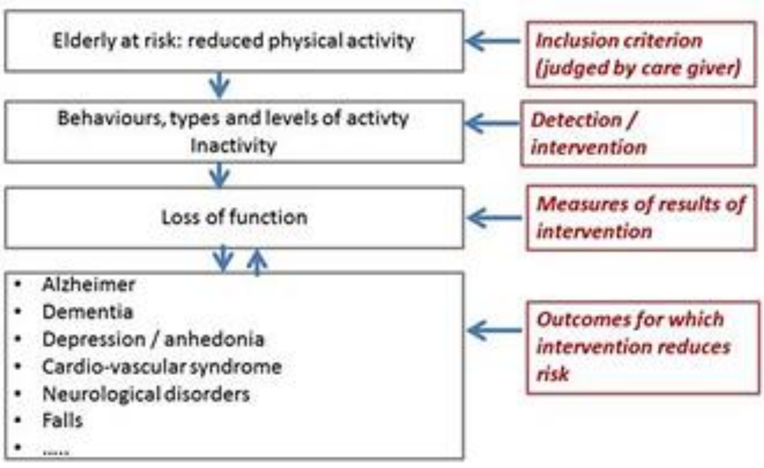


Figure 1-2: Physical inactivity enhances the risk of, is associated with, and is and indicator for the development of a variety of secondary conditions

The systemized early detection of physical inactivity and sedentary behavior (and an with this initiated personalized intervention) in a variety of settings such as homes and everyday life, day care centers, and other geriatric facilities will not only reduce significantly the risk of LTC admissions and re-admissions (and thus as targeted by REACH reduce overall health care cost) but also increase the elderly's functional ability through targeted intervention and thus their social participation, independence, and quality of life

1.3 REACH's Sensing-Monitoring-Intervention Activity Flow and the role of PI²Us

The REACH consortium has based on its initially defined Sensing-Monitoring-Intervention concept outlined in the DoA, as part of the work carried out so far, detailed and took this concept further towards a unique Sensing-Monitoring-Intervention Activity Flow (**Figure 1-3**).

- As part of the **Sensing** section physical activity was further detailed as the target condition and categorized into Physical Activity Dimensions (PADs), namely 1) macro-mobility, 2) micro-mobility, 3) socialising and nutrition, and 4) gaming and training. In that context, several early detection regimes were defined were defined such as a) one-off alarm, b) detection of short or long term activities and patterns, c) device integrated automatic early assessment, which can be applied in specific combinations for each PAD. Based on the PAD and the selected early detection regimes, a specific set of sensors, which is able to serve the selected condition, and detection regime can be selected in a target-oriented manner.

- Based on the selected sensing strategy, as part of the **Monitoring** section a combination of wearable and ambient sensors is chosen for each PAD (which equal the REACH Touchpoints). The task of the wearable sensors is obtaining uni- or multivariate physiological signals, whereas the ambient sensors supply in an automatic manner context and labelling. In the Data collation system, the obtained data set are managed and prepared for processing by various analytics methods and algorithm types. Two major types can be distinguished. Analytics type 1 focusses based on machine learning algorithms on the detection and prediction of activities, trends, and behaviour profiles. Analytics type 2 allows based on clustering algorithms on the matching and optimization of behaviour profiles and personalized intervention profiles through clustering algorithms.

- In the **Intervention** section, the through the analytics section generated output is used to, to select develop, and or personalize interventions that react on the early detected trends, patterns, or deviations of physical activity with each PAD. In that context, sophisticated motivational techniques and engagement strategies are used and tailored towards PADs, individual users, and user profiles to create a highly efficient and long-lasting behaviour change. Both programmed interventions and device interventions and interaction sin the REACH use case environments are informed, embedded in, and coordinated by the previously by the analytics section identified behaviour change strategy. With each new data set generated the system will learn better what behaviour change strategies and interventions work best for specific persons.

PI²Us/ Smart Furniture are used to integrate the above described activities and functional elements seamlessly into the different REACH health care environments.

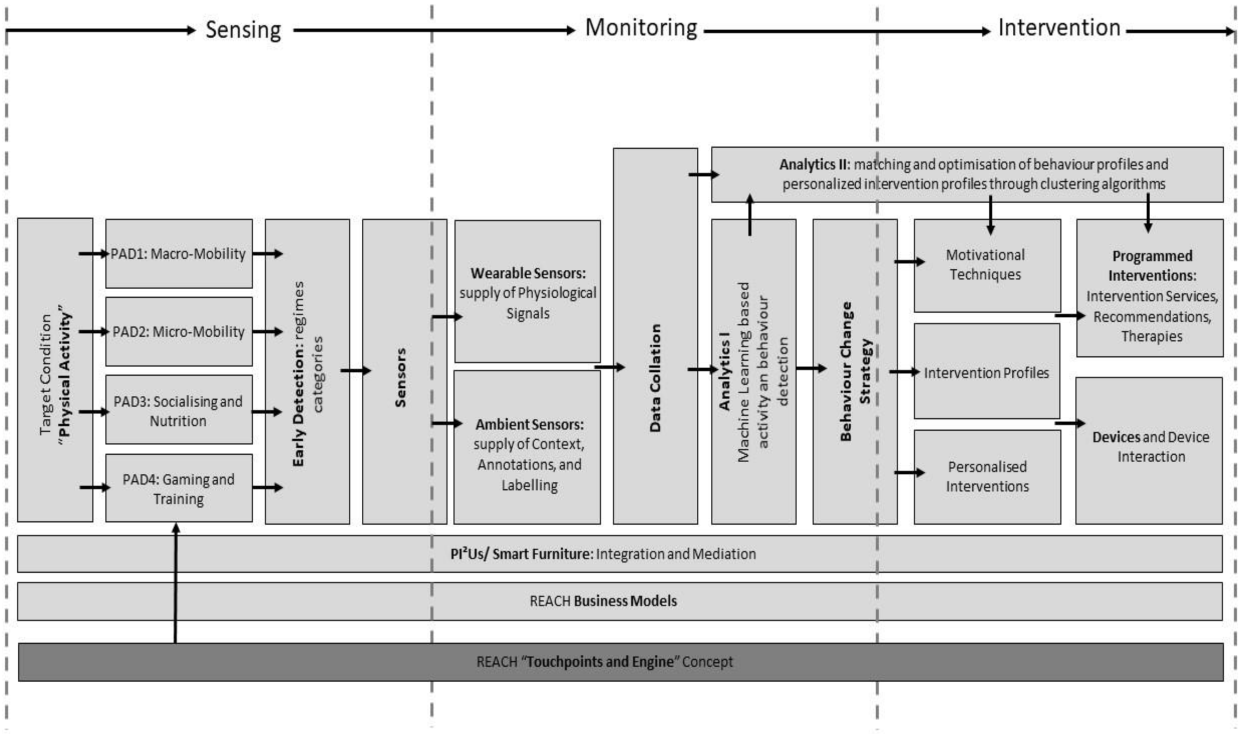


Figure 1-3: REACH's detailed, unique Sensing-Monitoring-Intervention Activity Flow

1.4 Role of T5.1 and the present Deliverable in WP5

In REACH, PI²Us/Smart Furniture are used to integrate REACH key functionality (e.g. ambient sensors), activities, and functional elements seamlessly into the different REACH health care environments.

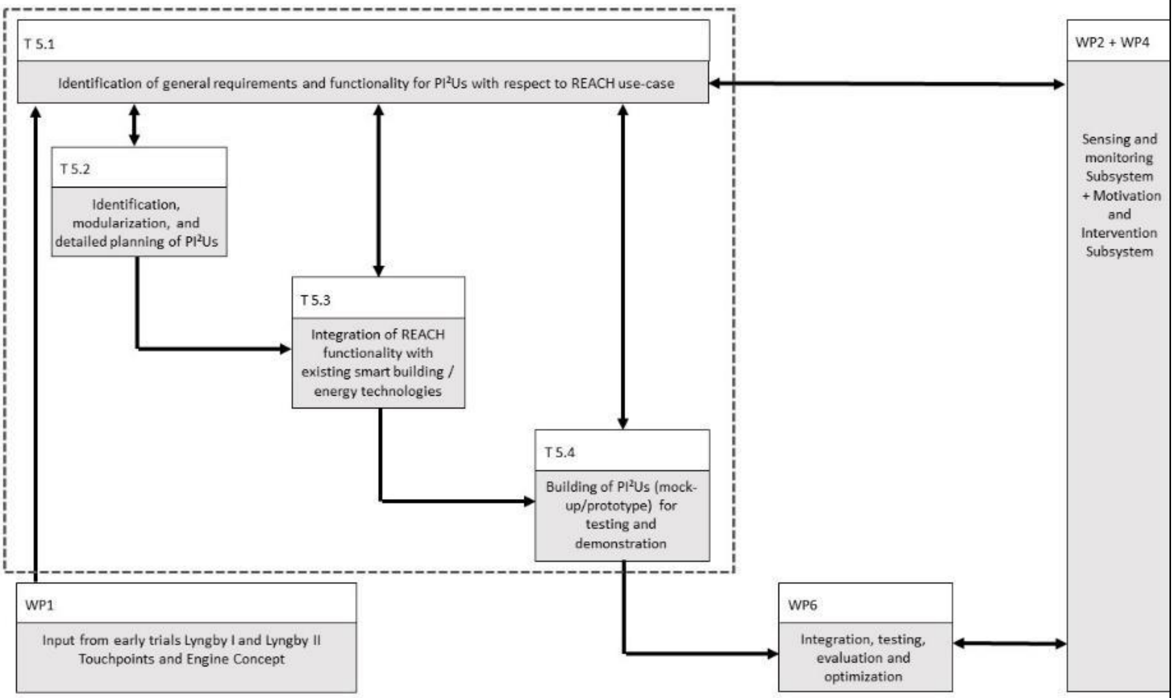


Figure 1-4: Structure of activities developed for WP5

The work conducted as part of WP5 in T5.1 contributes to the detailing of REACH's Touchpoints (see **Section 1.1**) and Sensing-Monitoring-Intervention activity flow (see **Section 1.3**), and established the requirements. It was clarified how PI²Us in REACH are used to integrate the above described activities and functional elements seamlessly into the different REACH health care environments/use case settings. In the following chapters (**Chapters 2-5**) requirements that apply in a cross sectional manner for Touchpoints and pI²Us are developed.

2 General Requirements

2.1 Overview of use case data and analysis of D1

The solution operators (*use cases)* manage different levels of complex dependency needs of elderly (Jacobsen, 2004)**.** The needs can originate from specific disease-based deficits or from general age-related degeneration. The use cases reflect specific application settings for the REACH system, i.e., an acute hospital setting covered by the Geneva Hospital in Switzerland, a rehabilitation setting covered by the Schon Klink Bad Aibling in Germany, the home care setting covered by ZuidZorg in the Netherlands (ZZ) and Lyngby-Taarbæk Municipality in Denmark (Lyngby). In addition, ZuidZorg and Lyngby covers the care home setting, where offer support to elderly living at home but are in need of assistance in the activities of daily living (e.g., personal hygiene, sufficient fluid intake, supporting household activities) (Vermeulen, Neyens & Rossum, 2011) and to improve their quality of life (e. g. social contacts, hobbies). In the Dutch and Danish home care setting (ZuidZorg and Lyngby in our case), seniors 65+ tend to live alone or with their senior partners but not with their children nor relatives (European Commission, 2008-2010)**.** The four use cases, acute hospital and rehabilitation hospital (HUG and SK), home care and homes (ZuidZorg and Lyngby) cover most scenarios where the REACH system could support a patient through the recovery process.

There are four use cases which are in line with the care continuum of REACH. *HUG* with its acute and geriatric unit, and rehabilitation and home care specialists will focus on the acute care, the transition between the use cases and the health states of end-users. SK will focus on physical and cognitive rehabilitation. Rehabilitation aims at reducing the impairment and handicap of patients/elderly and thus reducing their need of care and support. The treatment is based on relearning and exercising of lost abilities, adapted to the patients' individual capabilities. During rehabilitation, the patients also use assistive devices and acquire compensation strategies to gain an independent living. Lyngby and ZuidZorg are the use cases representing the environment of elderly at home. To reduce the risk of health deterioration caused by the natural aging process physical and cognitive training and sometimes therapy is needed. The natural aging process may be negatively affected by complications and adverse events which could cause accelerated deterioration and decline of the health status. REACH will prevent negative consequences in a variety of ways, e.g., by increasing the activity level, support social interaction, or motivate to perform cognitive training. *Lyngby* will focus on home care, representing end-users with a relatively good basic health in the care continuum of REACH. These persons receive some sort of care or household services and need to be motivated for physical and cognitive activity. Patients may receive in-home rehabilitation therapies addressing mild disabilities to avoid nursing home or hospital admission. *ZuidZorg* will focus on home care and elderly living in smart homes. In the REACH care continuum, the elderly in ZuidZorg with their relatively good health need to be motivated for physical and cognitive activity (including ADL training) (Vermeulen, Neyens & Rossum, 2011). Only some of them with lighter disabilities need rehabilitation at home to avoid nursing home or hospital/ acute care admission. More detailed description of the use cases are introduced in **D1**, with further settings and conditions.

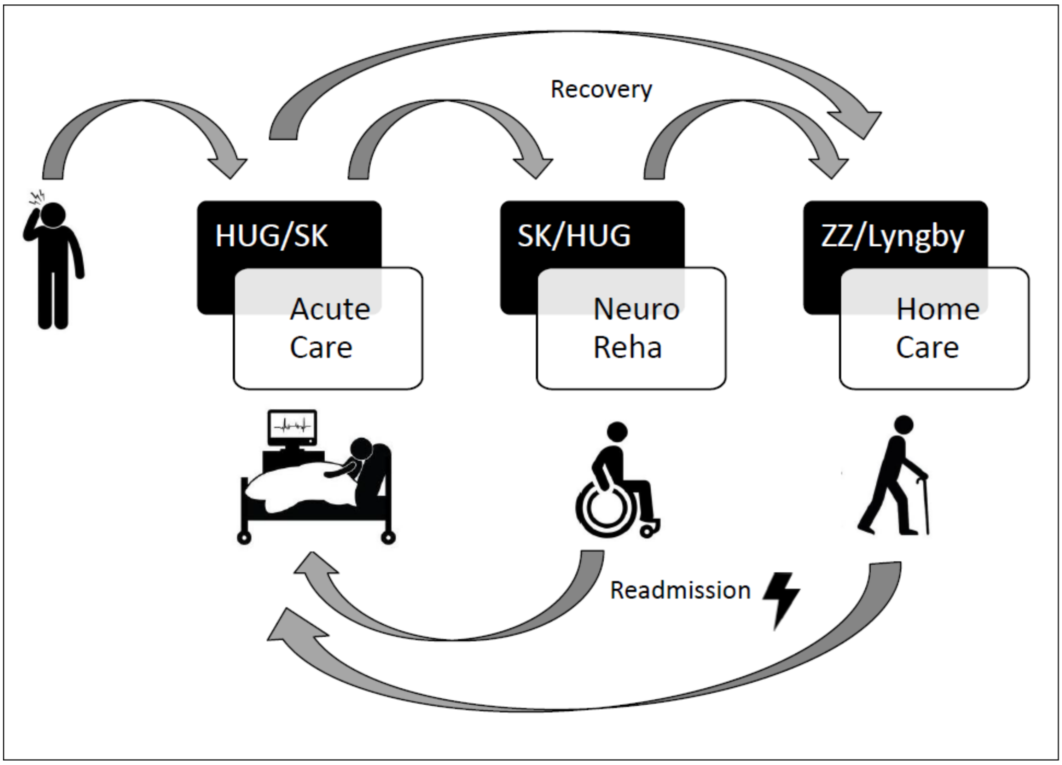


Figure 5: Possible connections between the use cases in REACH

D1 clarifies REACH use cases through collection and analysis on user data with scenarios, persona and experience maps. Persona describes user image, while the experience map visualizes situations, actions, emotions, and contacts a use case resident may experience during a typical day (Philips Design & Innovation Communications KPNV, 2017). Some scenarios are overlapping and some can be found in more than one use case.

First, we will have a look at hospital to home transition, which largely relate to HUG and SK use cases. More precisely, the time lines of patients in neurological rehabilitation hospital until discharge can be described as follows, focusing on problems that may occur:

Severely affected neurological patients, e.g., patients with dementia, may have impairments of cognition and memory. The REACH system can provide familiar information, music, and pictures, to enhance the feeling of security (e. g. dementia diary, family pictures) and allow interaction with care givers and family members. Other common neurological symptoms are motor and sensory deficits, aphasia, urinary and fecal incontinence, neuropsychological deficits, depression and anxiety. The interdisciplinary treatment team and the patient determine the therapy goal(s) at the beginning of the rehabilitation process. A functional environment can support the therapies and the target achievement control.

Two outcome scenarios are possible in inpatient rehabilitation:

1. Rehabilitation was successful: the aims of the patient and his/her relatives have been fulfilled. Inpatient rehabilitation is no longer necessary, outpatient rehabilitation may be sufficient to treat remaining deficits.

2. Rehabilitation has not been or has only been partly successful: Improvement of the patient is missing or is insufficient to reach the predetermined targets, so that the patient, his/her family or the insurance company (paying for the treatment) are no longer willing to continue treatment.

Before the end of the treatment the hospital has to assure that the patient gets the necessary support immediately after discharge. As the medical status of patients varies widely an individual medical aid supply plan has to be developed. The discharge process involves numerous persons and organizations within and outside the hospital (e. g. family members, insurance companies, outpatient therapists, authorities, employers, nursing homes). The financial situation after discharge is very often an important aspect. Financial considerations could be the reason for the care giver to decide to organize nursing at home. The REACH environment aims to significantly reducing the burden of nursing and enables more patients to live independently or with less support at home.

Hospital to home transition has been shown to be a critical period in the patient care to ensure a safe recovery and a long-term independency of elderly at home. In the Geneva context (*HUG*), frequent re-admission to hospital due to falls, heart failure and cognitive impairment were observed. To address this issue, HUG decided to focus on a use case, where REACH would offer a technological solution to smoothen the transition from hospital to home and continue the care process at home once the patient has been discharged.

Through the analysis of **D1** with patients, care givers, nurses, and physiotherapists to understand their needs, their expectations and any fears or doubts they may have towards a technological solution like REACH. We also had access to the patients' medical records that allowed us to refine the target population and to identify the main causes of hospital re-admission. We then proposed specific personas related to our use case and described their typical journey using the REACH system through an experience mapping.

In our particular use case, a typical persona (introduced in **D1: Analysis and description of use cases**) were described as follow.

Mr. Autumn is a 72 years old widower, living alone in his apartment on the second floor in the countryside. Former employees of sales company, he is now retired and enjoy watching TV, reading newspapers, and spending times with his friends in a coffee shop. He is not very technology oriented but uses an Ipad to play chess, check information and read news. He recently had a cerebral ischemic stroke and was unable to move or feel anything from the right part of his body. After some time in the hospital, he started to recover but remained limited physically. Due to multiple falls, he had to go back to the hospital again. Moving has become difficult. He is still doing paperwork but receives helps from IMAD every day for toileting and dressing up. A nurse is also coming every 3 days to check his vitals. His daughter comes from time to time to discuss and walk with him. Worried that anything may happen to her dad again, she is seriously considering placing him in a social heath institution. However, Mr. Autumn would like to keep as long as possible his independence at home.

To avoid the frequent hospitalization and ensure Mr. Autumn independence and safety at home, the REACH system needs to intervene while he is at the hospital and continue the care once he returns home. The system should respond to the hospital care givers needs and requirements to facilitate Mr. Autumn's recovery process. It should answer Mr. Autumn's need of assistance in his activity of daily living, in being physically active and in following his medical treatment, when he comes back home. Finally, it should be able to monitor Mr. Autumn's safety while at home to re-assure his family, caregivers, and doctors.

The following is another female persona (Figure 6) and experience map with minor motor and major cognitive deficit, which strongly related to Lyngby and ZuidZorg. The pictorial representation is held simple and easy to read. The information about characteristics are grouped around a centered photo of a typical representative.

> *Antonia is a married woman with three children, who live too far away to support her in her daily life but are available for special occasions, e. g., renovating the house, organizing family celebrations. In ADL she is dependent on the support of her husband, who finds it challenging to motivate Antonia and initiate activities with the adequate level of stimulation. Her mental health problems and the intermittent depressive episodes impedes her autonomy and social participation. He is responsible to generate a structured environment to fulfill her increasing need for safety. Lack of sleep due to Antonia's sleeping disorder, a common symptom of Alzheimer's disease* (Bliwise DL, 2004)*, frustration about her decreasing ability in basic activities of daily living, her inadequate reactions and mood swings, and the loss of spontaneity sometimes exhausts him. This leads to impatient and angry behaviour which has to be addressed in relationship counseling.*

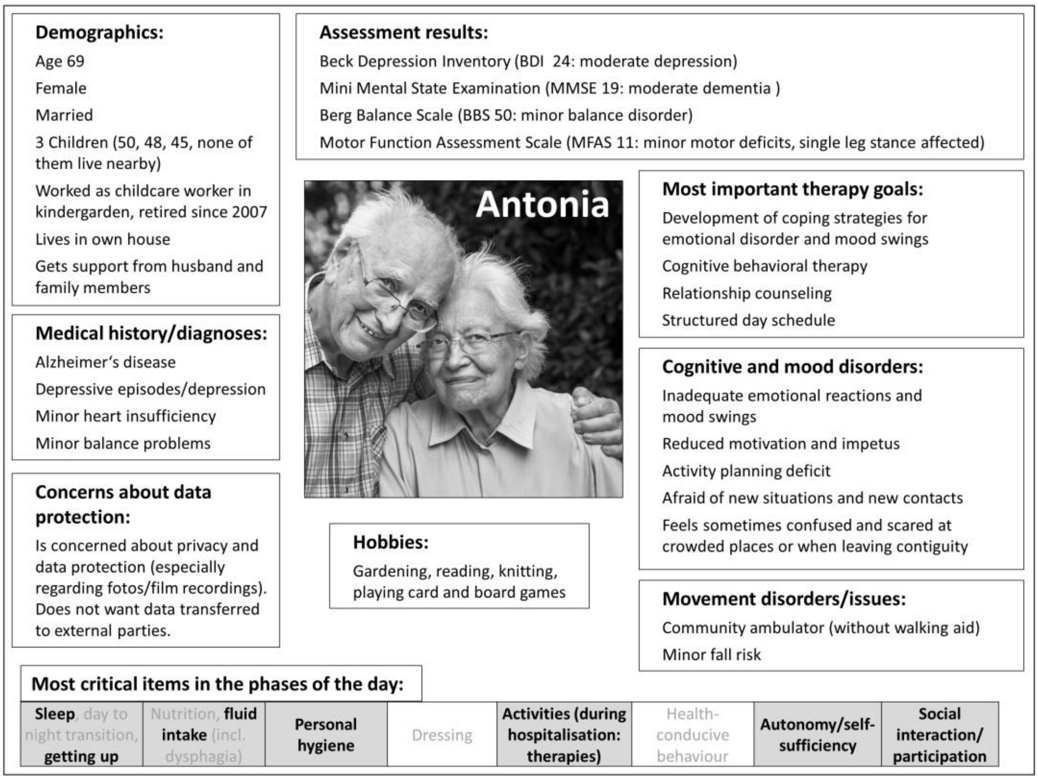


Figure 6: Persona Antonia

REACH could possibly support Antonia to perform cognitive training, guide her through household and other routine activities, recommend sufficient new activities, provide information to address her safety need, and remind her to drink enough. This would enhance her autonomy, reduce the support needed from her husband, and therefore increase the quality of life for both.

A schematic experience map example for a typical day in a rehabilitation setting were also described as shown in **Figure 7.** The timeline is set on the horizontal axis, the vertical axis shows the different layers of insight. For the application in REACH we used different layers **(Figure 7).** Mood and experience, both describe how the elderly/patient feels about specific events, activities, and interactions throughout the day. Equipment indicates the technology used. This can be rehabilitation equipment, but also technology to communicate with their family. Social contacts describe the interactions with friends, family and other persons who are an important part of the patient's lives. Depending on the context, the personality, and the available technology, people may engage in different types of social contacts and activities, as well as experience them in different ways. Medical professionals and stakeholders indicate which medical professionals and institutions are involved at certain points during the day.

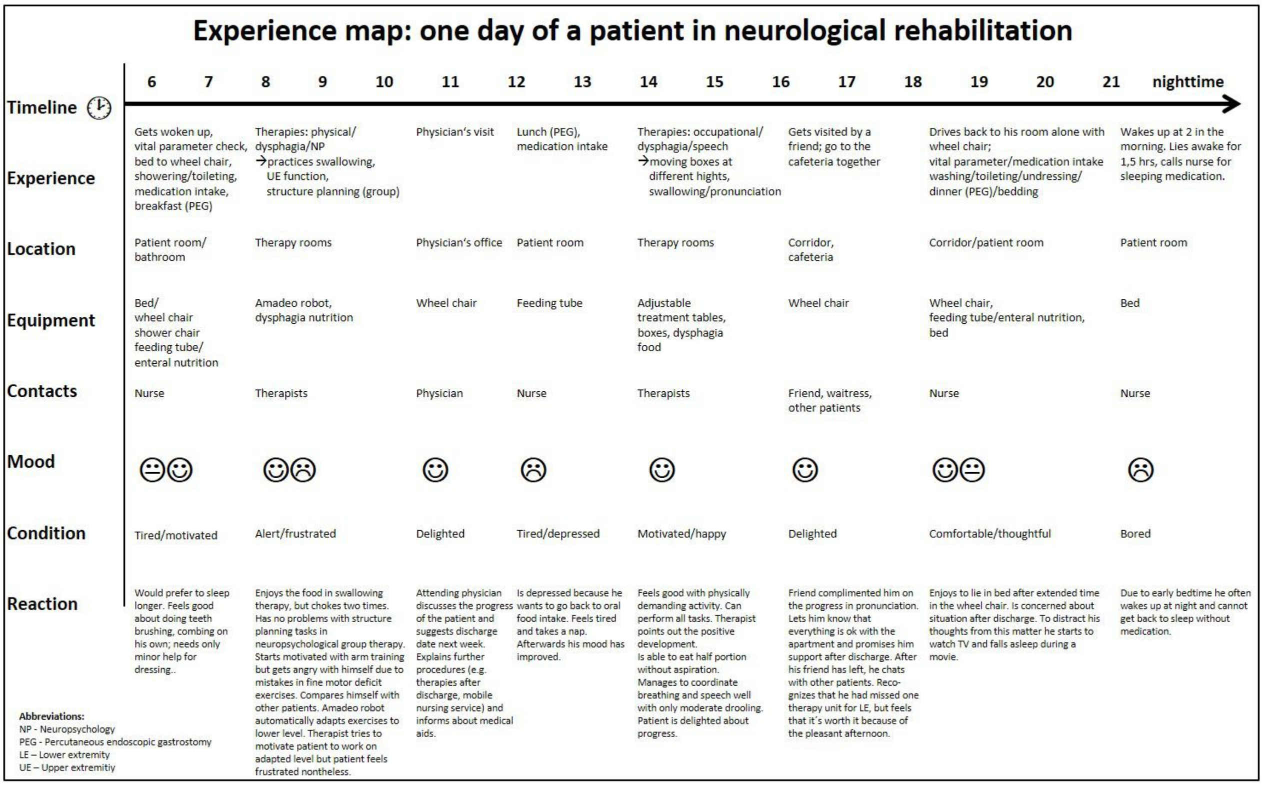


Figure 7: Experience map; one day of a patient in neurological rehabilitation

The modularity of the REACH system should allow customization with regard to varying needs of the elder citizens during their journey through the use cases. The use cases are not only separate settings in which REACH functionality can be integrated, they can be brought into a logical arrangement that represents the care continuum and the transition between health states.

In developing such complex user-centered system like the REACH system, it is essential to perform a requirement specification at the beginning of the project that includes a description of *the end-user* of the system. The end-user description was substantiated by creating *personas* - fictional characters representing a typical user of the REACH system – and experience maps for each use case. It is also critical to consider that the REACH system is not only related to the elderly themselves. It also affects or can be affected by individuals, groups, or institutions, which are related to the targeted end-user. These *stakeholders* need to be identified and analyzed to provide an overview of constraints, incentive structures, and interdependencies. Stakeholders can be categorized into primary and secondary stakeholders who are directly and indirectly affected by the system. To identify the requirements for REACH system, the project conducted the stakeholder analysis and overview is described in **Section 1.2.**

2.2 Overview of stakeholder analysis of D2

This section is concerned stakeholders and its analysis in four REACH use cases. By utilizing shared formats, the stakeholder analysis clarified similarities and differences among the four cases to support shared understanding among consortium members considering constraints, incentive structures, interdependencies among stakeholders and thus the space in which the REACH solution should seek to fulfil unmet needs of the users, both rational-somatic and emotional-social. The stakeholder analysis should not be expected to provide a future-scenario analysis (e.g., how the REACH system would work in practice 5-10 years in the future). But it can provide a necessary overview of the forces - pulls and pushes, incentives, and drives as well as concerns, and risks - that will influence adoption and use of the REACH system and its associated services.

Briefly reiterate, the stakeholder analysis in REACH identified primary, secondary, and key stakeholders as introduced in **D2**. Primary stakeholders are directly influenced by an action, i.e., an intervention, a socio-technical design or service. Secondary stakeholders are indirectly affected by the action, whereas key stakeholders do not belong to the former two groups but have significant influence on the action, e.g., use of the socio-technical design. For the REACH personalized prevention and intervention system aimed at 65+ seniors, it is important to identify and characterize their influencing relations among those who may have power to aid and persuade the elderlies (e.g., family, friends, caregivers), and who may have an interest in care and assistive technologies for both altruistic and selfish reasons.

To ensure maximal benefits from a stakeholder analysis while keeping the scope at a manageable and practical level, we selected three stakeholder templates (Figure 4). They are (a) stakeholder list (Brenner, 1992) (Schmeer K, 1999), which is a simple table with stakeholder characteristics, (b) the onion diagram (Bourne L, 2015) (Alexander, 2006) and (c) the stakeholder matrix (Mitchell, Agle, & Wood, 1997) (Polonsky, 1996).

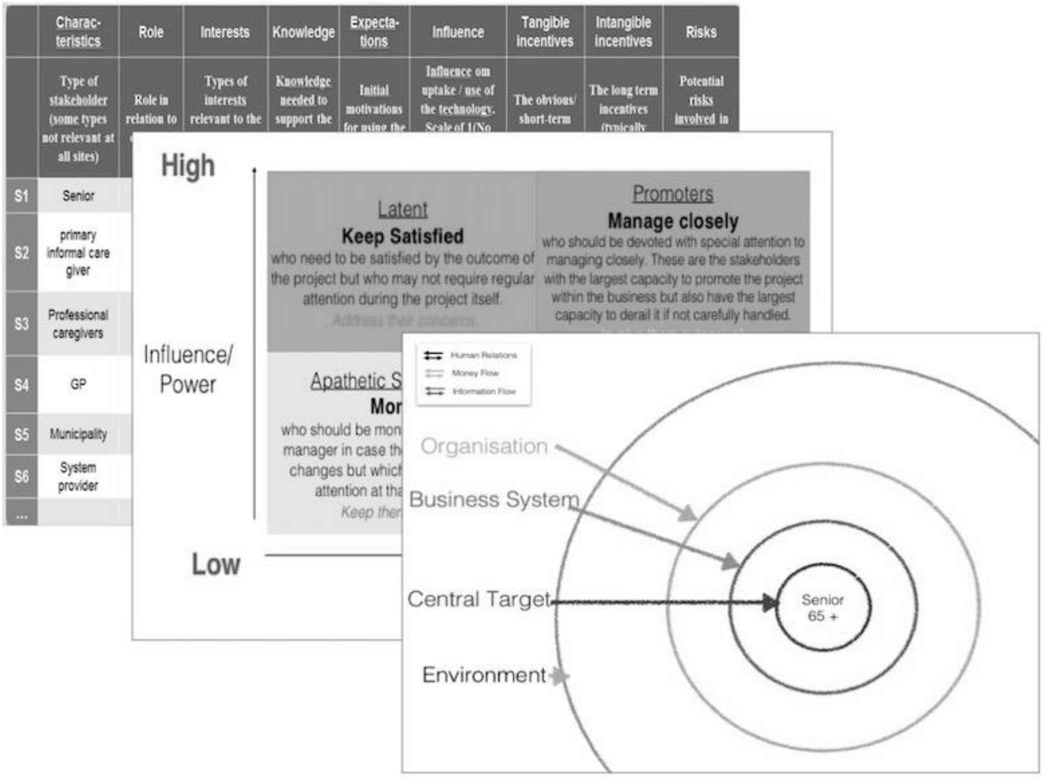


Figure 8: The three templates for stakeholder identification

By utilizing the 3 templates (Figure 8), stakeholders, their characteristics and relations to the 4 use cases were described and analysed.

Lyngby identified 6 stakeholder. Since care-taking is carried out in home settings, the core stakeholder are informal and formal care givers, municipalities and public authorities. Medical personnel beyond municipal nurses are not included among the stakeholder, and medical services and treatment at the hospitals are out of scope.

ZZ identified 7 stakeholder, among which informal stakeholder such as primary informal caregivers (relatives and friends) and the Meet and Greet Centre's community hold the biggest and most important roles. Insurance companies and municipalities are at present outside the circle of care, but are expected to play an important role in near future.

HUG identified 6 stakeholders. The informal supporters, such as caregivers and hospital caregivers, have a great influence on the patients despite the fact that the medical caregiving system considers informal caregivers to be less crucial. Insurance companies are also identified as key stakeholders.

SK identified 10 stakeholders - the biggest number among the 4 locations. This also indicates that there is a complex support system both in formal as well as informal relations to the patient at the rehabilitation hospital.

One *major difference* across the 4 use cases is their *use context*. One use context is the hospital (SK and HUG) where professional caregivers are constantly available and where the patients are typically monitored several times a day. The other use context is the population of elderly citizens living independently at home, with more or less daily or weekly assistance. For this latter user group, professional caregivers (nurses, nurse assistants) are available as well, but besides the scheduled visits they will be called on only for emergencies. These conditions lead to differences in societal characteristics and care continuum.

Differences in societal characteristics are obvious, for example in the role of insurance. In a home care setting, like ZZ and Lyngby, insurance companies play less critical roles compared to HUG and SK. There are several reasons, while the primary one is tied to the socio-political systems. As social welfare country, Denmark has considerable senior care already within the national care package for social and health needs, covered entirely by taxes. Insurance companies thus play a negligible role, covering mainly dentistry, hearing aids and a small part of medication. For ZZ the role of insurance companies is different, since the Netherlands has a dual-level system[9]. All primary and curative care (i.e., the family doctor service, hospitals) is financed from mandatory private insurance. But long term care for the elderly, the terminally ill, the long term mentally ill etc. is covered by social insurance. For HUG and SK, where insurance companies have a key role, it is much more important to consider insurance covered budget for prevention and treatment. Due to the societal differences, the influence of stakeholders thus differs.

Care continuum is another key factor. HUG and SK are, as mentioned above, hospitals where the elderly citizens are formally “patients”, and where more formal medical treatments and treatment related exercises are involved. Lyngby and ZZ settings are caregiving and daily care settings, where daily or weekly support and active living are central. According to the treatment stage in the continuum of care, influence and roles of stakeholders differ.

Both, informal and formal support is important in the health care setting for seniors. – Differences in the setting, however, as well as socio-political factors, and the treatment stage influence the level of importance of informal and formal support along the treatment process. Informal caregivers usually have a strong impact on the daily life of seniors while they sometimes - e. g., in the hospital use cases - have less influence on the formal treatment process. In this setting also the informal caregivers’ impact on the REACH system could be low. For example, shown in the onion diagram of HUG (Figure 9), informal caregivers are allocated outside the formal treatment process. When home care is the central care, the importance of informal care, such as meet-ups and chat with relatives and friends, was drastically increased.

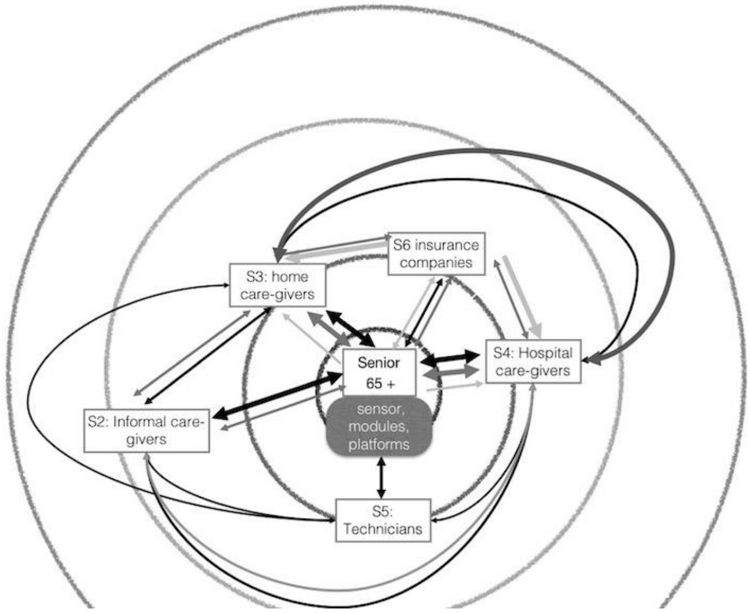


Figure 9: Onion diagram from HUG

The stakeholder analysis at the four use cases has provided interesting insights, which indicates further benefits of the REACH system and sub-systems developed for future care settings. Some stakeholders also expressed concerns which has to be taken in account to gain a high user acceptance of the REACH system.

For the primary users (elderly citizens) the main risks and drawbacks are their fear of data disclosure, and the stress associated with the use of technology. These risks are similar for relatives and friends (informal caregivers) and, to some extent, for the formal caregivers as well. For the latter group (e.g., municipality) there is the concern of being responsible for inadvertently disclosing data as well the burden on budgets of deploying and maintaining a system such as REACH. Insurers have the additional concern that they may be accused of misusing data.

The benefits for the primary users and their families and friends are the greater autonomy that the system may provide, greater independence, and self-determination. Relatives expect from the REACH system to simplify the organisation and supporting activities. For professional caregivers the improved efficiency in care (including better understanding of patient needs), more information about patients' activities or habits between treatments and visits, early warning and easier monitoring of changes in health status is more relevant. In addition to the aspects already mentioned, the REACH system should also support a smoother transition from rehabilitation hospital to home, when relevant. Finally, for insurers and funding entities the benefits rely on the prospect of getting an economically sound use of resources, lower costs due to prevention of readmission, of hospitalization, and of transition to (costly) long-term care.

The similarity of the results indicates the shared challenges and potentials across different use cases. Despite of similarities in the medical and therapeutic approach there are major differences in the healthcare eco systems in different countries. Thus, comprehensive analysis has to include both, the user-centered approach with the use cases from hospital to home care as well as the healthcare value chain perspective from business model approach[6]. Considering the target user (65 + seniors), the future REACH system and sub-systems and REACH business model will have to deal with the care level of the target user as well as societal medical settings.

2.3 Results of early trials Lyngby I and II

2.3.1 The Lyngby I early trial

There has been performed an 8 week randomized control trail in which there has been randomly assigned n=26 elderly aged 65+ to monitor vital signs such as heart rate, daily steps, sleep hours and etc. The activity levels were assessed using Pa monitor Fitbit type charge HR.

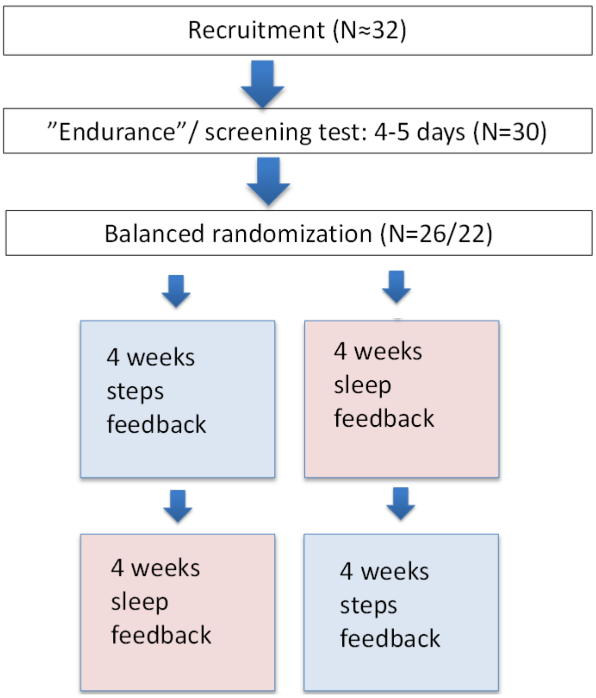
These Elderly people were recruited to the intervention through cooperation with elderly day-centers in Lyngby municipality in Denmark.

They were asked to wear the fitbit for 5 days to assess baseline physical activity level. Participants received no feedback from the armband during this period. After successfully completing the baseline measurement and signing the informed consent, eligible participants were randomized into two groups to perform cross over designed Randomized control trial.

Table 1: Overview of the trial condition

	Group A	Group B
First 4 week	4 weeks feedback on previous night's sleep	4 weeks feedback on yesterday's activity
Second 4 week	4 weeks feedback on yesterday's activity	4 weeks feedback about previous night's sleep

Table 2: Lyngby trial flow



Group A started receiving 4 weeks feedback on sleep hour and afterwards 4 weeks of daily steps count by Fitbit. Group B started receiving feedback on steps taken previous day and after 4 weeks the participant changed to get feedback on sleep hours. The aim is to evaluate the efficiency of providing feedback and whether daily feedback influence physical behavior. The secondary purpose was to examine acceptance/tolerability of wearables over time (8 weeks) by target group.

All interested participants had to sign an informed consent approved by the Medical Ethics Committee of the University of Copenhagen. The anonymity of the participants were ensured by use of coded patient identifiers (pseudonyms) in all process. Participants received fitbit with oral and written instructions for proper wear and were given the opportunity to wear and adjust the armband.

The experiment

Each day, except weekends, the participants would receive a phone call from either of the two experimenters. The objective measure for Friday, Saturday and Sunday were received Monday morning.

Depending on whether the individual was part of group A or group B the individual received feedback via phone call on amount of steps, distances walked the previous day or sleep hours and amount of weak up times for previous night.

These interventions were placed into two broad categories: self-report and objective measures.

Where the self-report part is based on telephone based coaching, depending on which intervention group the participant belong to. The participant were asked about their opinion on how active they were the day before or their opinion on how they sleep the night before. Participants were asked to rate their activity level in 3 categories, less, moderate, high.

After getting the self-report, the researchers provided the objective measures to the related participant. The objective measures were based on monitoring physical activity level by fitbit.

Every day the research assistants wrote the group's amount of steps, distance traveled and the reason for walking in a log, in the same way group B's sleep hours and their experience has been noted.

To get deeper into each individuals experiences with the tracker and opinion there have been conducted a semi-structure interview after the 8 week of intervention.

Thematic analysis were used to analyze interview transcripts.

Each transcript were coded independently by two research assistant, who subsequently has to come to an agreement to interpret a single coded version of each transcript.

Data Preprocessing

Raw data gathered from fitbit has a certain degree of erroneous, redundant information that caused by discharged batteries, and sync problems. To compensate for these effects, a data cleaning process were conducted, where only samples with complete outcome data were included in the analyses. To ensure complete outcome data, all steps measures were compared with heart rate data. Days within more than 4 hours of missing data was excluded from the analysis. In addition, subjective reports about weekends are not taken into account. Since many of the elderly indicated, that they cannot remember, their activity level for 3 days ago.

Analysis

The PA outcomes being studied are activity level in terms of steps. A primary comparison is between the PA outcome of participant from first 4 week, who started receiving feedback on previous day's physical activity and the second 4 week who started receiving feedback on previous night's sleeping hours.

We hepatize that receiving feedback on activity level will increase physical activity level compared having no feedback (during the weeks where sleep hours were measured).

The sample consisted of 26 participants, whose age ranges from 65 to 95. The average age was 85 and 73% of the participants were female.

Table 3: Result of Lyngby early trial

Mean daily steps	Min. age	Mean age	Max age
2930	71	86	94

Four participant (15%) withdrew from the trial within the first week: 2 person withdrew due to ill health and 1 due to privacy reason, the other 1 participant gave no reason. 22 participants remained in the study. The characteristics of the remaining 22 people (mean age: 86, 18(73%) females). About 11 persons (50 %) of participant were using walkers.

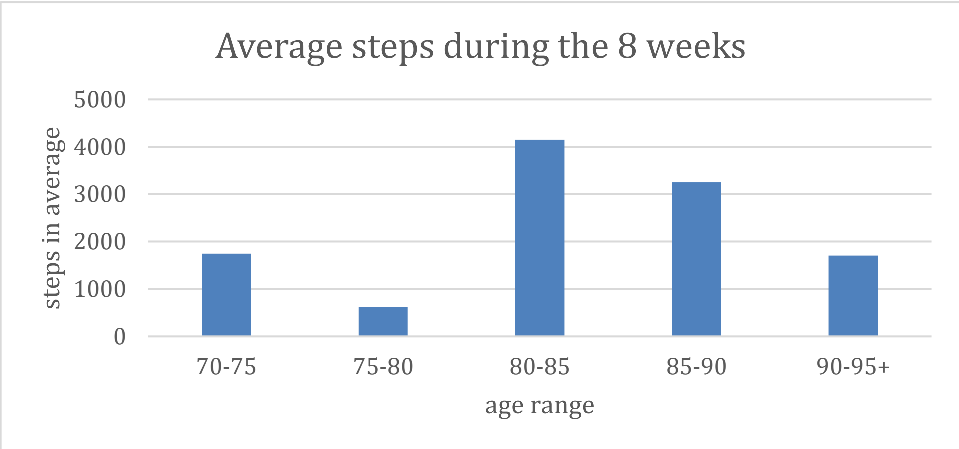


Figure 10: average steps during the 8 weeks per age group

The aged range of most active participant was between 80- 90 year, with 4150 average numbers of steps during the 8 weeks.

Our first objective was to examine whether receiving feedback on physical activity level would increase the activity. To answer this research question we compared daily average steps from the first 4 weeks where participant were blinded to feedback with the second 4 weeks where participant got feedback. As part of main objective we also want to examine whether providing feedback leads any behavior change. Such as stage of motivational readiness for Physical activity.

To evaluate the effect of providing feedback, spearmen's Rank correlations were used to calculate the relationships between the objective measurements and self-reported measures.

All Physical activity data collected by Fitbit were averaged to yield an average daily value. Average steps per day were calculated to estimate average daily activity level for the 4 week were participant were blinded for feedback and the 4 weeks where participants got feedback. The daily average steps of group 1 during the 4 weeks provided feedback was 143, which decreased with 8 steps in avg. to 135 during the second 4 weeks. The daily average for group2 during the first 4 week (no feedback) were 123 and increased with 9 steps to 132 after the second 4 week.

The overall average activity level of the 22 participant, time ordered during the 51 day is illustrated in the graph below.

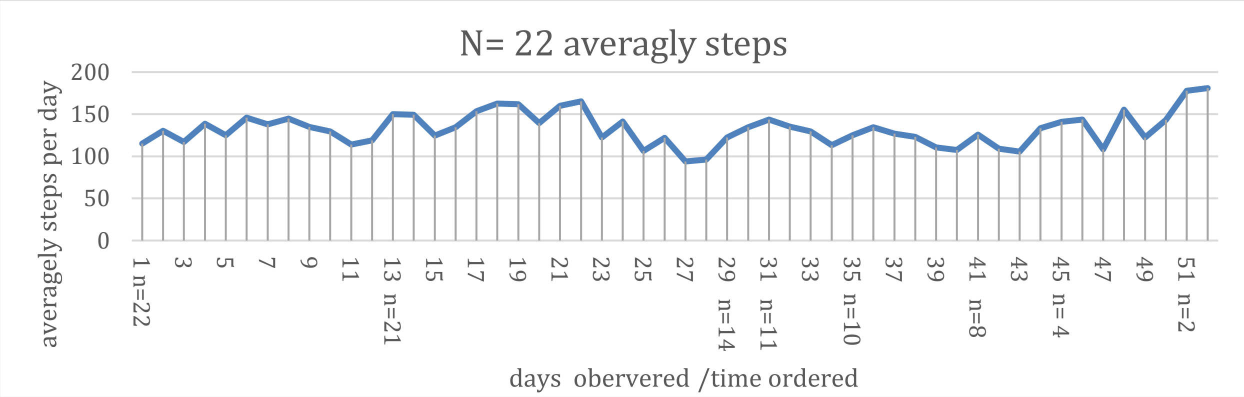


Figure 11: The average daily steps of all 22 participant, time ordered, from day 1 n= 22 to day 51 n=2

Comparing the average daily steps during trail with average steps at baseline (2998-2896=103 steps). There is 3.44 % increase to baseline. Comparing the mean steps per day for the first 4 week with second 4 weeks showed, no significant difference between those two means.

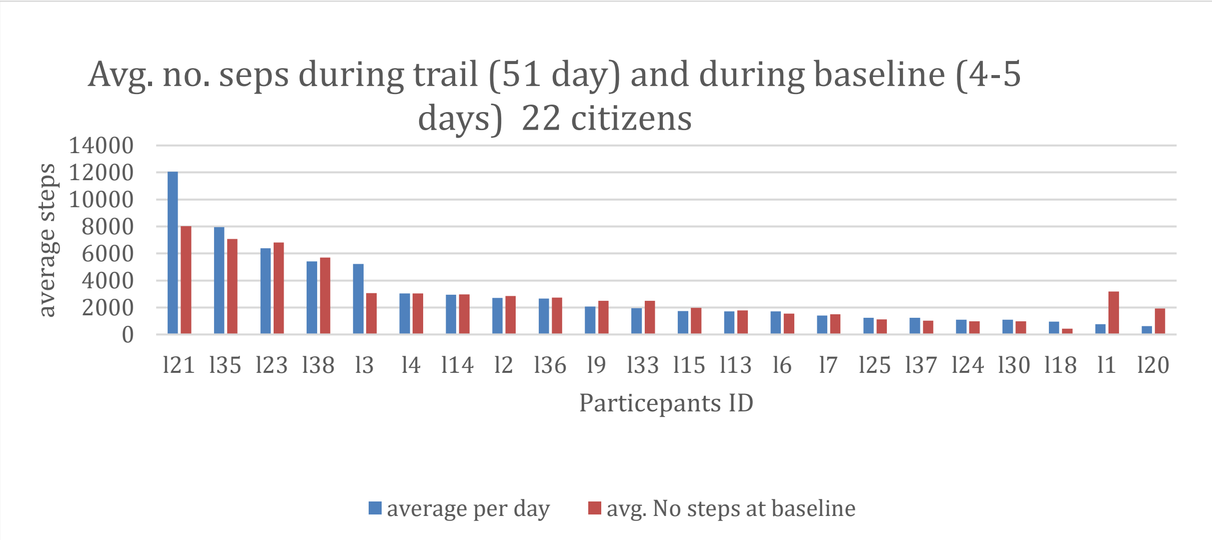


Figure 12: Avg. no. steps during 8 weeks, and avg. no. steps during baseline (4-5 days)

The overall results, correlation coefficient =0,0093 from the trial indicates that no correlation was observed between self- report and objective measures. Furthermore a chi-squared test was used to assess associations between Self-rated activity level and actual activity measurements. The Chi-squared =3,563, df=4, p=0,4 indicates no correlation between the objective measurements and self-related report. The result indicated that elderlies are misperceiving their activity level, by underestimating it; rating their activity level lower “less active”.

Getting insight into the average daily steps of the most active and less participant, the average daily steps of most active participant was 520. And the average of less active participant was 39 steps. The graph below illustrates the activity pattern of most and less active participants.

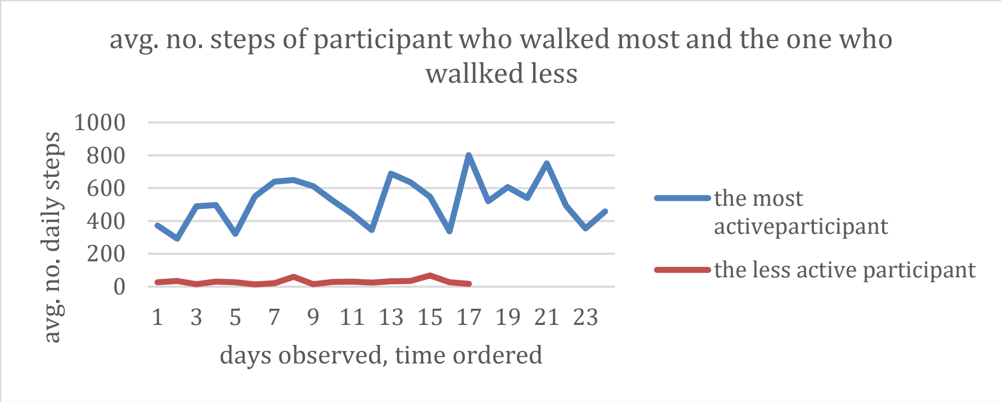


Figure 13: Avg. No. steps of participant who walked most and the one who walked less during the trial

Our second objective was to find out whether monitoring tracker such as Fitbit is accepted by elderlies. This research question is answered in section 4.1

Furthermore to evaluate our research objectives deeper, a semi structure interview has been conducted.

The interview was designed to include themes that shed light on use of technology that could support activities of daily life, personal health or safety, physical activity and personal development.

Among the 22 participant 11 (50%) participant indicated, that they spontaneously felt motivated and become more physically active and walked more by participating in this experiment because of the feedback about yesterday's activity level. 4 of these were using walking frames and the rest motivated participants were not. It is noticeable to mention, even thought, they are saying that there were motivated to walk more, but the objective measurements indicates no significant increases.

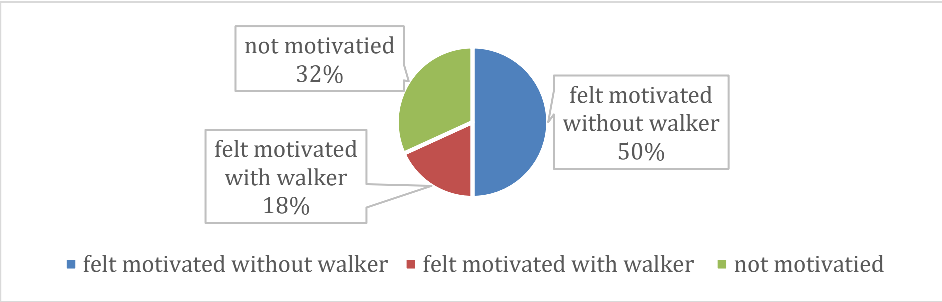
There are varieties in the answers. Some indicated, that daily telephoned based feedback, have been motivated factor in setting specific goals. IT has worked as kind of behavior strategy that made some participant to effectively change or consider change behavior pattern.

Furthermore the participant's opinion on social interaction and the influence of their friends on their motivation to be active has been asked. Among the 21 participants, 6 person indicated that comparing their daily results will have a motivational effect.

The participant appreciate that wearable activity tracker and means that it has improve self-awareness.

Discussion

Comparing daily average steps from the period where the elderlies were blinded for feedback with the second period where the elderlies got feedback, there are no significant increase in the objective measure in term of numbers of steps. That means that providing feedback have no influence on the numbers of steps thus no increase in numbers of steps are observed. But Our study shows that, when people are being measured, they become more self-conscious about the behavior. As it is shown in the table Table 4, 50% of the individuals felt spontaneously motivated to become more physical active [interview].



Furthermore the individuals rated themselves less active in the self-rated reports. Thus we observed no correlation between self-rated reports and objective measures. An alternative explanation for this discrepancy may be that the elderlies have misperceived their activity level by underestimating the intensity of their activities over 8 weeks. Which is in contrast with most of studies about older adults. Most of studies indicate, that elderlies are overestimating there activity level. Which indicated elderlies' lower intension to change physical behavior and false sense of their Physical activity level (Godino J. G., et al., 2014) , (Lechner, Bolman, & Van Dijke, 2006) (Ronda, Van Assema, & Brug, 2001) (Godino J. G., et al., 2013) (van Sluijs, Griffin, & van Poppel, 2007)).

In addition a semi-structure interview was conducted to get deeper insight into elderly's perception of their activity level over the 8 monitoring weeks. What the interviews indicates is that providing feedback increase awareness. It is thus possible that participant may have become aware of their activity level, they become more self-conscious about the behavior and therefore perceived and rated their activity level low. This means that the elderlies are recognizing a need to increase their activity level. The RTC somehow have impact the elderly's intention to change their behavior.

Thus, it appears that we have dissociation between the "felt motivation to walk" – the subjectively felt inclination to engage in additional walking – and the actual walking.

The other 32% participant who felt not motivated were those who suffers physically dishabilles that prevents them to walk. Even though they are aware that they walk less, but they cannot do anything due to their physical health problems. As Cohen- Mansfield noted, this research also indicates that the barriers to promote physical activity in elderlies, are highly related to motivators for example, deteriorating health, which can reduce an older adult's ability to walk more (Cohen-Mansfield, Marx, & Guralnik, 2003). Our findings are in line with Brubaker et al. findings, that say: being aware of being reassessed motivates individuals to consider change in behavior (Brubaker, Rejeski, Smith, Lamb, & Sotile, 2000)

Like Kang et. al our study indicates that the use of pedometers and providing feedback has a moderate and positive effect on the intention to change the behavior. Although we observed no increase in numbers of steps in our objective measures, but this may explain the reason for elderlies' underestimating of their physical activity level in self-reported measures (Kang, Marshall, Barreira, & Lee, 2009).

Furthermore our results are in line with Godino, weather or not feedback on PA stimulated behavior change. Godino found that the providing feedback about physical activity level was not associated with changes in activity level but it may increase awareness of behavior(Godino et al., 2013).

Conclusion

The study investigated change in activity level using objective measures and coaching/providing feedback on PA. The Randomized control trail, did not observed any significant increase in average daily steps between the first and second 4 weeks. Based on that, we conclude that providing feedback has no short term effect on physical activity level. But it indicate receiving feedback could work as kind of indicator that motivates individuals to consider behavior change in long term. As the elderlies are underestimates their physical activity level, it might create a sense of awareness. Like Godino, we also conclude that feedback may increase awareness of behaver, but it is not sufficient to change behavior in the short term; It might affect intentions to change behavior in long term.

Our second objective was to examine the acceptability of the monitoring device by elderlies. The results of this objective is concluded in Section 4.2.

2.3.2 The Lyngby 2 early trial

The Lyngby 2 trial was conducted April-July 2017. This was a feasibility study, in preparation of the planned Lyngby 3 trial, and involving 10 elderly participants engaging in playful exercise and from whom movement tracking data were collected throughout the day over 8.

First we summarize the protocol and next we provide a summary of results of measurements.

<u>Test Protocol</u>

Table 5: Test protocol

Type of experimental design	Cohort study. Feasibility study wrt. logistics of recording simultaneously physical activity via Fitbit tracker, Sens tracker and (during play/exercise sessions) Moto tiles,
Number of participants / power calculation	Participants recruited and screened (5 days wearing a Fitbit and a Sens patch) until 10 eligible persons have been recruited. No power calculation made.
Purpose of test	Primary purpose is to examine to what extent playful physical exercise of older (65+) citizens: a) is accompanied by changes in non-training physical activities b) is accompanied by changes in measured performance during playful exercises Secondary purpose is to: - estimate the variation over time of physical within and outside, respectively, of training sessions

	- whether activity trackers (Fitbit and Sens patch) as a monitoring technology are perceived as acceptable by users - whether training on Moto tiles is adhered to and is perceived as acceptable by users over an 8-week period - correlations between registration of activity by Sens patch and Fitbit
Short description of test	A cohort of 10 elderly Lyngby citizens will be divided into two teams of 5 persons. Each team will engage in 1 hour of playful activity session twice a week at a municipal center. For each session, led by Moto play master, each team member will engage in 12 minutes of activity divided into 2-minute exercises. The experiment will run for 8 weeks, so each participant will have 16 sessions. During the test participants will wear two types of activity trackers: Sens patch and Fitbit Charge HR that measure physical activity (steps: per minute/hour/day), sleep durations and heart rate. Tracking data will be uploaded from the trackers to a smartphone in participants' home. Data upload will be monitored at DTU and if data connection is lost, the analysis team will make a phone call and, if accepted, a visit to reestablish data collection.
Demographics of test persons (age group, health/mobility status ….)	Inclusion: Citizens aged 65+ at Lyngby activity center. Exclusion: Dementia or mental incapacity preventing participants from understanding simple instructions; Much reduced vision Inability to maintain a standing position either alone or with the use of support; Participation in a physical rehabilitation program.
Planned start and finish dates (approx.)	Recruitment and screening: ASAP Start and end dates: Middle of May – Early July 2017 Duration: 1 week screening followed by 8 weeks of sessions and tracking.
Sensors and equipment to be used	Fitbit Charge HR; Sens patch; Smartphones to pick up and transmit data, MOTO Tiles to actively engage the elderlies
Specific conditions to be detected/recorded	Semi-structured interviews of each participant after trial to elicit attitudes and experiences (privacy; motivation; personal acceptance; usability).
Data collection, storage and processing approach	Anonymous Fitbit and Sens patch accounts accessed and downloaded to proprietary secure database at DTU server (with access log) collecting data from Fitbit, Sens and Moto.tile activity. Data pseudonymized (personal data kept in separate system, deleted by the end of 2018).
Ethics application necessary	Ethics approval (personal data registration for research purposes) obtained via DTU Data Registration Board (03/05/2017)

Potential risks/harm to trial participants. Insurance issues	Risk of privacy violation controlled by: (i) strict data security protocol of DTU (ii) informed consent procedure (iii) detailed written and oral instructions to staff involved Risk of minor discomfort of wearer due to rubber bracelet Risk of falls and strains during engagement in "dancing" –supervised by play master assisted by nurses/physiotherapists.

The setting for testing was that each participant was asked to come at a certain timeslot. The testing was done in this order: Chair Stand, Timed Up and Go, Bergs Balance Score and then 6 Minutes Walking Test. The participants were instructed on what was to be done, what the goal of the project was and why they were being tested. Further they were told that they could always so no to any test and that they should only do it if they felt confident. Two testers were present at the testing to support and help in the harder parts of the tests.

Tests performed

The first three are from the Senior Fitness Test. This test is developed to measure if community-dwelling elderly are in risk of functional decline (see (Rikli & Jones, Development and validation of a functional fitness test for community-residing older adults, 1999) (Jones, 2002) (Rikli & Jones, Senior fitness test manual, 2013)). The last is a **

Timed Up and Go (TUG)

The TUG test used to both speed, agility and balance of the participant. The test is performed in these steps (see description also in (Rikli & Jones, Senior fitness test manual, 2013)):

1. The participant is sitting with the hands on the thighs and the feet flat on the floor. One foot is placed a bit ahead of the other to be ready to rise and walk.
2. A marker (cone or other) is placed on the floor 3 meters from the chair.
3. The tester will start the stop watch on the word "go" and on that signal the participant has to stand up, walk, around the marker on the floor, go back to the chair and sit down. The participant should walk as quickly as possible, but making sure to be secure in the movements. The time is stopped when the participant is sitting firmly down on the chair.
4. The participant is allowed to press on the thighs, but not use the hands on the chair when rising.
5. The best out of two tries are recorded.

As modifications in the Lyngby II, the particants where allow to use the hands to get up, as they were unable to stand otherwise.

Chair Stand (CS)

The CS test is used to measure the strength in the lower body. The test is performed in these steps (see description also in (Rikli & Jones, Senior fitness test manual, 2013)):

1. Place a chair against a wall to secure it will be stable
2. The participant is sitting with a straight back in the middle of the chair with the feet shoulder width apart, flat and firmly placed on the floor.
3. The arms are crossed and placed on chest

4. The participant is asked to rise to a full stand (no bent knees or the rise does not count), and sit again as many times as possible within 30 seconds.

Modifications in the Lyngby II:The participant is not supposed to use the hands or touch the back. During our pilot, this was not possible, so they were allow to use the hands to get up, but still had to get to a full stand.

6 Minute Walking Test (6MWT)

The 6MWT is used to measure aerobic capacity and endurance. The test is performed in these steps (see description also in (Rikli & Jones, Senior fitness test manual, 2013)):

1. A 45.7 meters (50 yards) course is setup.
2. The participants are asked to walk around the course for 6 minutes. The tester notes how many meters is walked.
3. If the participant needs a break this is allowed, but the time keeps on going.

Modifications in the Lyngby II: The test course was adjusted to the length of the backyard of the activity center (76 meters).

Bergs Balance Score

The Bergs Balance score was developed to create an appropriate measure of balance for elderly individuals (Berg K. W.-D., 1989), (Berg, Wood-Dauphinee, & Williams, 1995). It consists of 14 different tests that reflects movements in everyday life. In each of the tests the participant is getting a score from 0 to 4 dependent on how they perform the test, if they need support or similar. The 14 tests are (see attachment):

1. Sitting to standing: Getting up from a chair, preferably without using the hands.
2. Stand unsupported: Able to stand unsupported for 2 minutes.
3. Standing to sitting: Sitting down again.
4. Sitting unsupported (if they are able to do test 2, then they get full score here without doing it). Sitting on a chair with back support for 2 minutes.
5. Transfer from one chair with armrest to one without (or a bed). Move from the chair to a bed or unarmed chair placed in 90 degrees angel from the chair. And moving back again.
6. Stand with closed eyes. Standing for 10 seconds with the eyes closed.
7. Stand with feet close together. Placing the feet next to each other, standing for up to one minute.
8. Reach forward with stretched arms. See how far the participant are able to reach forward.
9. Pickup object from the floor. Picking up a shoe from the floor.
10. Turning the body and looking backwards. First turning the trunk and looking to the left then to the right.
11. Turning 360 degrees. Turn all the way around first one way then the other way.
12. Stool stepping. Placing one foot on a stair tread changing to the other foot until each foot have touch the stair tread 4 times.
13. Tandem standing. Standing with one foot in front of the other for up to 30 seconds.
14. Standing on one leg. Standing unsupported on one leg for up to 10 seconds.

Modifications in the Lyngby II:Not many modifications, as any problems are showed in the scoring. But none of the participants was able to place the feet together, all had a small distance between them.

Tests results

Each participant was test before and after the intervention. The results are summarized in this table:

Table 6: Before test scores

Participant number	Year born	**Pretest dato**	TUG	Chair stand	6 MWT	Bergs score
100	1927	**17/05/2017**	10,14	10	300	42
103	1927	**22/05/2017**	12,98	7	Did not attend	37
104	1933	**16/05/2017**	18,8	5	208,5	30
105	1933	**22/05/2017**	18,72	3	150	22
106	1940	**17/05/2017**	25,53	6	185,5	21
107	1944	**16/05/2017**	11,39	0	390,5	36
108	1924	**22/05/2017**	9,97	11	293	45
111	1931	**17/05/2017**	22,26	5	154	24
114	1951	**15/05/2017**	33,51	3	256,5	35
115	1932	**22/05/2017**	20,51	0	75	16
116	1930	**19/06/2017**	15,54	6	245,5	8

Table 7: After test scores

Participant number	**Post test date**	TUG	Chair stand	6 MWT	Bergs score
100	**27/07/2017**	8,21	13,00	343,00	50,00
103	**27/07/2017**	15,35	6	Did not attend	32
104	**27/07/2017**	19,58	5	210,5	44
105	**28/07/2017**	16,21	5	190	39
106	**28/07/2017**	21,95	8	286,5	36
107	Did not attend	Did not attend	Did not attend	Did not attend	Did not attend
108	**27/07/2017**	8,22	13	342	50
111	**28/07/2017**	20,77	8	169,5	42
114	Did not attend	Did not attend	Did not attend	Did not attend	Did not attend
115	**27/07/2017**	16,26	0	Did not attend	37

116	**28/07/2017**	15,04	8	228	16

Table 8: Differences in before and after scores

Participantnumber.	TUG	Chair stand	6 MWT	Bergs Score
100	1,93	3	43	8
103	-2,37	-1	Did not attend	-5
104	-0,78	0	2	14
105	2,51	2	40	17
106	3,58	2	101	15
107	Did not attend	Did not attend	Did not attend	Did not attend
108	1,75	2	49	5
111	1,49	3	15,5	18
114	Did not attend	Did not attend	Did not attend	Did not attend
115	4,25	0	Did not attend	21
116	0,5	2	-17,5	8

Results

The test scores were analysed using paired T-test. The results can be seen in table 9 to 10:

Timed up and go

The data here shows that the participants had a mean improvement of 1.43 seconds in the test from pre-to post testing. This is to be understood as the participants being 1.43 faster to stand up, walk around the cone and siting back down again. The 95% confidence interval shows that the improvement is between -0.16 and 3.02 seconds.

Paired t test

Table 9: Paired t test of Timed up and go

Variable	Obs	Mean	Std. Err.	Std. Dev.	95% Conf. Interval	
preTUG	9	17.16111	1.800794	5.402382	13.00847	21.31375
postTUG	9	15.73222	1.637218	4.911654	11.95679	19.50765
diff.	9	1.428889	.6900713	2.070214	-.1624185	3.020196

mean(diff) = mean(preTUG - postTUG) t = 2.0706

Ho: mean(diff) = 0 degrees of freedom = 8

Ha: mean(diff) < 0 Ha: mean(diff) != 0 Ha: mean(diff) > 0

Pr(T < t) = 0.9639 Pr(|T| > |t|) = 0.0722 Pr(T > t) = 0.0361

6MWT

The data here shows that the participants had a mean difference of -33.3 meter in the test from pre-to post testing. From this we can see that the participants were able to walk 33.2 meters longer within the 6 minutes after than before the intervention. The 95% confidence interval shows that the improvement is between -68.8 and 2.23 meters.

Paired t test

Table 10: Paired t test of 6MWT

Variable	Obs	Mean	Std. Err.	Std. Dev.	95% Conf. Interval	
Pre6MWT	7	219.5	23.37887	61.85467	162.294	276.706
Post6MWT	7	252.7857	26.95474	71.31553	186.8298	318.7416
diff.	7	-33.28571	14.51266	38.39689	-68.79692	2.225489

mean(diff) = mean(pre6MWT - post6MWT) t = -2.2936

Ho: mean(diff) = 0 degrees of freedom = 6

Ha: mean(diff) < 0 Ha: mean(diff) != 0 Ha: mean(diff) > 0

Pr(T < t) = 0.0308 Pr(|T| > |t|) = 0.0616 Pr(T > t) = 0.9692

Chair stand test

The data here shows that the participants had a mean difference of -1.44 stands in the test from pre-to post testing. This is to be understood as the participants being able to perform 1.44 more stands after the intervention than before. The 95% confidence interval shows that the improvement is between -2.54 and -0.35 stands.

Paired t test

Table 11: Parited t test of Chair stand test

Variable	Obs	Mean	Std. Err.	Std. Dev.	95% Conf. Interval	
PreChairStand	9	5.888889	1.111111	3.333333	3.326662	8.451116
PostChairStand	9	7.333333	1.354006	4.062019	4.210989	10.45568
diff.	9	-1.444444	.4746669	1.424001	-2.539028	-.3498607

mean(diff) = mean(preChairstand - postChairstand) t = -3.0431

Ho: mean(diff) = 0 degrees of freedom = 8

Ha: mean(diff) < 0 Ha: mean(diff) != 0 Ha: mean(diff) > 0

Pr(T < t) = 0.0080 Pr(|T| > |t|) = 0.0160 Pr(T > t) = 0.9920

Bergs balance scale

The data here shows that the participants had a mean difference of -11.22 points in the test from pre-to post testing. This is to be understood as the participants getting a better score of 11.22 points in the Bergs Balance Score test from before to after the intervention. The 95% confidence interval shows that the improvement is between -17.42 and -5.03 points.

Paired t test

Table 12: Paired t test of Bergs balance scale

Variable	Obs	Mean	Std. Err.	Std. Dev.	95% Conf. Interval	
PreBergs	9	27.22222	4.098705	12.29612	17.77059	36.67385
PostBergs	9	38.44444	3.464547	10.39364	30.45518	46.4337
diff.	9	-11.22222	2.686271	8.058812	-17.41677	-5.027671

mean(diff) = mean(preBergsscore - postBergsscore) t = -4.1776

Ho: mean(diff) = 0 degrees of freedom = 8

Ha: mean(diff) < 0 Ha: mean(diff) != 0 Ha: mean(diff) > 0

Pr(T < t) = 0.0015 Pr(|T| > |t|) = 0.0031 Pr(T > t) = 0.9985

Conclusions on the data and analysis

The analysis shows promising results that should be investigated further which is also planned in the upcoming study Lyngby III. The Bergs Balance Score and the CS test shows most promising results, while also TUG and 6MWT show improvements worth further investigations.

3 Requirements of care givers

3.1 Rehabilitation in clinical setting HUG and SKBA

Rehabilitation aims at reducing the impairment and handicap of patients/elderly and thus improving their independence from care givers. The treatment goal is to relearn prior abilities by performing preparatory exercises and actually practicing these abilities. Motivation and behavior changes are important elements in successful rehabilitation. The future REACH system will use motivational and persuasive techniques to promote physical and cognitive activity, and to induce health behavior patterns.

Due to the limited financial and personnel resources a system is needed to increase the efficiency of rehabilitation treatments and therapies. As part of the system a functional and supportive environment will motivate the patients to make healthier decisions (e. g. food, exercises, smoking), practice in a target-oriented manner without therapeutic support, and keep track of their progress. Devices included in such a system could be functional furniture, ambient and wearable sensors, and mobility devices.

The following functions should be covered:

Functions/capabilities:	**Examples:**
Early detection/prediction	Detects decrease in health status (e. g. balance problems, inactivity, malnutrition, sleeping disorders)
Motivation	Motivates to perform health activities and to participate in therapy sessions; gives positive feedback
Intervention	E. g. furniture components (bed + bed periphery + mobility device) allows seamless indoor mobility; a large screen in the patient room provides training instructions and infotainment; system sends information to the care giver to indicate (possible) critical events (e. g. decubitus, falls, depression)

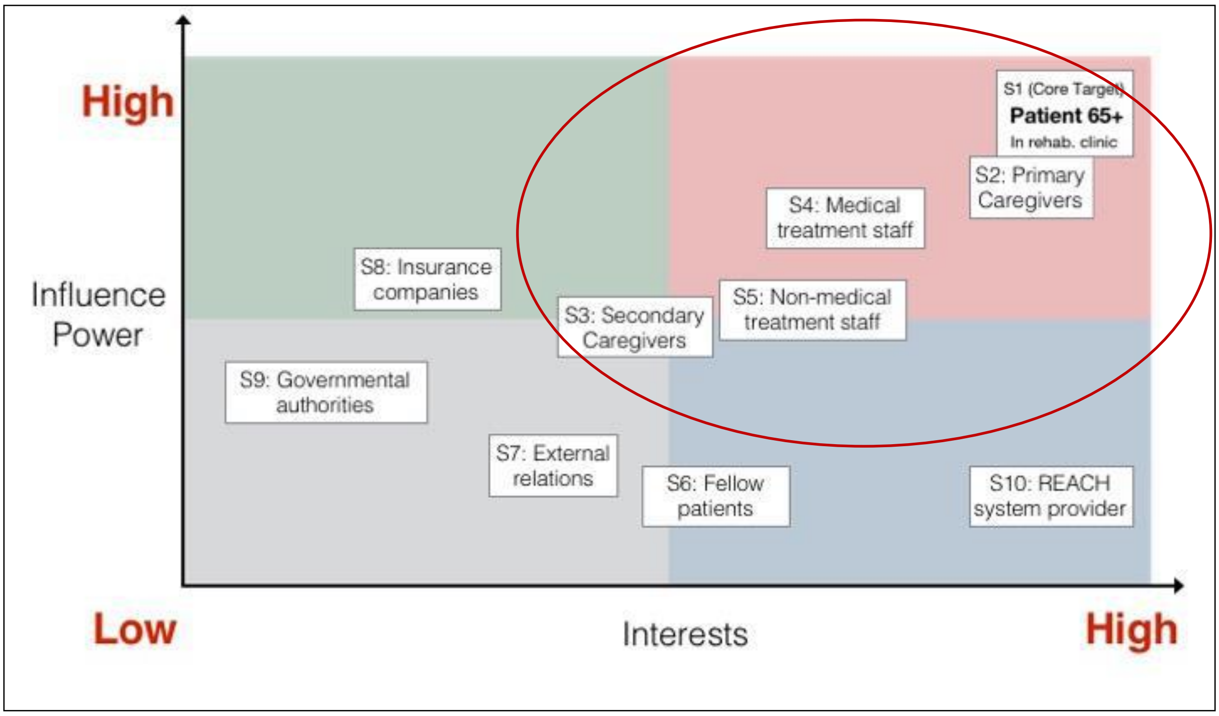


Figure 14: Stakeholder matrix: Influence and interest of stakeholders in the rehabilitation setting

The stakeholder analysis revealed that primary and secondary care givers, and medical and non-medical hospital staff are stakeholders with very high influence power and interest during the rehabilitation process. The patient himself is the stakeholder with the most influence and interest, therefore the core target of the REACH system. In the following the roles and requirements of these key target group will be described.

To describe the requirements of care givers, we will start by presenting Mr. Autumn's journey from hospital to home, with his different stakeholders, while using the REACH system.

Following his cerebral ischemic stroke, Mr. Autumn underwent surgery and had to stay three weeks at the hospital. The first days at the hospital were gloomy. Mr. Autumn was afraid to not be able to use the right part of his body anymore. But a few days later, he started to have a light physical session with his physiotherapist. The physiotherapist used REACH equipment to help him do the exercise in a safe setting, to ensure that he will not fall and to make him confident in being able to do the task. Every day, Mr. Autumn's progress and his vitals were monitored by the system in real time, so that the physiotherapist could help him immediately adjust the exercise if needed. In the beginning, the doctors and the nurses came every day to check on his health status and the evolution of his vital parameters. He also had a daily session with the physiotherapist using the REACH equipment, where he was assisted while performing the exercise. After a week, Mr. Autumn were asked to do the exercise alone, at the hospital, using the equipment. The physiotherapist introduced to him a new way of exercising while playing a game on the screen and gave him a certain score to reach on the game. As he got used to play the game and do the required exercise, the physiotherapist wanted in a second phase to use the REACH system to check whether Mr. Autumn were doing the exercise correctly or not. Through the system, Mr. Autumn could see in real time if he must repeat or correct a motion. In a third phase, the physiotherapist and the doctors wanted to see, if performing the daily exercise has improved Mr. Autumn's health and autonomy while staying at the hospital. Through the history from the REACH system, they could see that his vitals were more stabilized and that Mr. Autumn became more active. If in the beginning, he was sitting or lying in bed all day, his intelligent sensors showed that he is doing a lot more steps. The systems also measured his stress level to help the doctors see if Mr. Autumn is confident enough to go back and continue the recovery at home.

After three weeks, Mr. Autumn went back home equipped with the REACH system. Although, he was away from the hospital, the doctors and the physiotherapists wanted to receive every day, all his vital parameters, his health status and his physical activity during the first days back home, so that the system would alert them if anything was abnormal. The system would allow the doctors and the physiotherapists at the hospital and the caregivers who comes every day at Mr. Autumn house to exchange information about his health evolution. After some days, Mr Autumn was encouraged through different gamification techniques to use the equipment to do physical exercise in a safely manner. All of his activity was monitored, analyzed and then transmitted to his caregivers in order to detect a potential fall or a deterioration of his health. The physiotherapists and the doctors could congratulate him through the system when he was following correctly their recommendation. Depending Mr's Autumn's need of care, the system could notify the corresponding caregivers who can come and help him if needed. Mr. Autumn's daughter was happy to be able to follow her father's health evolution through the REACH system. Being able to check on his vitals, activity, mood, and nutrition in real time, she felt more at ease and less worried when she was not with him.

List of requirements HUG

From this experience mapping, we produced the following table to summarize the potential care givers' requirements from the REACH system to ensure a correct rehabilitation in clinical settings.

Table 13: The potential care givers' requirements from HUG

Location	**Requirement**
Hospital	Equipment safety
	Real time vitals monitoring
	Real time activity / exercise monitoring
	Health progress monitoring
	Activity progress monitoring
	Real time adjustment of the exercise or treatment
	Independence while doing the exercise
	Exercising in a fun way
	Being able to set a goal/score to reach through the system
	Being able to check in real time if the exercise is done correctly

	Monitor his mood and stress level
Home	Receive daily his vitals, health status and physical activity record
	Receive an alert if there is anything abnormal
	Exchange information with different caregivers / stakeholders
	Motivate and engage elderly in doing the recommended exercise (through gamification or other motivation techniques)
	Keep the elderly safe while doing the exercise
	Continuously monitor his daily activity and health parameters and receive an analysis that will allow to predict if a fall or health deterioration may occur
	Congratulate the elderly when he is correctly following the recommendation
	Notify the corresponding caregivers depending on the situation
	Follow the elderly's daily life and health evolution in real time

3.2 Care givers in activity centers for the elderly

3.2.1 Lyngby activity centers for the elderly

Two semi-structured focus group interviews were performed. The first were with 4 care givers at an activity center, the second with a leader and nurse from the home care for community-dwelling older citizen.

The interviews had a focus on the requirement for a system that monitors and reports on community-dwelling older adults. During the interviews, the participants both explained the current practice, the possibilities of future systems and the requirements for it to be useful in their daily practice.

The overall structure in the Danish system is that in order to either participate in activities at the activity center or receive home care, the citizens needs to be referred by the municipality. This starts with either the citizens own doctor, the hospital or sometimes family contact the municipality an inform of important changes that indicated the citizen needs extra care or should attend the activity center.

Once the citizen is referred by the municipality the activity center or the home care "diagnose" how much and what kind of need the citizen should receive. It is these diagnosed citizen that is the focus of this study.

Results

The care givers at the activity center arrange different kinds of activities for the participants ranging from teaching iPad use, knitting, reading circles, singing and gymnastics. The participants come one or more times a week depended on the needs they have. Each participant can only have one session (1 hour) of gymnastics each week, as the session are very popular. They have good contact with the home care givers and the check the journals of the participants on a regular basis (indicated that they do it every day). They pointed out, that they would like to receive information regarding the activity levels and changes of the participants at the center, so they could talk with them and maybe nudge them to be more active or investigate reasons for changes in the daily contact with them.

Regarding the requirements for a system the care givers would like a system that could inform them of important changes, but it should be easily accessible, as they have limited “planning time”. A system that notify them whenever they certain events happen would be preferred. They have no other requirements, but expressed interest in the possibilities of having more information about the elderly and their activity levels.

3.2.2 ZuidZorg activity centers for the elderly

ZuidZorg is a major home care institution in the southeast of the province of North Brabant, known in Europe as the Brainport region. The area of ZuidZorg is approximately equal to the Brainport region. This has been a great source of food for a unique form of collaboration, better known as Triple Helix.

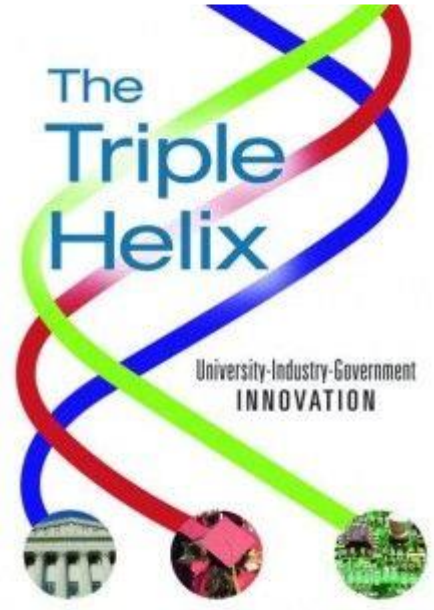


Figure 15: The Triple Helix

The Triple Helix of university-industry-government relations is an internationally recognized model for understanding entrepreneurship, the changing dynamics of universities, innovation and socio-economic development. Triple Helix is a model of managing interactions among universities, business and government on common projects.

With the TU/e and industries, ZuidZorg has built up an intensive cooperation relationship in recent years. This causes cross-pollination in many areas. ZuidZorg Extra is the member organization of ZuidZorg and has about 50,000 families who are members. Most members are middle aged or older. In our mission and vision, we have focused the aging of the human being, emphasizing vulnerable and lonely elderly. In our Meet and Greet centers we express this. These are low-threshold centers where we invite elderly people to come for a chat, coffee, lunch, participation in a social activity or sport on a low level.

The guiding principle is to come together, be together and stay together. The first and largest *Meet and Greet center* now exists over 2 1/2 / year and we receive an average of 200 unique people each week. At the start of REACH, we have made an inventory of our guests and use of interviews, scores on the Tilbury Frailty indicator (TFI) client journals, personas made, which are further used at the start of WP XXX.

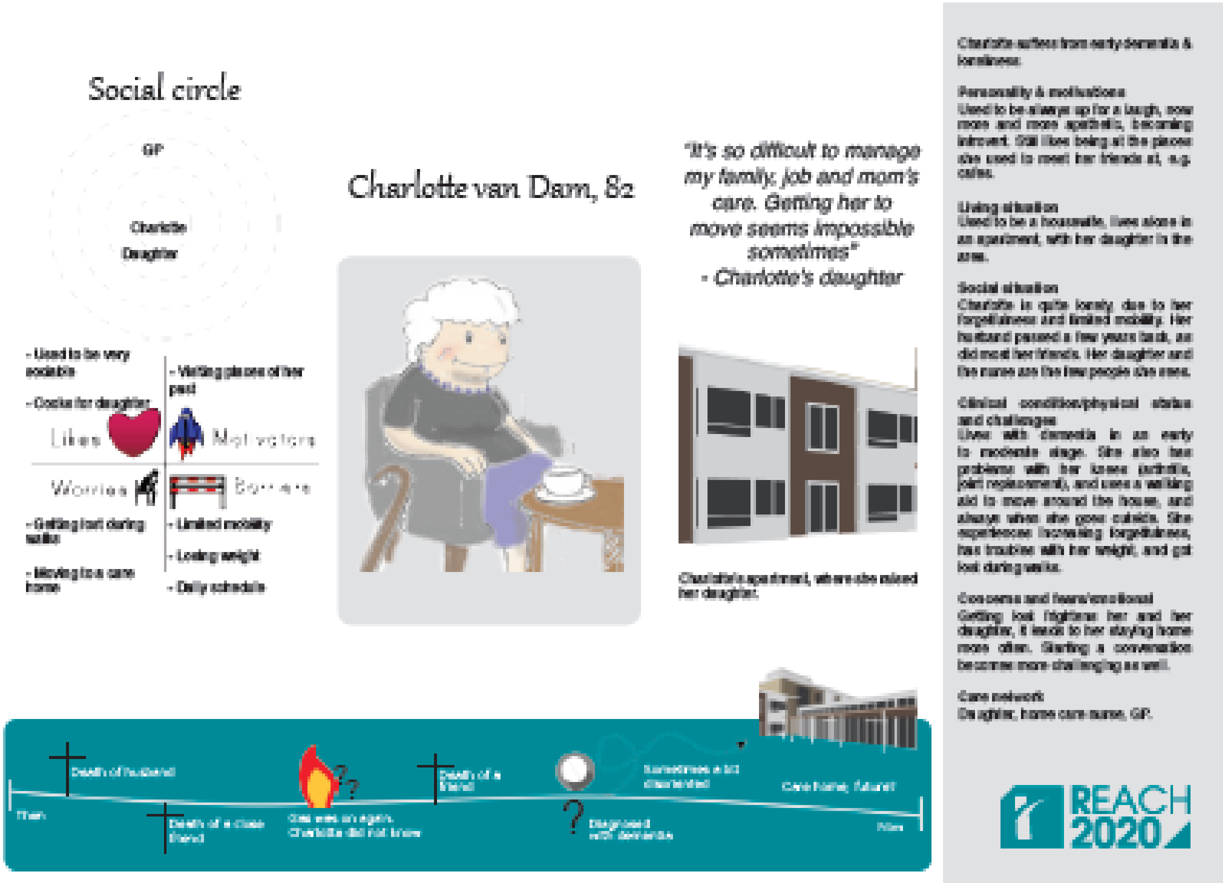


Figure 16: Meet and Greet Centre in ZuidZorg.

In fact, there is only one formal healthcare provider attached to an Meet and Greet center. It is mainly working with volunteers. ZuidZorg has trained these volunteers and the volunteers will learn how to cherish the HEART principle (*Van Harte* in Dutch). Van Harte is an acronym in Dutch, which is best described as *you are very welcome, you are our guest, we welcome you from my heart, we will give you attention, we treat you with respect and we give you a home feeling and we hope you get energy*.

Figure 17: Workshop with the elderly

Our volunteers are mostly people, who once received care or social care in the past one way or the other. Some came ZuidZorg as vulnerable elderly themselves and others came as volunteers. There are some elderly who took care of their beloved partner with us as volunteers, and later their partners were admitted to a nursing home or passed away, then they continued to be at ZuidZorg as volunteer. Furthermore, of course there are the many university students, high School students and secondary education students. They are only available virtually due to their studies, however, they are occasionally willing to give hands for help when ZuidZorg holds big events. From time to time, professionals are hired for the sporting activities.

With the wide varieties of activity offerings, there are something suitable for each guest. The activities range from knitting, baking cookies, cooking, hiking in the neighborhood, moving and sporting, board games, using ipad, gaming on a magic table, talking, reading, trips to museums, music shows etc.

Most of our guests have physical and/or cognitive problems due to aging or chronic diseases. According to the interviews that ZuidZorg conducts on their first visit and after a few visits, majority elderlies felt better mentally and physically. For example, data shows that after a ½ year, that they gave a score of their lives at 8- 8 ½ on average, which were initially 6-6 ½ on average. In physical tests, they also found themselves not only fitter or at least reversible, but they also feel mentally stronger, empowered. ZuidZorg tries to focus heavily on health and behavior, so that ZuidZorg encourages elderly people to participate in moving activities and try to make this happen by using gaming. Since ZuidZorg offers a certain kind of living lab settings to the students at the TU/e, many things for REACH can be tested and prepared. For example, the MI band, a simplified Fitbit is one of them. A master student has conducted the first tests with almost 50 guests, 25 of whom were also offered an intervention.

Through the experiment, much has been learned in the area of interest and motivation of the elderly. At the same time, data collection became a prelude to scientific research.

In the last quarter of the year 2017, ZuidZorg will start a pilot experiment as for transportation of our guests. This StuMobiel will be conducted as a project in corporation with students of the TU/e. Furthermore ZuidZorg plans to test *Istander* from AlrehMedical and the playware, *the Moto tiles*.

Figure 18: The MI band

3.3 Care givers for home residing citizens

3.3.1 The home care givers in Lyngby

The home care givers already work with different interventions and motivations to become more active. When the care givers are in the elderlies' homes, they work under the philosophy that people need help to help themselves (self-help), by inviting them to participate in the different activities (e.g. washing the plates and personal care).

Currently the care givers conduct observations at senior homes by utilizing the main notice metrics of changes (observation schema in Danish is attached). For example, the observations points are dry plants, which indicate the senior waters the plants any longer), or dirty dishes/garbage, which indicates the seniors clean up or tidy-up any more).

The Danish care givers are going to implement new guidelines for monitoring and interventions: They are "Early Warning Score" (EWS) and "Common language [across sectors]".

The EWS guides have been used in hospitals for many years for quickly determining the degree of patients' illness. The "Common Language" guide derives from a Danish project on establishing a well-defined vocabulary for processes, events and entities across sectors, thus going from home care, GPs to hospitals and clinics. The project's guideline is now in version 3 and is being implemented.

The interviews further revealed that the home care used physical/analogue boards to represent what state the citizens were in. A green board indicates no special focus/problems, while a yellow board indicates that a certain change has been observed and informed. This includes that the elderly has been falling at early observations due to cystitis etc. And finally, a red board indicates serious problems or hospitalization.

The care givers expressed high interests in accessing and receiving information based on monitoring, e.g. information when certain changes started happening. This could be changes in regard to movement or activity level, personal care, cleaning and tiding-up in the home, not watering the plants anymore among others. It would be information to make follow-up interviews and observations of the practice to investigated exactly what trigger points they have.

3.3.2 The home care givers in ZuidZorg

ZuidZorg employees who pay a visit to homes are nurses and household assistants. In total, this is about 2500 people.

The care conducted by nurses and nurses varies from routine operations, such as helping to get up, wash, shower, attract tools, to complex wound care, install and operate pumps for infusion therapy, pain relief and terminal care.

Since these nurses and household assistants are deeply involved in the private living, they can easily detect slight changes in seniors' health conditions or living situation and, if necessary, take actions on them. With *ZuidZorg Extra* service, ZuidZorg tries to get in touch with vulnerable elderly people more frequently so that elderly members could be motivated to try and activate them and come to an Meet and Greet center.

4 Requirements of elderly citizens

In REACH, elderly citizens are key as well as central stakeholder for considering future REACH system, which can be installed in their daily living environment. Thus, it is critical to study and understand the core target such as how elderly citizens can be motivated for maintaining their activities, and for training a little bit extra for maintaining better health. Similarly, it is also important to pay attention to elderly citizens' data privacy and its sharing with wider stakeholders. This section goes into such matters as motivation of elderly citizens for better health and their privacy challenge.

4.1 Motivational feedback from sensing environment in *The Lyngby II study*

In order to understand elderly citizens' mindset as well as potentials for the use of motivational feedback from sensing environment, Lyngby conducted a study particularly focusing on this motivational feedback influences and value.

In the Lyngby II study, nine older adults were monitored with both the *Fitbit* (step and heart rate monitor) and SENS patches (sensors that detect movements). They participated the study for eight weeks of training on *the Moto tiles*. The Moto tiles are tiles that light up and react when pressed, they allow for making different kind of games that requires the user to use the body and mind to complete.

The study aimed at investigating an influence of a physical training and its intervention, to see if the training would result in more movement outside of the training and generate better scores in physical ability tests. This study is designed based on the understanding that play can motivate participants to move even when they are not convinced about the benefit of the training. Earlier studies on the Moto tiles have shown that the participants tend to forget about time and place while playing, and there are indications that the elderly subjects make movements which they usually try to avoid even though the movements strengthen their overall physical abilities.

4.1.1 Data collection

In the study, varied of data such as observation data during the intervention, post-training questionnaires and semi-structured interviews, were collected. In this data collection, motivation on activities was focused and investigated as a core topic.

The participants for the study was received intervention and the process was observed. The observational data focused on elderlies' activity, playing on the Moto tiles. They are, for example, how they engaged in the games, how the social aspects influenced the elderly, and how they were motivated by the games.

After the study with intervention, post-training questionnaires and a semi-structured interview was conducted. The questionnaire was focused on the intervention, such as how they judged the outcome, the motivational aspects and issues of privacy and sharing. The interview focused on their understanding of what it is to be active, what their days look like when they are active (what are they doing), how important the equipment is, how weather and social settings influence their activity level, and how they could be motivated to be more active.

4.1.2 Results

In this section, the results of the intervention are reported and analyzed.

Questionnaire: The results of the questionnaire show that the all nine participants enjoyed participating the study (agree or strongly agree). They found the training fun (8 agree or strongly agree, 1 neither agree or disagree), and six participants associated the training with increasing better balance. Only two found that they believed the intervention made them train more than they would otherwise do, and only two also believed the games had motivated them to train harder or move more than they would otherwise have done, while 3 found that the intervention had made them more active.

Interviews: The interview concerning about motivation indicated a couple of causes of being active both inside and outside their house. For inside activities, they pointed out of tidying-up as a main source of activities and training. For those who had a garden, gardening is one of the motivation for them to get out and be active especially during the summer time. For outside activities, many answered shopping as a main activity. Apart from shopping, they also pointed out visiting friends and family as important activity. Some of them also mentioned nature related activities and cultural events as things that motivated them to move around and be active. Some mentioned that they need someone to encourage them and they value such social characteristics of external motivation.

The interviews also investigated if the participants were interested in reminders that would remind them to move more. The seven out of nine participants had a positive attitude towards reminders from e.g. the Fitbit. Two of the participants didn't want this kind of "pressure" to be active, mainly because they believed they were active enough already.

Of special interest was the fact that several of the participants didn't notice any significant change, but several pointed out that friends and family had told them, that they were able to move more freely that before the intervention. This is also in line with the results from the physical abilities test that show improvements above the minimal detectable change score. This must be regarded as an important finding, because it indicates that self-reporting about physical improvement is not a credible measurement. The finding is in line with the observations described below

Observations: During the observations, it became clear that the participants moved around in different way than what was observed during the initial screening. It was clearly indicated in their engagement of the games. In many cases, participants took longer steps, and played with less and less assistance such as two hands to begin with and only one in the end.

The participants were very autonomously motivated to participate in the training sessions. Among elderly groups, the participants mentioned freedom to choose as a key factor of participation in the training. The participant chose the training because of its enjoyments and they found it important to improve their own health.

The training on the MOTO tiles created a playful atmosphere, which improved motivation compared with standard rehabilitation training and exercise. There have been a high degree of competition among the elderly players for most points, and against themselves to beat their own records. The competition part of the session made individuals to feel competent and The attention and concerns form us made individuals to feel connected. Furthermore the social part of the training session made individual to feel connected and motivated participant to participate. Even the times, they felt no need for participating in the training, but they come because of the social part of it. Our collaboration with care givers has made sense of trust and relatedness and thereby played a major role to make individual likely to adopt behaviors.

4.1.3 Analysis on theory and previous research

Already there are quite a few studies are conducted in the relation between playware and motivation. Previously, research in playware, with a focus on motivation, are investigating the difference between convincing people to do things (be more active) e.g. in the form of gamification, social incentives, goal-directed behavior or self-reflection/self-efficacy (as suggested in WP 1.2) or making people do things “for the fun of it”

Strategies for motivations of the elderly as described in D19

- Personalisation

Adjust the feedback to the participants preferences.

- Triggers (e.g. reminders)

As described in D14, triggers can be used to “nudge” people in the direction of the desired behavior, here being more active. Most of the participants were positive towards the reminders for being active.

- Preformance feedback

In the Lyngby I pilot trial it was investigated how raw performance feedback would affect the participants. Results from this study indicate that raw performance feedback had no effect on physical activity.

4.2 Sharing and privacy

4.2.1 Background: what is known already

A growing number of studies ((Wild, Boise, Lundell, & Foucek, 2008), (Rashidi & Mihailidis, 2013), (Boström, Kjellström, & Björklund, 2013), (Townsend, Knoefel, & Goubran, 2011)) propose that use of monitoring technology can play a key role in monitoring health status of elderlies living at home. However, the use of pervasive monitoring also raises issues of privacy. The ability to monitor not only physical activity, location but also daily activities, communication, social interaction etc. requires careful analysis of the limits of paternalism.

Some of the studies of monitoring technologies also investigate elderlies’ acceptance and uptake of these and seek to identify research gaps related to privacy and security issues. (Claes, Devriendt, Tournoy, & Milisen, 2013; Kanis et al., 2013; van Hoof, Kort, Rutten, & Duijnstee, 2011; Pol et al., 2016). This research shows that, in general, while elderlies have some concerns regarding sharing private information most elderlies are positive and accept monitoring when it enables them staying in their own home (Boström et al., 2013)(Fischer, David, Crotty, Dierks, & Safran, 2014)(Townsend et al., 2011). Similarly, research has uncovered issues of concern indirectly related to privacy and ethics (Choi, Capitan, Krause, & Streeper, 2006), user perception of design and use of technologies (Rashidi & Mihailidis, 2013) and concerns about lack of security of private information (Peek et al., 2016).

A common point for most of the studies is that feeling safe outweighs privacy concerns (Townsend et al., 2011), (Yusif, Soar, & Hafeez-Baig, 2016). The authors describe different scenarios of willingness of elderlies to trade privacy for sense of safety and security. Participants perceive monitoring technologies as tools that may help them to stay independently in their own homes (Rashidi & Mihailidis, 2013), (Boström et al., 2013). Similarly, mental and somatic health condition and social relationships (Peek et al., 2016),(Townsend et al., 2011), (Demiris et al., 2004), as well as technology type and design (Rashidi & Mihailidis, 2013) are factors that play a major role in making the individual feel safe and less concerned about privacy issues.

The above studies investigating monitoring and other smart home technologies shed light on factors that influence elderlies' willingness to accept sensor-based surveillance. However, few studies (Boise et al. 2013; Pol et al. 2016) have elicited the view on privacy of elderlies who have actual experience with 24/7 monitoring. In the Lyngby 1 trial we conducted interviews with the 21 elderly participants to uncover their attitudes and possible concerns about privacy. The study thus contributes to the small body of knowledge of the attitudes and preferences of elderlies who have (or have had) first-hand experiences of being surveilled on a daily basis.

4.2.2 Results about privacy issues from the Lyngby 1 trial

The interview study was the final part of the Lyngby trial 1, an activity monitoring study stretching over 8 weeks, collecting data via Fitbit Charge HR. To provide background about the set-up and interview participants' experience of being surveilled we outline the main details of the monitoring part of the study before describing the interviews.

The main aim of the tracking and monitoring trial, run from Oct. to Dec. 2016, was to determine whether daily feedback about number of steps participants made would lead to changes in physical activity among elderly people.

The trial was a randomized cross-over trial where half the participants would receive feedback via a daily phone call (excluding weekends) on the amount of steps they had made the day before, and the other half feedback on the amount of sleep and waking periods the previous night. After 4 weeks, the two groups switched, so that those who had received feedback on sleep would now receive feedback on steps, and similarly, those who had had feedback on steps would now get feedback on sleep. While the focus of the study was on physical activity, we included feedback on sleep, although was to control for any influence of the social contact and attention provided by the daily phone call. Each phone calls lasted around 3-5 minutes.

A sample of 26 elderly citizens were recruited via an Elderly Care & Activity Center of a local municipality (Lyngby-Taarbæk). The Center provides elderly citizens living independently at home with a typical regimen of a twice-weekly 3-hour sessions consisting of light exercise (light movements while sitting on chairs due to frailty), social activities and a lunch. Participants All participants lived independently alone in their own homes, but received home care once a week or once every second week. None of the participants had serious health conditions.

Participants were asked to wear a bracelet (Fitbit Charge HR) which uploaded tracking data via Bluetooth to a smartphone. None of the participants owned or knew how to operate a smartphone and the count of steps was not visible on the bracelet.

After the first week of the trial, which had been reserved for screening of tolerability of comfort and providing baseline data, 4 participants withdrew (2 because of health problems, 2 for private reasons). The remaining 22 participants had a mean age of 85 (range 71-94), 18 female (73%).

During the trial participants were visited by a research assistant who installed the smartphone and its charger and showed how to charge the bracelet (once every 4 or 5 days) and, in addition, whenever there were problems with upload of data. Data from the steps-and-sleep monitoring study will be reported in detail separately.

Participants reported that they enjoyed wearing the activity trackers because, mainly because it made them feel safe and cared for. As some of the expressed this, “someone is looking after me, some cares about me” [L6, L7, L20]. All 21 participants declared that they did not feel watched or observed by sensors. On the contrary, they indicated that sensors can support them in their goal to stay at their own home, and can minimize the unnecessary control visits by health care professional [L7, L25]. All of the 21 (100%) participants said they felt no surveillance when they were asked “Did you felt monitored during the experiment when we could see the amount of steps taken / sleeping hours”?

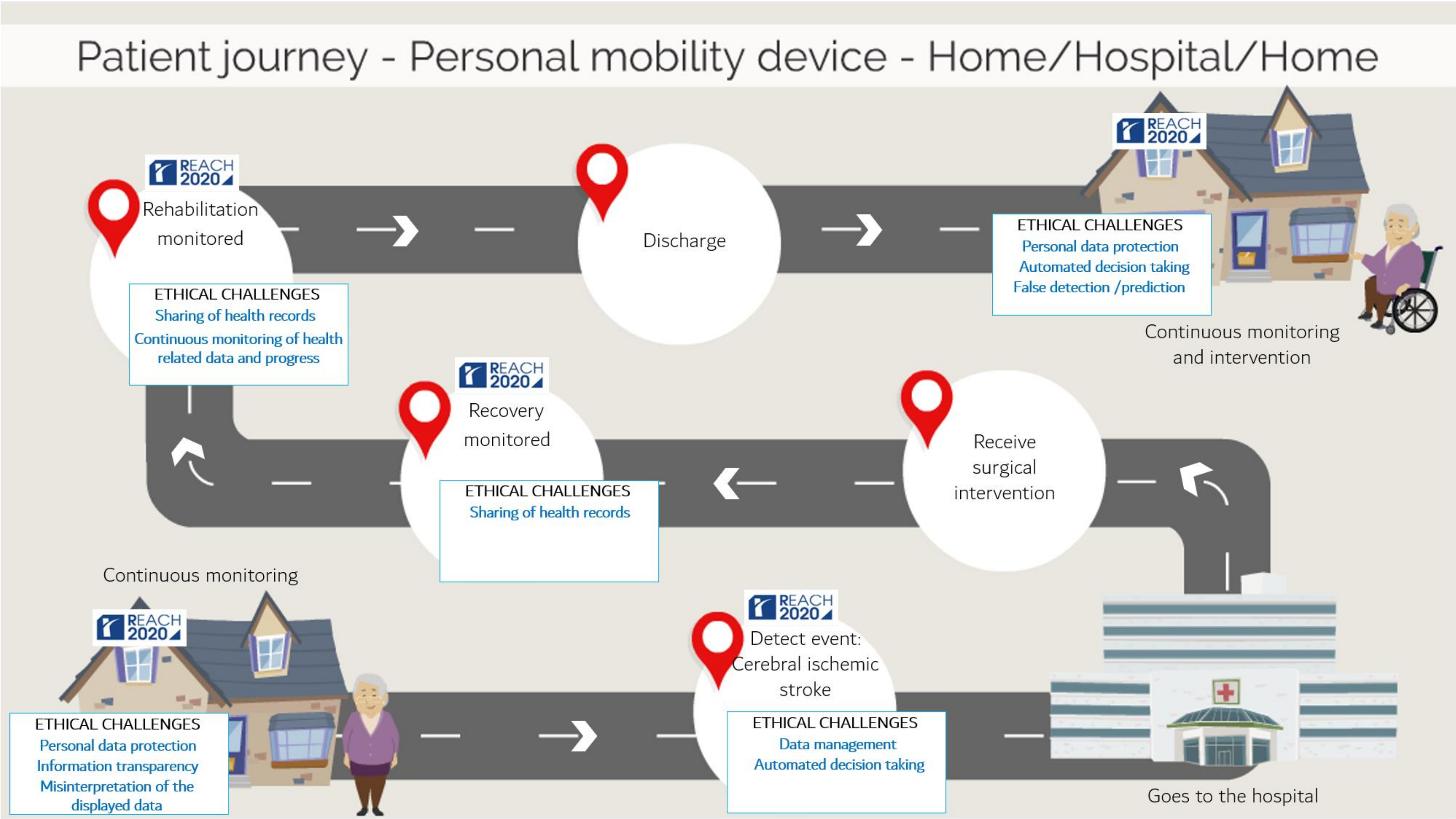
Participants mentioned different factors that has made them feel unconcerned about monitoring. One factor mentioned was the membership in a social network of other elderlies who had in common that they were been monitored during the trial. Another was when elderlies recognize the technologies from their grandchildren or children (“my kids think it is cool that I wear a gadget like this”). This created a sense of security and comfort where privacy concerns were absent. Another factor which makes individual feel unconcerned is the experience of being watched in earlier stages of aging when they have had health issues. Being watched over created a sense of comfort which now, later, made it easy to health care monitoring technology.

4.2.3 Privacy issues in the patient’s journey

Below we illustrate the patient journey for each of the four touchpoints and identify the primary ethical challenges associated with each of the steps of the journey.

Touchpoint 1: Personal mobility device / Home – Hospital - Home

The patient is at home	**An event occured: the patient had a cerebral ischemic stroke**	**The patient is brought to the hospital**	**Recovery at the hospital**	**Rehabilitation at the hospital**	**Discharge**	**The patient is back home**
The patient daily activity and health parameters are continuously moni-tored by the REACH system. The data is accessible to him (and/or his doctors/caregivers) through an easy to use and user friendly interface.	The system interpret the data, detect the event and alert the hospital and the caregivers	The patient goes to the hospital and receive surgical in-tervention	The patient recovers at the hospital and is monitored by the system	The patient fol-lows a rehabilita-tion process at the hospital using the personal mobility device	Depending on the patient progress and recovery, the doctors decide with the help of the system to discharge the patient	The patient is back home and continue the rehabilitation process at home with the personal mobility device. His daily activity and health parameters are continuously monitored to detect decrease in health status or abnormalities
Ethical challenges linked to: personal data protection, In-formation trans-parency, misinter-pretation of the displayed data	Ethical challenges linked to: data management and automated decision taking		Ethical challenges linked to: sharing of health records	Ethical challenges linked to: sharing of health records, continuous moni-toring of health related data and patient progress		Ethical challenges linked to: personal data protection, automated decision taking, false detec-tion/prediction

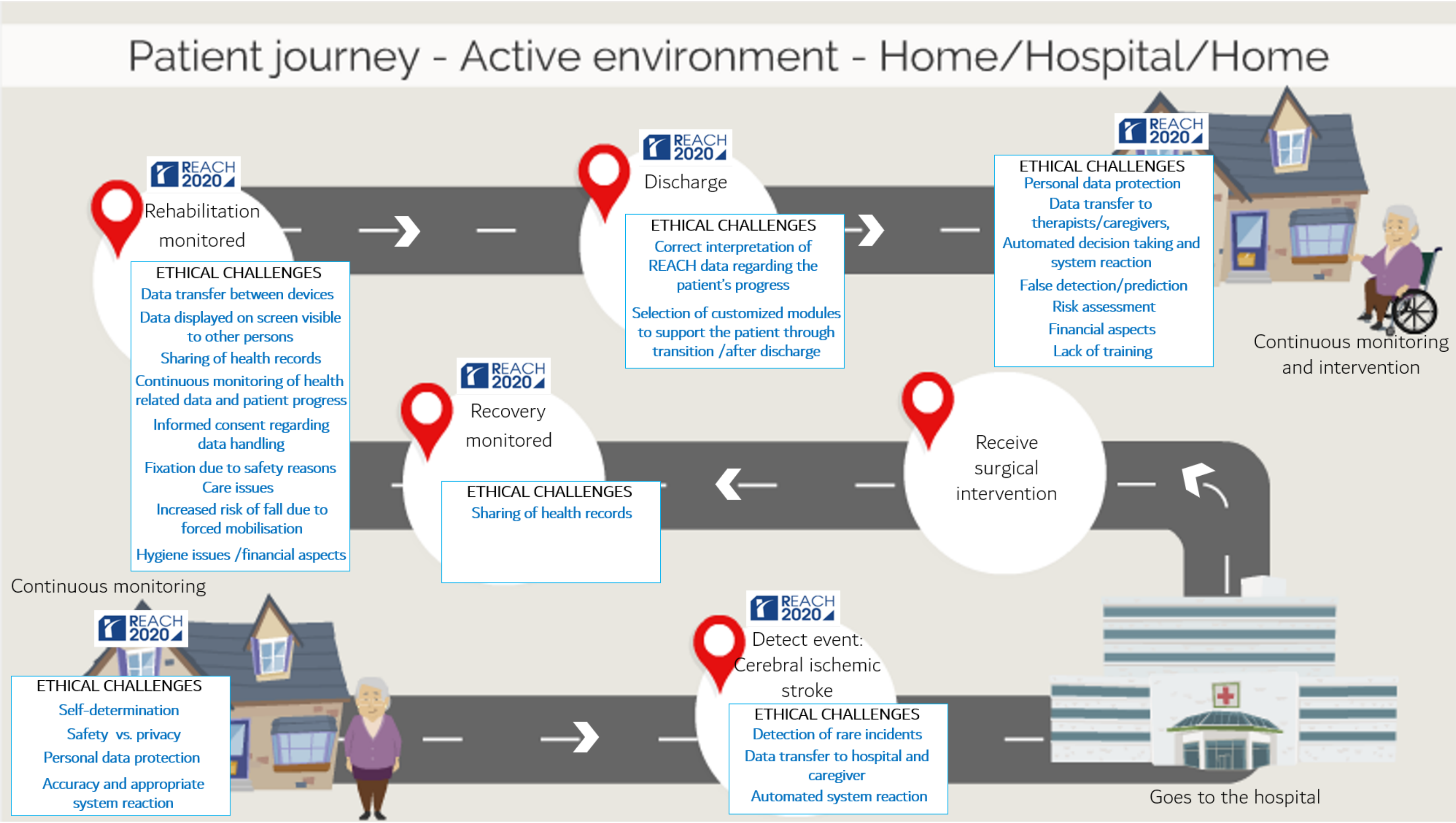


Patient journey - Personal mobility device - Home/Hospital/Home
Rehabilitation monitored
ETHICAL CHALLENGES
Sharing of health records
Continuous monitoring of health related data and progress
Discharge
ETHICAL CHALLENGES
Personal data protection
Automated decision taking
False detection /prediction
Continuous monitoring and intervention
Recovery monitored
ETHICAL CHALLENGES
Sharing of health records
Receive surgical intervention
Continuous monitoring
ETHICAL CHALLENGES
Personal data protection
Information transparency
Misinterpretation of the displayed data
Detect event: Cerebral ischemic stroke
ETHICAL CHALLENGES
Data management
Automated decision taking
Goes to the hospital

Touchpoint 2: Active environment / Home – Hospital - Home

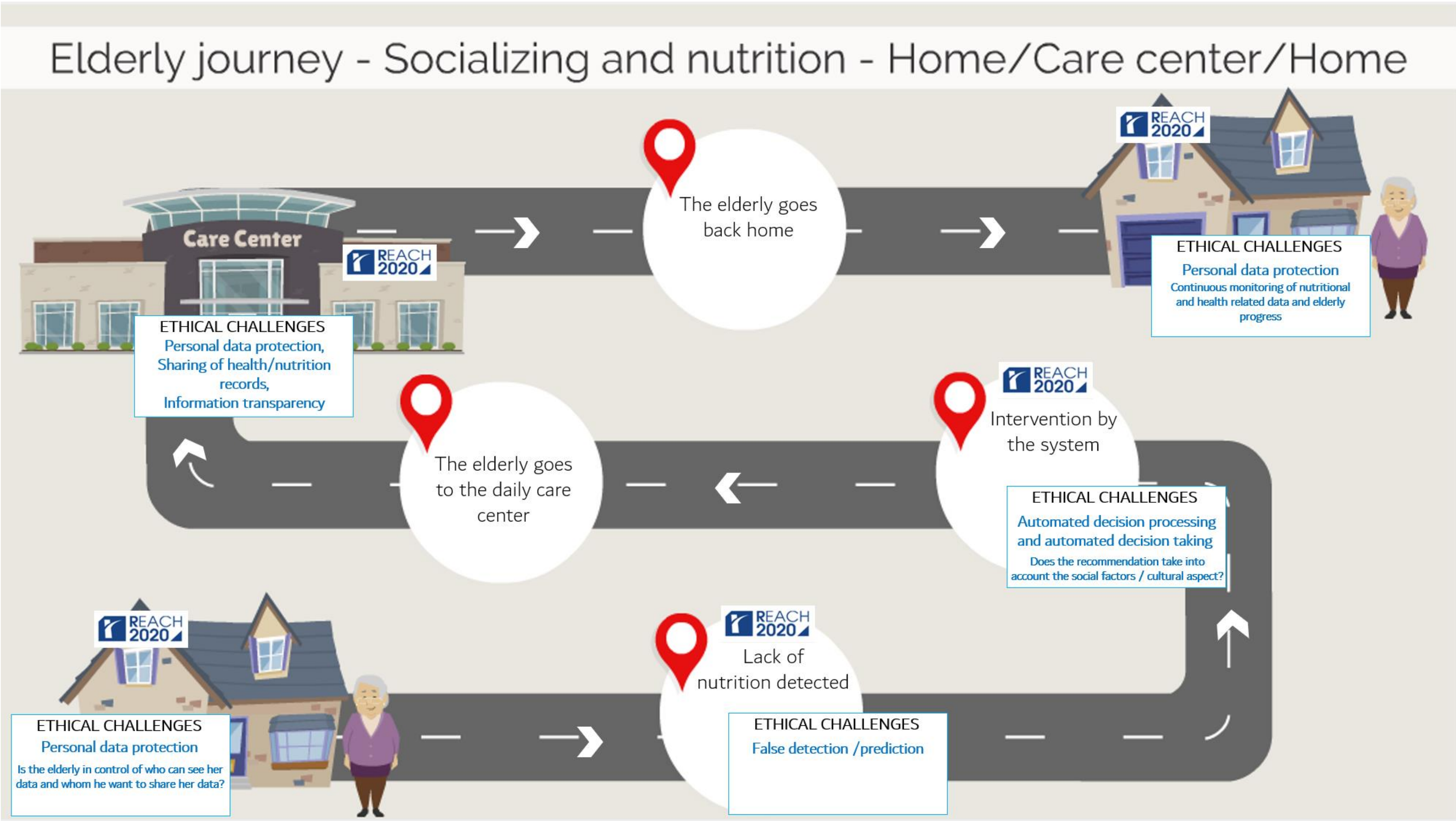
The elderly is at home	**An event occured: the patient had a cerebral ischemic stroke**	**The patient is brought to the hospital**	**Recovery at the hospital**	**Rehabilitation at the hospital**	**Discharge**	**The patient is back home**
The patient's daily activity and health parameters are continuously monitored by the REACH system. The data is accessible to him (and/or his doctors/caregivers) through an easy to use and user friendly interface.	The system interprets the data, detects the event and alerts the hospital and the caregivers	The patient goes to the hospital and receives surgical intervention	The patient recovers at the hospital and is monitored by the system	The patient follows a rehabilitation process at the hospital using the personal mobility device	Depending on the patient progress and recovery, the doctor decides supported from REACH data to discharge the patient	The patient is back home and continue the rehabilitation process at home through the active environment. His daily activity and health parameters are continuously monitored to detect decrease in health status or abnormalities
Ethical challenges linked to: Self-determination, safety vs. privacy, personal data protection, accuracy and appropriate system reaction	Ethical challenges linked to: detection of rare incidents, data transfer to hospital and caregiver, automated system reaction		Ethical challenges linked to: sharing of health records	Ethical challenges linked to: data transfer between devices, data displayed on screen may be visible to others (patients, visitors …), sharing of health records, continuous	Ethical challenges linked to: correct interpretation of REACH data regarding the patient's progress (e. g. early discharge), selection of customized	Ethical challenges linked to: personal data protection, data transfer to therapists/caregivers, automated decision taking and system reaction, false detection/prediction, risk assessment,

		monitoring of health related data and patient progress, informed consent regarding data handling (e.g. in case of limited consciousness), fixation due to safety reasons (e.g. in case of motor impairment), care issues (e.g. when nursing staff relies on REACH system and reduces awareness), increased risk of fall due to forced mobilisation initiated by system, hygiene issues with multiple technical devices, financial aspects (e.g. no insurance coverage).	modules to support the patient through transition /after discharge	financial aspects (e. g. cost of module exchange when patient progresses), system use at home although users could not be sufficiently trained; if system cannot be delivered to home for financial reason a person could be/feel short-stuffed


Patient journey - Active environment - Home/Hospital/Home
REACH 2020
Continuous monitoring
ETHICAL CHALLENGES
Self-determination
Safety vs. privacy
Personal data protection
Accuracy and appropriate system reaction
REACH 2020
Detect event: Cerebral ischemic stroke
ETHICAL CHALLENGES
Detection of rare incidents
Data transfer to hospital and caregiver
Automated system reaction
Goes to the hospital
Receive surgical intervention
REACH 2020
Recovery monitored
ETHICAL CHALLENGES
Sharing of health records
REACH 2020
Rehabilitation monitored
ETHICAL CHALLENGES
Data transfer between devices
Data displayed on screen visible to other persons
Sharing of health records
Continuous monitoring of health related data and patient progress
Informed consent regarding data handling
Fixation due to safety reasons
Care issues
Increased risk of fall due to forced mobilisation
Hygiene issues /financial aspects
REACH 2020
Discharge
ETHICAL CHALLENGES
Correct interpretation of REACH data regarding the patient's progress
Selection of customized modules to support the patient through transition /after discharge
REACH 2020
ETHICAL CHALLENGES
Personal data protection
Data transfer to therapists/caregivers,
Automated decision taking and system reaction
False detection/prediction
Risk assessment
Financial aspects
Lack of training
Continuous monitoring and intervention

Touchpoint 3: Socializing and nutrition / Home - Activity Center – Home

The elderly is at home	Lack of nutrition detected	Intervention by the system	The elderly goes to the activity center	The elderly goes back home
Elderly receives invitation to join a social tasting event at the activity center;	The system interprets the data, detect the change (decrease) in daily nutrition intake	The system notify caregivers/doctors/nurses about the detected abnormalities (decrease) The system provides per-sonalized recipes through an app depending on the elderly health status and preference for food.	The elderly joins the social tasting event at the activity center to socialize, cook and taste together with the vol-unteers using the recipes suggested by the app. The elderly can select their preferred recipes to be taken with them and try themselves at home.The nutrition intake is then monitored and the data is automatically updated in the elderly profile in the app so that his dietist/doctors/caregivers are aware of his progress.	The elderly goes back home and feels more confident in cooking themselves and eating with others together. Elderly cooks for himself for friends at home using a preferred recipe from the social tasting event at the activity center; Elderly shares their cooking and dining experiences at home through an app. The nutrition intake is continu-ously monitored by the REACH system.
Ethical challenges linked to: personal data protection (Is the elderly in control of who can see his data and whom he want to share his data?)	Ethical challenges linked to: false detection /prediction	Ethical challenges linked to: automated decision processing and automated decision taking (Does the rec-ommendation take into account the social factors / cultural aspect?)	Ethical challenges linked to: personal data protection, sharing of health/nutrition records, information transparency	Ethical challenges linked to: personal data protection, continuous monitoring of nutritional and health related data


Elderly journey - Socializing and nutrition - Home/Care center/Home
REACH 2020
ETHICAL CHALLENGES
Personal data protection
Is the elderly in control of who can see her data and whom he want to share her data?
Lack of nutrition detected
ETHICAL CHALLENGES
False detection /prediction
Intervention by the system
ETHICAL CHALLENGES
Automated decision processing and automated decision taking
Does the recommendation take into account the social factors / cultural aspect?
The elderly goes to the daily care center
Care Center
ETHICAL CHALLENGES
Personal data protection, Sharing of health/nutrition records, Information transparency
The elderly goes back home
ETHICAL CHALLENGES
Personal data protection
Continuous monitoring of nutritional and health related data and elderly progress

Touchpoint 4: Gaming and training: patient Journey

Seniors at home	Change in activity level	Physical ability tests pre- and post-test	Seniors at activity/care centers (GAMING SESSIONS)	Senior back at home
Elderlies 65+’s daily physical activity (24/7) is monitored by Reach system. The daily monitored data are stored and are accessible to researchers through web interface.	the system interprets the data, detect the changes in individuals performance or activity level	Pre-test such as (Timed up and Go, 30 second Chair Stand, 6MWT, sway test/force plate; SF12 (shortened SF36) and Questionnaire used to get overview of individual physical ability and the same tests are conducted mid and after trail to detect the development in each individuals physical condition	Seniors are offered gaming and training on moto tiles twice a week	After training the individuel goes back home. their daily activity and health parameters are continuously monitored to detect changes in health status
Ethical challenges are linked to: Self-determination, safety, privacy, personal data.	Ethical challenges are linked to: false detection, prediction	Ethical challenges are linked to: Personal health related data	Ethical challenges are linked to: false detection, prediction, safety, privacy, personal data.	Ethical challenges are linked to: Self-determination, safety, privacy, personal data.


Elderly journey - Gaming and training - Home/Care center/Home
Care Center
REACH 2020
ETHICAL CHALLENGES
False detection,/prediction
Safety
Privacy
Personal data. protection
The elderly goes back home
ETHICAL CHALLENGES
Self-determination
Safety
Privacy
Personal data protection
The elderly goes to the care center for Gaming sessions
Physical ability tests: pre- and post-test
ETHICAL CHALLENGES
Personal health related data
ETHICAL CHALLENGES
Self-determination
Safety
Privacy
Personal data protection
Change in the activity level detected
ETHICAL CHALLENGES
False detection /prediction

5 Overview over technical and functional requriments of PI²Us

The mission of REACH is to develop novel ambient sensing approaches, novel prediction analytics and recommendation systems, a set of unobtrusive intervention products and services and a novel generation of smart furniture, which allows inserting REACH functionality into care environments in an unobtrusive manner. Therefore, a series of Personalized Interior Intelligent Units (PI²Us), or in other words smart furniture, will be designed to support the intervention regimens. These PI²Us are conceptualized in a way that they both serve as add-ons to existing furniture and as stand-alone units that contain physical and virtual services to increase activity level. Specifically, they are PI²U-Stander, PI²U-Bed, PI²U-silverArc, and PI²Us-miniArc, which will be designed in a unified, curved, and natural design language in order to promote the user acceptance. Furthermore, smart furniture products will allow for additional value creation through furnishing, building, and renovation industries and markets, and will allow turning a variety of built environments into service platforms.

Platform strategy: The platform strategy is used in many successful branches such as the automobile industry. The platform is the parts of the car, which are crucial for operating. These parts are the same for different models of a brand. In the second level of the platform strategy, the system parts are added. These parts are also shared among different models but they were adjusted in terms of size, shape and material. The third level is the cover parts. The cover platform and the system parts are highly individualized for each model. Platforms vary in terms of openness. For example, for a car only professionals should change the parts, while for a computer every user can change the parts such as RAM, hard drive, monitor, mouse, keyboard and printer (Linner, 2017)**.**

The design of the PI²Us embraces the platform strategy. The design of a variety of products using the same modules of components is called the "platform". A platform is useful for mass production, allowing savings and easy manufacturing. The platform strategy provides a structured modularity in more levels and a high degree of standardization (Jose & Tollenaere, 2005). The structure levels of the PI²Us is described in Table 14 below.

Table 14: Structure levels of the PI²Us.

Level 1:	PI²Us = Platforms
Level 2:	Individualization by add-on Modules
Level 3:	Further Individualization by Plug-ins such as Sensors

The types of modularity: Modularity is the best method to achieve mass customization. It minimized costs and in the meantime maximize individual customization. Usually, there are following six common types of modularity in present modular products: Bus Modularity, Slot Modularity, Sectional Modularity, Component Sharing Modularity, Component-Swapping Modularity, and Cut-to-Fit Modularity (Mascitelli R, 2007) (see Figure 19: Figure Illustration of the six basic types of modularity in present modular products).

The type of modularity to be applied in the PI²Us' design is mainly Bus Modularity. Bus Modularity refers to providing a common structure, which allows modules of various type, number, and location to be plugged in. The appearance of this system can variate through the type, number and location of the added modules. For example, the motherboard of a computer can be seen as the common structure that accepts different types of CPU, RAM, hard drive and expansion cards.

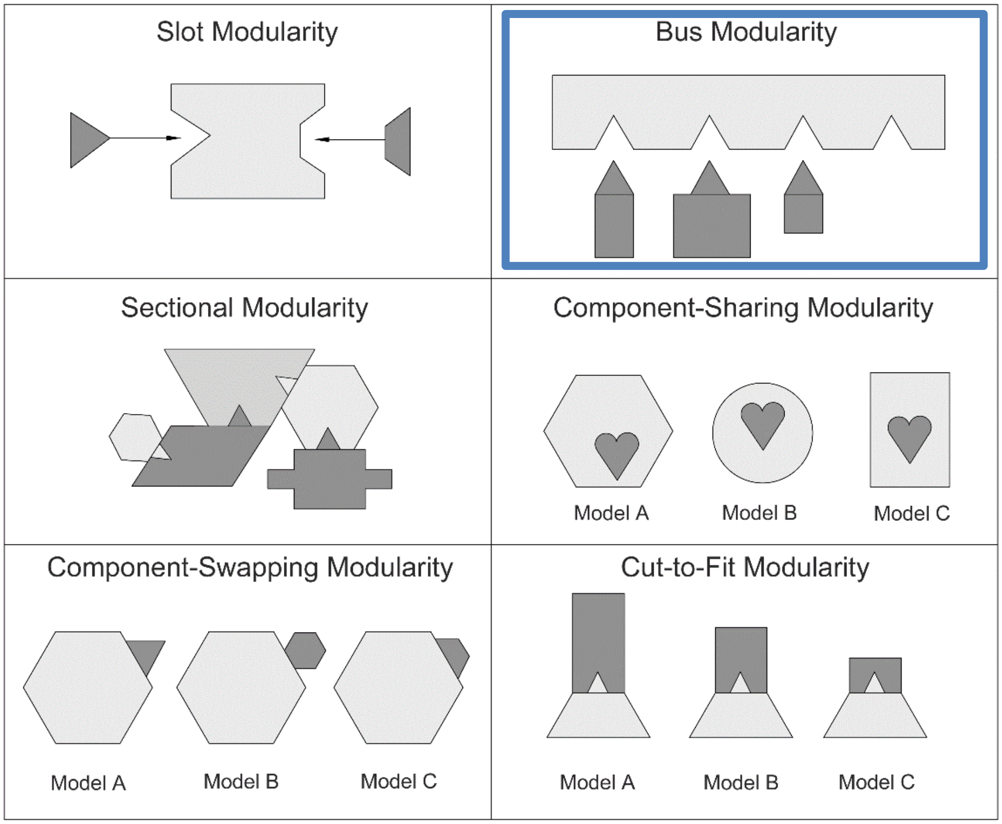


Figure 19: Figure Illustration of the six basic types of modularity in present modular products.

In the following section, there is a description of the design concept of the four PI²Us for the first and second level. The development of the three level will be addressed in REACH-Deliverable 5.

5.1 PI²Us Functions as Main User Interface

In the muscle training, a focus is placed on the muscles necessary for walking. To build up the leg muscles the body needs a protein-rich nutrition. In addition, activities such as walking in the fresh air are needed interventions. Patients who have already experienced falling are often so afraid of experiencing the same situation again that they want to totally stop walking. Consequently, this weakens even more muscles and significantly increases the risk of falls. Such patients shall be well advised to visit a psychologist in order to overcome their fears. To overcome the misconception that psychotherapy is just for people with mental illness is the responsibility of the behavioral interventions for psychological treatment.

The design of PI²U-Stander derives from Alreh Medical's stander device, which originally is an advanced dynamic stander designed for people with deep disability (e.g. paraplegics caused by traumata, multiple sclerosis, tumors etc.) to support their rehabilitation of musculoskeletal system in a step-by-step manner. PI²U-Stander is mainly used in patients' living environments together with other PI²Us, in order to assist and promote activities of daily living (ADLs). There are multiple add-ons to the PI²U-Stander, such as EMG sensors and pulse sensors (see Figure 20).

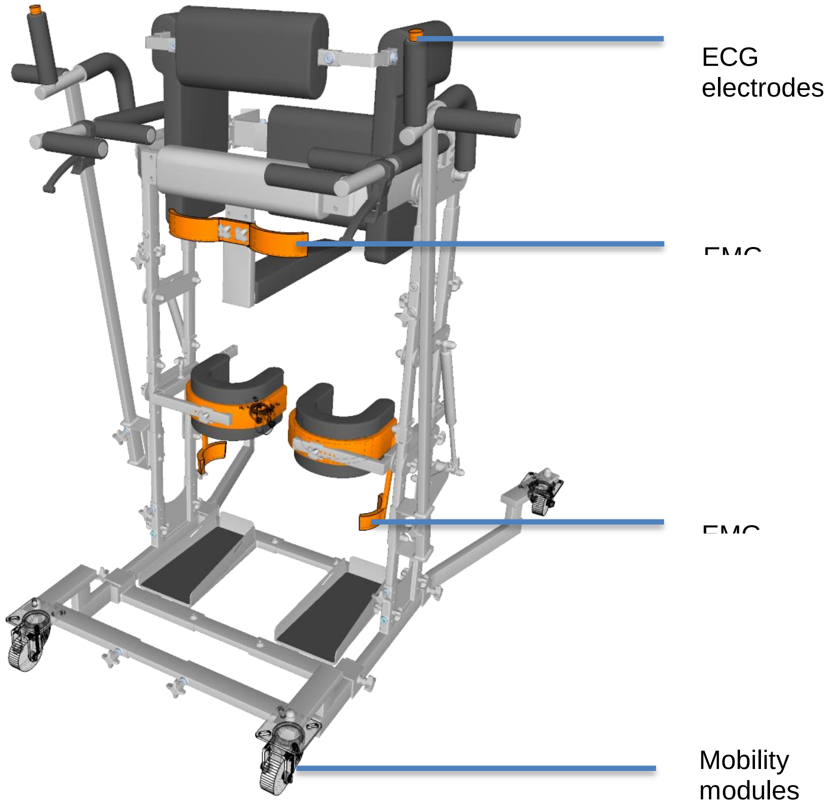


Figure 20: Initial visualization of the PI²U-Stander

In addition, the model has mobility function, which can further help the elderly to move between different locations and gradually train their muscles for standing and walking (see Figure 21:).

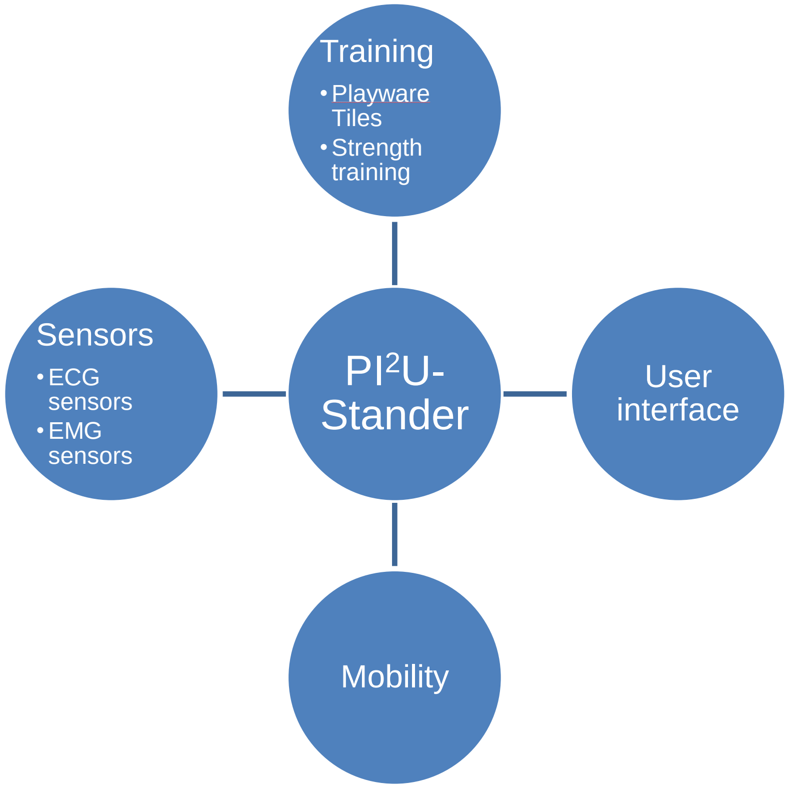


Figure 21: Functions to be integrated into PI²U-Stander platform

5.2 PI²Us Functions for Gaming & Training

Many elderly citizens experience loneliness and depression in high age, either because of living alone, after the loss of their partner, or due to lack of close relationship. Gradually the circle of friends diminishes and the possibility to meet new people through work or through activities with their children is no longer available. Furthermore, most of the times elderly citizens find it more difficult to establish new friendship (Misra & Singh , 2009). Therefore, it is important for the elderly to build a sociable and active lifestyle through the smart furniture solution.

The PI²U-silverArc platform is designed specifically to promote the users' social activities in public interior environments such as a community kitchen. As shown in **Error! Reference source not found.**, the PI²U-silverArc platform shall integrate and promote training functions, two ultra-short projectors (one for the screen and one for the external table) for user interface, motion detection sensors, and mobility function. This platform can be connected to existing furniture such as kitchen table to accomplish more functions (e.g. cooking tutorial). It allows more than one elderly citizen to do physical training and socialize with friends at the same time. It also integrates mobility function, which allows the PI²U-silverArc to be moved to different areas, in order to adapt to various usages (see Figure 22:)

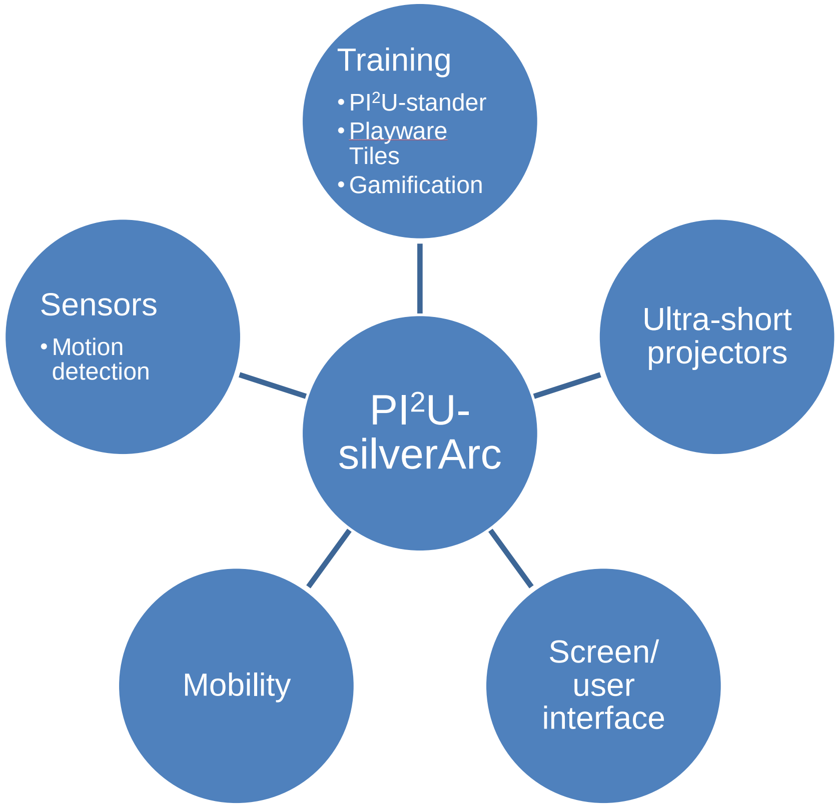


Figure 22: Functions to be integrated into PI²U-silverArc platform.

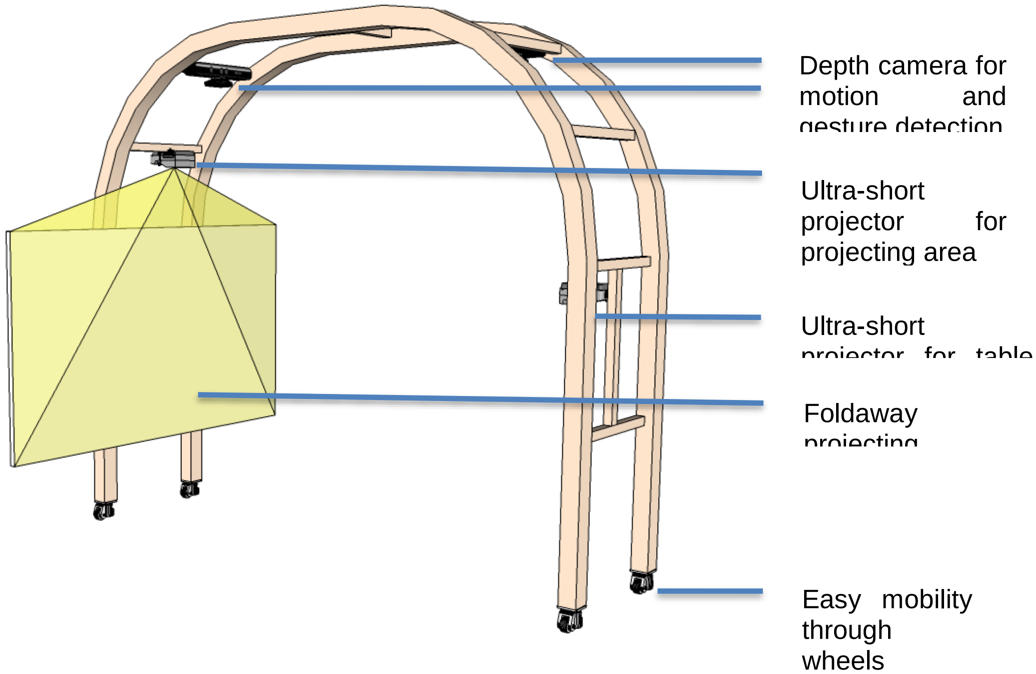


Figure 23: Initial visualization of the PI²U-silverArc.

In Fig. 24, the PI²U-silverArc is installed in a community kitchen. The patient behind the PI²U-Stander is looking at the interactive physical training program on the large screen of the PI²U-silverArc, meanwhile using the PI²U-Stander as an assistive device for the training. At the same time, there is an interactive cooking tutorial displayed on the kitchen's table. The person behind the stove is following the cooking tutorial on the table to cook some dishes for her and her friends. In this case, the application of the PI²Us establishes an interactive environment in the community kitchen and promotes users' social activities.

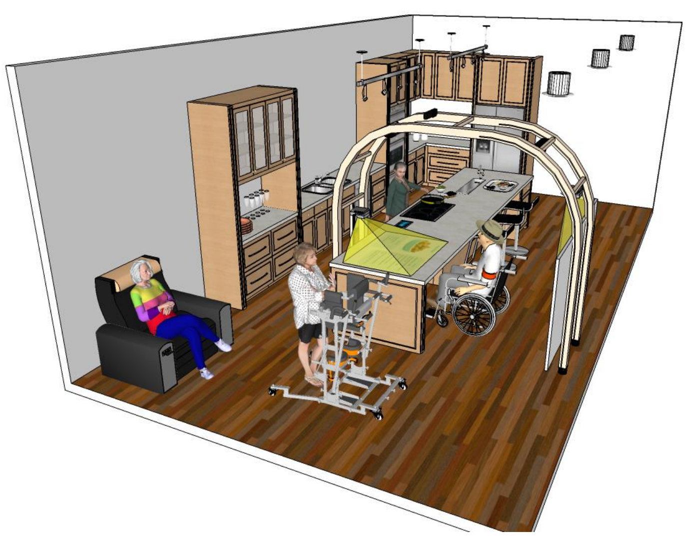


Figure 24: Simulation of PI²Us application in the community kitchen scenario

5.3 PI²Us Design and application for the home environment

Since there are also elderly citizens who prefer to stay independent and self-sufficient without a community apartment, PI²Us have been designed for private home environment. Nevertheless, according to the modularity approach in REACH, these modules are also compatible to community apartment, retirement homes, or hospitals. The main target is the implementation into the private apartment, which normally offers less space compared to the public accommodations of a retirement home and hospital rooms.

5.3.1 PI²U-miniArc

The PI²U-miniArc platform can be seen as a smaller, lighter, and simplified version of the PI²U-silverArc. It features multiple functions including training, easy mobility, two ultra-short projectors (one for the external screen and one for the foldaway table) for user interface, motion detection sensor, and docking function (e.g. for wheelchair) (see **Error! Reference source not found.**).

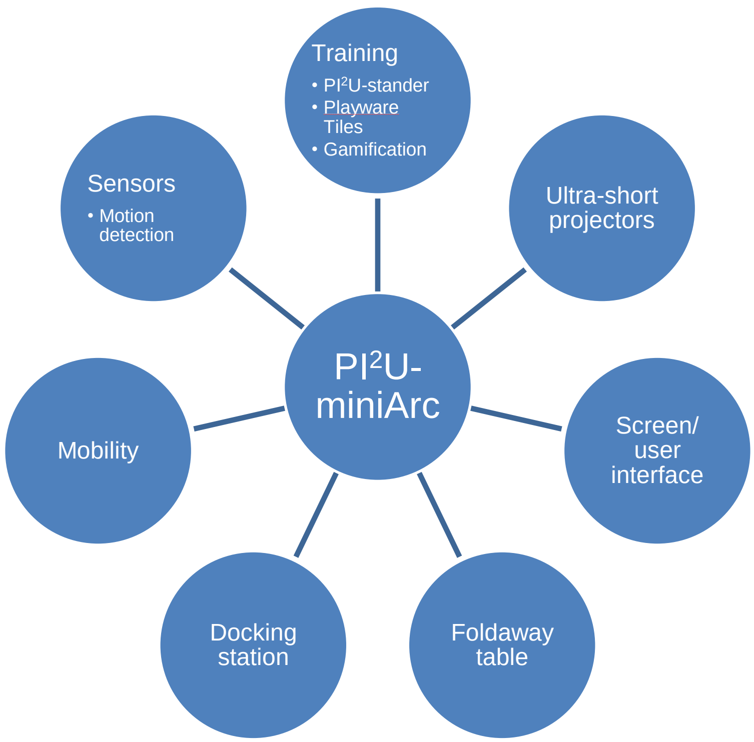


Figure 25: Functions to be integrated into PI²U-miniArc platform..

Compared to the PI²U-silverArc, the PI²U-miniArc is a much smaller and more flexible device. It can be applied in even smaller space such as living room, bedroom, and care room. The existing facilities like walls in the care room can work together with the PI²U-miniArc to form a display area of the user interface. With the help of the PI²U-miniArc platform, the elderly can do their own training through the user interface, meanwhile enjoying more freedom and privacy during the training process (see Figure 26).

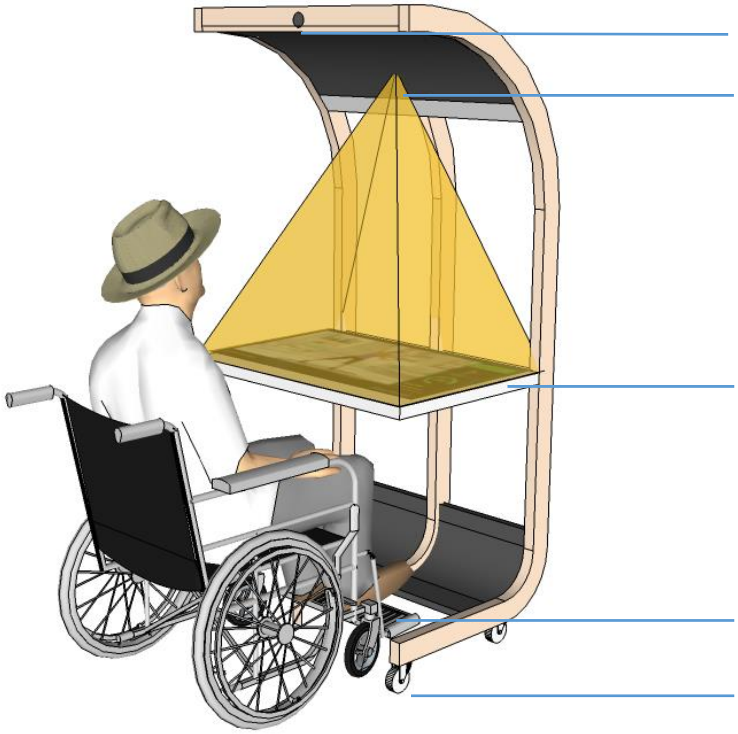


Figure 26: Initial visualization of the PI²U-miniArc

5.3.2 PI²U-Bed

In this section, three most important aspects regarding prevention and intervention approaches will be discussed, first the pressure ulcer prevention & treatment, second the temperature & breath monitoring and third the verticalization.

One of the most imperative problems in the care of immobile, sick and elderly patients is the prevention and management of pressure ulcers, also known as bedsores or decubitus. They are localized visible damages to the human skin and/or the underlying tissue near a bony protrusion, which are caused by persistent external pressure. In case of long term contact pressure over a skin area, exceeding the blood pressure in the capillaries will happen which will lead to decubitus development. Usually, a period of two hours is considered critical. Once emerged, pressure ulcers are very painful for the patients and furthermore very complex and expensive to treat, and the healing process takes a long time (Leffmann, et al.,, 2002). As a result, it will be critically useful for the PI²U-Bed platform to include a body pressure mapping system to prevent the pressure ulcer from developing.

In addition to the elderly, one can consider the paraplegic patients who are posed to high risk of developing pressure ulcer (DW Byrne, 1996)**.** As a result, pressure mapping systems which will be introduced in the following can also be very useful for such cases.

It is particularly interesting in the anti-decubitus treatment to know exactly how high are the shear forces in combination with the pressure. In the care environment, usually the unmovable patient has to be turned or moved every two hours. It will be very useful to know whether the turning activity can be postponed for a few minutes or an hour, so that the patients, as well as the caregivers, can sleep longer and better especially at night.

Furthermore, pressure mapping will present the caregivers with the information on how and in which direction to move the patient to peak the effectiveness.

Implementing a monitoring approach will provide the caretakers with two important data. Firstly, which parts of the patient's body are undergoing higher pressure than they should. Secondly, how long this pressure is being applied to the specific part of the patient's body. According to these two data, the REACH system can inform the caretaker to move the patient before they are posed to high risks of developing pressure ulcer. Therefore, products such as the BodiTrak, Tekscan, Sensorprod or Xsensor should be useful in developing a solution for these cases.

The BodiTrak Monitor consists of a stretchy Lycra sensitive material on which the patient is lying and a software based on the Reswik Rogers time/pressure curve to help the caregiver identify and manage the skin surface of a patient. BodiTrak shows how high the pressure and the shear forces are, and how long they are in a certain part of the body. The real-time feedback helps nurses to find a position that leads to better pressure distribution. The software also includes a time-to-turn alarm with selectable time slots. Caregivers access the BodiTrak Monitor information with a tablet wirelessly connected to the system, or they can view the data on the computer in a web browser in the nursing station. Presented at the tablet or mobile device, the gradient, which is an expression of how the pressure changes from one place to another over patient's skin, is displayed in mmHg/cm. Warmer colors indicate rapid changes in which shear forces can adversely affect the skin (**BodiTrak**).

The BodiTrak provides a fully functional product, however in case of the REACH project the partners will be trying to implement and integrate such a pressure mapping system into a larger system with different technical requirements. Consequently, other pressure mapping systems should and had also been studied.

The BPMS, Body Pressure Measurement System, developed by Tekscan measures the pressure distribution of a human body on support surfaces such as seats, mattresses, cushions and backrests. The thin and conforming sensing mattress can measure body pressure distribution with minimal interference of the support surface and can be confidently incorporated into the application without altering the characteristics of the support surface. The BPMS pinpoints anatomical structures that cause concentrated pressure. This system is comprised of data acquisition electronics, sensors and software which is configurable depending on the needed application. The BPMS has a resolution as fine as one sensing element per square centimeter. The software provided by Tekscan includes features such as access to real-time or previously recorded data in 2D & 3D, providing different metrics e.g. total force and peak pressure and center of force, multiple graph options to plot data and others. There are many different applications defined for such a sensor system e.g. comfort testing and analysis, material testing, seating and positioning research and preventive and treatment measurements in the medical field. The Tekscan also provides a fully functional product.

The “Body Mapping Mattress” produced by the Sensorprod Inc. allows the pressure distribution and magnitude measurement on the sleeping surface. This sensor system captures data from a series of sensor points across the body surface and sends to a software system which provides the user with colorized pressure maps and detailed statistical reports. Additionally, this system provides dual capability of measuring both pressure and temperature distributions. This sensor system uses a matrix of “Piezo Resistive” pressure sensors with resolution of 1 sensing point per 25x25 millimeter. Furthermore, the software system provides the user with data interpretation and meaningful visual tools. Comparing to other producers, this company provides a simple and easy interface which is ideal for developing prototypes and research purposes.

The company Xsensor provides the customers with several pressure mapping sensor solutions for different purposes e.g. Wheelchair Seating, Mattress Assessment and Patient Monitoring. Xsensor pressure mapping systems combine flexible sensor mats with software and electronics to create real time video of the interface pressure distribution on a support surface. Using this information, clinicians are able to locate areas of high pressure. The Mattress Assessment is designed for large surfaces such as hospital beds and surgical tables. The Xsensor product combines plug & play electronics and ForeSite desktop software to create a complete package for medical analysis.

In this part, the temperature monitoring aspect will be addressed. Infrared Sensors/Cameras can be used for temperature monitoring. These sensors use a technical method which is called thermographic imaging and it is based on forming an image based on infrared radiations which means that these sensors translate thermal energy to visible light. Considering the PI²U-Bed, thermal screening can be used as a monitoring method for detecting many health metrics or signs e.g. fever detection either from the skin or from the eyes or breath detection. In a study by Bardoua (Bardoua, 2017), they have performed temperature measurement on 625 persons using thermal cameras. They concluded that Infrared thermal cameras are a rapid and reliable way to detect fever in infected persons in clinical settings. As a contributing factor, the prior calibration of the thermal sensitivity of infrared cameras according to ambient temperature is required to obtain greater accuracy. Alternatively, the thermal imaging can be used as a method for breath monitoring during sleep. In another study by S. L. Bennett (S. L. Bennett, 2015)**,** the authors proposed an inexpensive and unobtrusive method for identification and distinction between different types of sleep apnea. To implement this, the authors used a thermal camera to gather video of a subject while nasal breathing and simultaneously, they used a respiratory inductance plethysmography band to gather respiratory data. At the end they concluded that breathing behavior can be captured using thermal video and furthermore the detection and distinction between types of sleep apnea can be identified.

Verticalization is another important feature in the PI²U-Bed platform. For example, ICU (Intensive Care Unit) patients sometimes need to perform the so-called "early mobility" (**Arjo Huntleigh, n.d.**). It includes the transfer of a patient from the lying position into sitting or vertical positions. The passive standing by a standing frame aims to improve respiratory function and cardiovascular fitness, increase the levels of consciousness, functional independence and psychological well-being and reduce the risk for delirium and the negative effects of immobility (Stiller & Phillips, 2003).

Therefore, the PI²U-Bed is designed as a modularized smart bed integrated with various functions, such as movable table, verticalized bed, breath detection, and pressure sensors. It integrates the modularity function, which features the ability to connect other functional modules such as bathing, privacy, and dining. It also features a screen that allows visualization and in-bed training function (see Figure 27:andFigure 28).

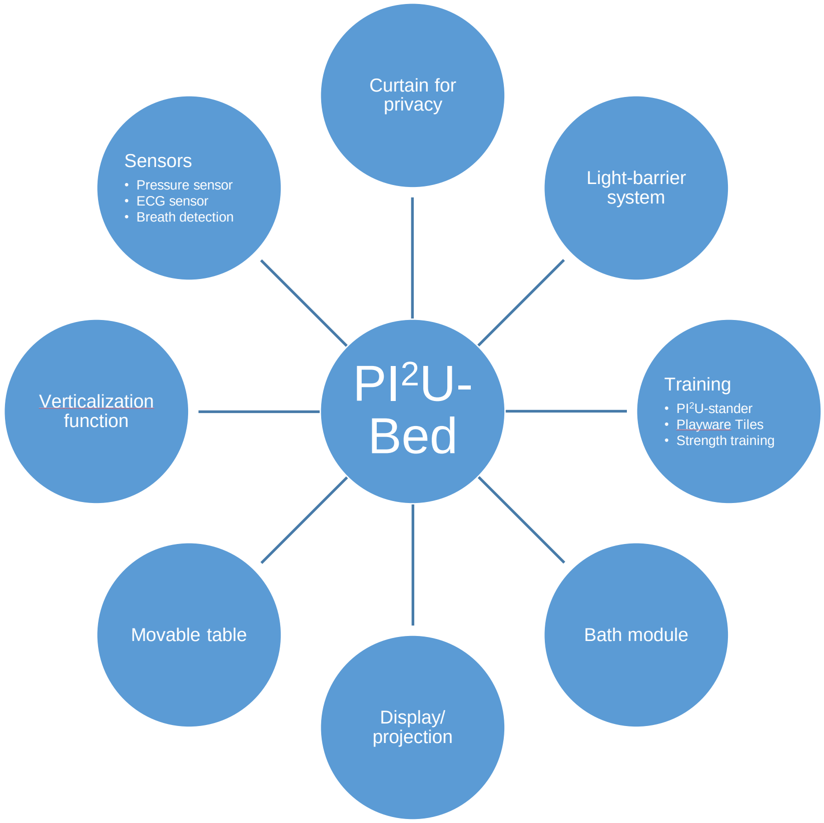


Figure 27: Functions to be integrated into PI²U-Bed platform

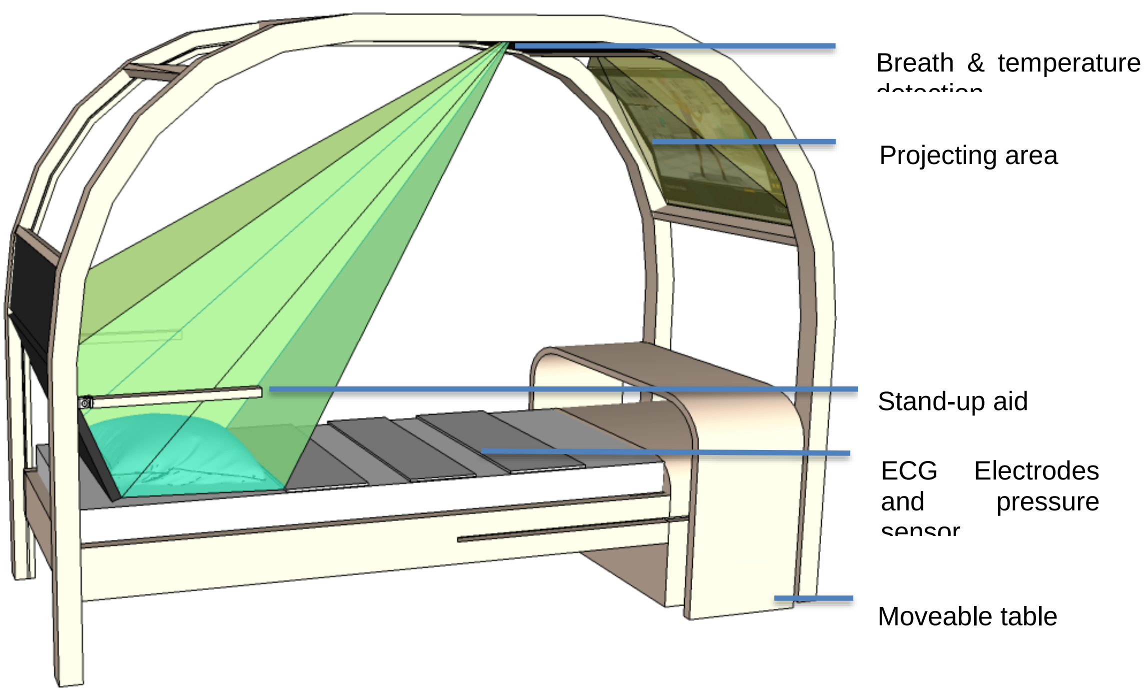


Figure 28: Initial visualization of the PI²U-Bed

5.3.3 Simulation of the PI²U home applications

In Figure 29:, the PI²U-miniArc as well as the PI²U-Bed are installed in a private apartment. The user is enabled to perform a physical training program with the help of the PI²U-Stander and the Playware Tiles, following the instructions displayed on the wall from the PI²U-miniArc. Meanwhile, the PI²U-Stander also serves as a mobility device for the patient's transfer between different locations in the room.

In the night time when the user rests, sensors such as breath detection, ECG, and pressure sensor on the mattress ensure that the patient to have a safe and sound sleep. Once abnormal event occurs, the system can make sure that e.g. relatives or responsible caregiver will be informed as soon as possible. Thus, the application of the PI²Us establishes an autonomous care environment in the care room.

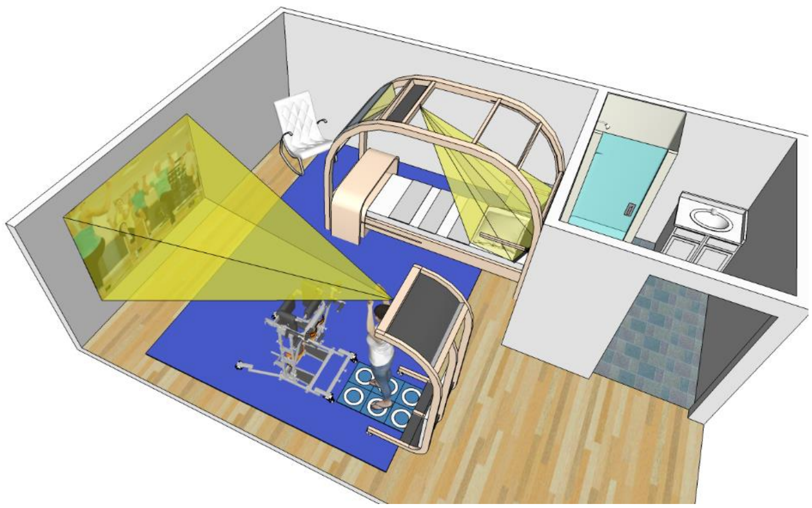


Figure 29: Simulation of PI²Us application in the community kitchen scenario.

6 Conclusion

The work carried out in **T5.1** task is ongoing and will not be concluded until **M36**. The requirements that come out of the work made so far are therefore *intermediate* and will be refined during the further work.

The requirements detailed in this report center around the PI²U concept and are therefore not requirements to the overall REACH systems architecture. Nevertheless, the PI²U is central in the REACH system and may be seen – in a wider perspective - as the central *Sensing and Engagement Environment* which the REACH project is developing.

In D5/T2.1 is contained a matrix analysis for sensing systems and we thus primarily focus in this summary on "engagement", that is, the social and motivational involvement of the elderly target users in physical activation in their specific social care context.

The Use Cases (Chapter 2) serve to illustrate that the Physical Activation Dimensions share commonalities across the four Touchpoints. The overall functions that must be supported are:

- one-off alarm to alert caregivers (professional or informal caregivers such as friends and family) that a (relatively) sudden deviation from normal pattern of behavior has been recorded
- detection of longer term activities to establish normal behavioral patterns
- device integrated automatic identification of critical trends or deviations from normal behavioral patterns

In addition to these overall functions of detection, the sensing environment supplies motivational feedback to the elderly users – for instance, in the form of nudges and context-dependent recommendations.

The early trials (Lyngby 1 and 2 – Chapter 2) were used to investigate reactions of the elderly to close monitoring 24/7 over long periods (8-10 weeks) and the feasibility of using wearables as an indicator (one among several to be introduced over the project duration) of physical activity. It was shown that feedback to the elderly of the amount of activity the day before had no effect on feedback. Therefore, feedback must be much more motivational and more timely, such as being tied to the present day or some short term goals.

An important user group is the somewhat heterogeneous group of professional caregivers including nurses, nurse assistants, doctors, physiotherapists, ergotherapists etc. In Chapter 3 we report on interviews with representatives of this group. Our interviews indicate that the professional care givers find high value in being able to monitor several of their patients or clients simultaneously. Their requirements concern easy-to-understand overview and a proper management of false positives and low probability of false negatives.

In Chapter 4 we reported outcomes from early trials about elderlies' reactions to playful exercise and their views in on privacy issues. Important requirements from the playful exercise trial is that the elderly seem to prefer exercising in groups, that most of them like to "compete" against themselves and therefore want to see progress from session to session, that some of them want to have a wide selection of physical activity options. With respect to privacy the elderly tend to regard the benefits and drawbacks of privacy and monitoring as a tradeoff: they prefer to allow private data be shared– under agreed terms and with assurance of transparency about sharing data – for the purpose of greater security. Moreover, many of the elderly are curious about getting access to their own activity data, but they have little confidence in their ability to manipulate and make use of devices for a younger public.

We also provide in Chapter 4 an overview of the choice points when ethical issues arise during a patient's journey for each of our four REACH touchpoints.

In Chapter 5 the PI²U architecture is described and illustrated. The different sensing and activation interiors – the PI²Us/Smart Furniture - are used to integrate REACH key functionality (wearable and ambient sensors; feedback), activities, and functional elements seamlessly into the different REACH health care environments

7 Bibliography

Alexander, I. (2006). A taxonomy of stakeholders, human roles in system development. *Issues and Trends in Technology and Human Interaction*, 25-71.

Baldwin, C. Y., & Clark, K. B. (2000). *Design Rules, Vol. 1: The Power of Modularity.* Cambridge: MIT Press.

Bardoua, M. (2017). Modern approach to infectious disease management using infrared thermal camera scanning for fever in healthcare settings. *Journal of Infection*, 95-97.

Berg, K. W.-D. (1989). Measuring balance in the elderly: preliminary development of an instrument. *Physiotherapy Canada, 41*(6), 304-311.

Berg, K., Wood-Dauphinee, S., & Williams, J. I. (1995). The Balance Scale: reliability assessment with elderly residents and patients with an acute stroke. *Scandinavian journal of rehabilitation medicine, 27*(1), 27-36.

Bliwise DL. (2004). Sleep disorders in Alzheimer's disease and other dementias. Clinical cornerstone. *Suppl 1A:S16-28*. Retrieved from https://doi.org/10.1016/S1098-3597(04)90014-2

Bourne L. (2015). Making projects work: Effective stakeholder and communication management. *RC Press Auerbach Publications*.

Brenner, N. S. (1992). The stakeholder theory of the firm.

Brubaker, P. H., Rejeski, W. J., Smith, M. J., Lamb, K. A., & Sotile, W. M. (2000). A home-based maintenance exercise program after center-based cardiac rehabilitation: Effects on blood lipids, body composition, and functional capacity. *Journal of cardiopulmonary rehabilitation, 20*(1), 50–56.

Cohen-Mansfield, J., Marx, M. S., & Guralnik, J. M. (2003). Motivators and barriers to exercise in an older community-dwelling population. *Journal of Aging and Physical Activity*.

DSMweb.org. (n.d.). *Design Structure Matrix (DSM)*. Retrieved April 4, 2017, from http://www.dsmweb.org/en/understand-dsm/tutorials-overview/descripton-design-structre.html

DW Byrne, C. S. (1996). Major risk factors for pressure ulcers in the spinal cord disabled: a liturature review. *International Medical Society of Paraplegia* .

European Commission, T. (2008-2010). *Ministry of Social Welfare-Ministry of Health and Prevention. National Report on Strategies for Social Protection and Social Inclusion. Denmark.*

Firesmith, D. (2013, November 11). *Using V Models for Testing*. Retrieved March 26, 2017, from https://insights.sei.cmu.edu/sei_blog/2013/11/using-v-models-for-testing.html

Godino, J. G., Watkinson, C., Corder, K. M., Sutton, S., Sharp, S. J., Griffin, S. J., & van Sluijs, E. M. (2013). Impact of Personalised Feedback about Physical Activity on Change in Objectively Measured Physical Activity (the FAB Study): A Randomised Controlled Trial. *PLoS ONE, 8*(9).

Godino, J. G., Watkinson, C., Corder, K., Sutton, S., Griffin, S. J., & van Sluijs, E. M. (2014). Awareness of physical activity in healthy middle-aged adults: a cross-sectional study of associations with sociodemographic, biological, behavioural, and psychological factors . *BMC Public Health, 14*(1), 421.

Goedkoop, M. J., van Halen, C., te Riele, H., & Rommens, P. (1999). *Product Service systems, Ecological and Economic Basics.* Pre Storrm C.S.

Harer, J. (2014). *Anforderungen an Medizionprodukte.* München: Hanser GmbH.

InLoox. (n.d.). *Agile Project Management Methods: With reliable flexibility to project success: A guide on agile project management and how it helps you achieve great things at work*. Retrieved April 4, 2017, from https://www.inloox.com/agile-project-management/

International Standards Office. (2011, 12 1). *ISO/IEC/IEEE 42010: Systems and software engineering - Architecture description.* Retrieved April 4, 2017, from http://cabibbo.dia.uniroma3.it/asw/altrui/iso-iec-ieee-42010-2011.pdf

Jacobsen, I. L. (2004). Yesterday, today and tomorrow. *Software and Systems Modeling, 3*(3), 210-220.

Jacobson I. (2004). *Use cases–Yesterday, today, and tomorrow. 2004. Software and Systems Modeling.*

Jones, C. J. (2002). Measuring functional. *The Journal on active aging, 1*, 24-30.

Jose & Tollenaere. (2005). modular and platform methods for product family design: literature analysis. *journal of intelligent Manufacturing. June, Volume 16, Issue 3*, 371-390.

Kang, M., Marshall, S. J., Barreira, T. V., & Lee, J. O. (2009). Effect of pedometer-based physical activity interventions: A meta-analysis. *Research Quarterly for Exercise and Sport, 80*(3), 648–655.

Langford, G. O. (2012). *Engineering Systems Integration: Theory, Metrics, and Methods.* Boca Raton : CRC Press.

Lechner, L., Bolman, C., & Van Dijke, M. (2006). Factors related to misperception of physical activity in the Netherlands and implications for health promotion programmes. *Health Promotion International, 21*(2), 104–112.

Leffmann, et al.,. (2002). Gesundheitsberichterstattung des Bundes: Heft 12. Retrieved May 20, 2017, from http://www.gbe-bund.de/gbe10/ergebnisse.prc_tab?fid=8056&suchstring=Dekubitus&query_id=&sprache=D&fund_typ=TXT&methode=2&vt=1&verwandte=1&page_ret=0&seite=&p_lfd_nr=1&p_news=&p_sprachkz=D&p_uid=gast&p_aid=58390244&hlp_nr=3&p_janein=J

Linner, T. (2017, Januar). Lecture "Design for production, Assembly, and disassembly" .

Mascitelli R. (2007). *The lean product development guidebook; everthing your design team need to improve efficiency and slash time-to-market.* Northridge: CA: Technology Perspectives.

Misra & Singh . (2009). loneliness, depression and sociability in old age. *Industrial Psychiatry Journal jan-Jun* , 239-257.

Mitchell, R. K., Agle, B. R., & Wood, D. J. (1997). Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts. *Academy of management review, 22*(4), 853-86.

Moran, A. (2015). *Managing Agile: Strategy, Implementation, Organisation and People.* Heidelberg: Springer International Publishing.

NASA. (2007, December). *NASA Systems Engineering Handbook.* Retrieved April 4, 2017, from https://www.google.de/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwijx7Ttt_zSAhXLWSwKHfahCVkQFggoMAA&url=http%3A%2F%2Figs.nigc.ir%2FSTANDS%2FBOOK%2FHB-NASA.PDF&usg=AFQjCNEqquFnIx1L9irCl3XApi6Fq9s2kA&cad=rja

NASA. (2012). *Technology Readiness Level*. Retrieved April 04, 2017, from https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html

Nicholls, G., Lewis, N., & Eschenbach, T. (2015, May 6). Determining when simplified Agile Project Management is right for small teams. *Engineering Management Journal*, pp. 3-10.

Northrop Grumman Corporation. (2011, November). *Best Practices for Systems Integration.* Retrieved April 4, 2017, from https://www.google.de/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwi7kJzeuPzSAhUBPSwKHRiiBaAQFggrMAA&url=http%3A%2F%2Fwww.dtic.mil%2Fndia%2F2011%2Fsystem%2F13007_HouserThursday.pdf&usg=AFQjCNFltrkLjgjyJI9WkpVrQqrcIRFq-w&cad=rja

Osborne, L., Brummond, J., Hart, R., Zarean, M. (., & Conger, S. (2005, October). *Clarus: Concept of Operations.* Retrieved April 4, 2017, from https://ntl.bts.gov/lib/jpodocs/repts_te/14158_files/14158.pdf

Philips Design & Innovation Communications KPNV. (2017). Experience Flows Understanding people and their experiences to deliver meaningful innovations [Internet], [cited 30.05.2017]. Retrieved from Available from: http://www.newscenter.philips.com/pwc_nc/main/design/resources/pdf/Inside-Innovation-Backgrounder-Experience-Flows.pdf

Polonsky, M. J. (1996). Stakeholder management and the stakeholder matrix: potential strategic marketing tools. *Journal of Market-Focused Management, 1*(3), 209-29.

Rikli, R. E., & Jones, C. J. (1999). Development and validation of a functional fitness test for community-residing older adults. *Journal of aging and physical activity, 7*(2), 129-161.

Rikli, R. E., & Jones, C. J. (2013). *Senior fitness test manual.* Human Kinetics.

Ronda, G., Van Assema, P., & Brug, J. (2001). Stages of change, psychological factors and awareness of physical activity levels in the Netherlands. *16*(4), 305–314.

S. L. Bennett. (2015). The detection of breathing behavior using Eulerianenhanced thermal video. *37th Annual international conference of IEEE Engineering in medicine and iology society.* Milan.

Sauser, B., Verma, D., Ramirez-Marquez, J., & Gove, R. (2006). From TRL to SRL: The Concept of System Readiness Levels. In *Conference on Systems Engineering Research.* Los Angeles.

Schmeer K. (1999). Stakeholder analysis guidelines. Policy toolkit for strengthening health sector reform. 1-43.

Stiller & Phillips. (2003). Safety aspects of mobilising acutely ill patients. Physiotherapy Theory and Practice. *19*, 239-257.

van Sluijs, E. M., Griffin, S. J., & van Poppel, M. N. (2007). A cross-sectional study of awareness of physical activity: associations with personal, behavioral and psychosocial factors. *International Journal of Behavioral Nutrition and Physical Activity, 4*(1), 53.

Vermeulen, Neyens & Rossum. (2011). Vermeulen J, Neyens JC, van Rossum E, Spreeuwenberg MD, de Witte LP. Predicting ADL disability in community-dwelling elderly people using physical frailty indicators: a systematic review.

VersionOne. (n.d.). *Agile Project Management: Agile Project Management Done Right!* Retrieved April 4, 2017, from https://www.versionone.com/agile-project-management/