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***Deliverable D1.2*:** Stakeholder networks, motivational strategies (promoting physical health), sensor technologies for monitoring daily activity; early user involvement trials, outline of implications for and applicability in REACH **(associated with task T 1.2)**

Abstract: This deliverable report presents three key contributions and a preview of a fourth. The approach of the report is complementary to the bottom-up approach of **D1.3** that has identified "Touchpoints" and "Engine functionality" based on stakeholder workshop results. While this task continues the work of **T1.1,** which made a basic stakeholder analysis and developed personas for each of the four demonstration, we seek to complement the results of **T1.3.** In doing so, the work behind this report refers back to the original objective of the REACH project: reducing the risk of functional impairment or loss by elderly citizens by sensor-based and motivational socio-technical solutions that support the preservation of functional ability of elderly citizens in order that they may continue living independently as long as possible. Pursuing this overall objective, **T1.2** has made a detailed stakeholder analysis of the four REACH demonstration sites in order to uncover differences in roles, interests, incentives and concerns. A second key contribution is a review of current knowledge of motivational techniques and models to identify those that are most promising in the REACH context and thus to promote physical activity and reduce risk of functional loss; and the third key contribution is a review of technologies to pick up signals of beginning functional loss and activity status by stationary or wearable sensors. Finally, we describe plans and status of early trials involving users and conclude with a summary of the implications and expected risks and benefits.

Lead Partner: DTU
Participants: DTU (1,5 PMs); Tu/e (2,5 PMs); Kop (1PM); Alreh (1PM); Philips (3PM); ZZ (1PM); Lyngby (1PM); HUG (5PM).
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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	Define scope, lead task, lead stakeholder and sensor analysis, contribute to motivation, collect early trials data
Tu/e	Coordinate between 1.2 and 1.3, co-lead stakeholder analysis, contribute to motivation, early trials
Kop	Contribute to early trials
Alreh	Observer
Philips	Contribute to motivation analysis
ZZ	Contribute to motivation analysis and stakeholder analysis
Lyngby	Contribute to early trials and stakeholder analysis
HUG	Lead motivation analysis and contribute to stakeholder analysis
TUM	Major review, coordination and links with other tasks

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Key Expressions

Accelerometer: an instrument for measuring the acceleration of a moving or vibrating body. Lately, some smartphones, digital audio players and personal digital assistants contain accelerometers for user interface control.

Algorithm: a step by step process or set of rules to be performed in calculations, other problem-solving operations, especially by a computer.

Application program interface (API): is a set of routines, protocols, and tools for building software applications.

Behavior Change Wheel: Michie's Behavior Change Wheel (BCW) represents 9 dimensions in successful introduction of changes in behaviour and culture at the level of individuals, communities and populations.

Care continuum: refers to the fluent transitions between pre-acute care, acute care, and post-acute care and to the natural way of elderly citizens/patients though health states, settings, care-need levels, and institutions (cf. D1.1, Section 6.1).

Confidentiality: the right of an individual to have personal, identifiable medical information that is given to a health care provider kept secret and not disclosed to others unless the individual has given specific permission for such release.

Contextual sensors: Sensors measure qualitative environment data, such as GPS and RFID.

Core user: end users.

End-user: the person(s) whose needs (for a given context) that a given system or design is primarily developed to support.

GPS (The Global Positioning System): a satellite-based navigation system made up of a network of 24 satellites placed into orbit. Many commercial applications use one or more of GPS's three basic components: absolute location, relative movement, and time transfer.

Key stakeholder: stakeholders who do not belong to Primary stakeholder nor Secondary stakeholder but who are significant affected by the action. In REACH they influence the end user or end user's usage of REACH system and subsystem.

Machine learning: a method of data analysis that automates analytical model building. Using algorithms that iteratively learn from data, machine learning allows computers to find hidden insights without being explicitly programmed where to look.

Moderate activity: light physical activities such as lying, sitting, standing, walking, house chores and outdoor walking.

Movement sensors: sensors detect movements, such as accelerometers and infrared light. They are the most widely used sensors in detecting human physical activities and are primarily used in-door.

Onion diagram: one of the three templates used in REACH stakeholder analysis. Onion diagram is a visual representation which shows relations among stakeholders with the target items (cf. End user).

Outlier: originally used in statistical expression, which is an observation point that is distant from other observations and sometimes excluded from the data set as an error. Outlier in sensor technology in healthcare context is often used as outlier pattern or outlier events which indicate unexpected happenings and things to be paid attention.

Physiological sensors: sensors which are used for more clinical purposes such as taking blood pressures, body temperatures, blood chemistry.

Primary stakeholder: stakeholders who are directly affected by an action (an intervention, a sociotechnical design or service). In REACH, they influence the end user, or end user's usage of REACH system and subsystem.

Privacy: is people's right to keep their personal matters and relationships to themselves including their right to determine whether, when, how, and to whom, their personal information can be shared.

Privacy by design: is an approach to systems engineering which takes privacy into account throughout the whole engineering process. The concept is an example of value sensitive design, i.e., to take human values into account in a well-defined manner throughout the whole process.

Promotion focused: promotion focused persons are concerned with growth and development (compare prevention focused).

Prevention focus: prevention focused people are driven by a need for security (compare Promotion focused).

Regulatory focus theory (RFT): considers that the way in which people move toward pleasure and avoid pain changes depending on the needs they are trying to satisfy, based on their individual self-regulation focus, either promotion or prevention focus.

RFID (Radio-frequency identification): uses electromagnetic fields to automatically identify and track tags attached to objects. The tags contain electronically stored information.

Secondary stakeholder: stakeholders who are indirectly affected by the action. In REACH they influence indirectly or weakly the end user, or end user's usage of REACH system and subsystem.

Societal differences: are differences between countries or regions in terms of economic, social and cultural structures.

Stakeholder analysis: identify stakeholders through relational attributes such as relational proximity, and power/influence and interests/involvements. In REACH, the relation with the end user, 65 + seniors is analysed.

Stakeholder list: one of the three templates used in REACH stakeholder analysis. Stakeholder lists are often used as a first step in stakeholder analysis to understand the roles, interests, concerns and influences of stakeholders.

Stakeholder matrix: one of the three templates used in REACH stakeholder analysis. Stakeholder matrix is a 2 by 2 matrix which indicates relative relations with possible communication strategies to stakeholders. The most common attributes in the stakeholder matrix are power/influence, and interests/involvement.

Stakeholder: group or individual who can affect or is affected by the REACH system, and REACH subsystem.

Treatment stage: a stage in the continuum of care for of the individual patient, where a treatment stages range over pre-acute care, acute care, and post-acute care typically at home.

Wearable sensor: sensors which can be attached to human body such as waist, hip, wrist, head and other locations of body. Consumer products, such as the Apple watch, Fitbit are widely available.

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1 Background and task definition

1.1 Background

In the REACH project a sensing-monitoring-intervention system will be developed that can be placed in an unobtrusive manner in various care settings and living environments of elderly citizens. The system will be able (1) to use a set of sensors to detect selected vital signs, behavioural/care patterns, and health states, (2) predict – as early as possible - future health states, risks or events (loss of function, frailty, stroke, etc.) and (3) 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 and playful activities - for the purpose of preventing or delaying functional loss and, correspondingly, reinforcing functional ability of the elderly.

Early intervention by REACH should allow that the time spent in a desirable health state (baseline health), and Healthy Life Years (HLYs) are increased and that the time spent in Long-Term Care (LTC) facilities is reduced. In that context, it will be shown that REACH can improve and speed up, on the one hand, the physical and cognitive rehabilitation of elderly citizens in deteriorated health states or suffering from a sudden incident, for example, by speeding up their transfer from acute care to rehabilitation to home care as well as their health state improvement within one of these institutions. On the other hand, it will be demonstrated that REACH can be utilized in home/ home care contexts to keep people as long as possible in a desired base-line health state, mitigate the risk of deterioration, and finally slow down or prevent deterioration.

In order to develop the above-mentioned features in a target oriented manner REACH, integrates various stakeholders such as knowledge providers (research, universities) technology providers (sensors, prediction, intervention mechanisms), multiplicators (insurances, standardization organizations, etc.), and solution operators (clinics, rehabilitation centers, home care and care home providers) into a joint development team. REACH will carry out the development of the mentioned features within four years, through nine work packages and in three iterative development cycles (phase 1: mock-ups and lab testing of single technologies; phase 2: mock ups and short term tests with sub-systems in real-world environments; phase 3: system prototype long term testing in real-world environment). The four solution operators (in the context of this report called “use cases” since they reflect concrete application cases for the REACH system) Geneva Hospital (HUG), Schön Klinik (SK), ZuidZorg (ZZ), and Lyngby-Taarbæk Municipality (Lyngby) that are part of the REACH consortium, in that context reflect two dimensions:

1. **Health state dimension:** the four use case partners represent the most relevant ways of transfer possibilities of elderly through various health states and institutions (e.g. from hospital to rehabilitation to home in case of a health state improvement; alternatively, from home to hospital/rehabilitation in case of a health state deterioration). The REACH system should be able to move with the elderly through the various health states/institutions.

2. **System development dimension:** the four use case partners represent the development strategy. Development will in the beginning phases of the project target the

more “structured environments” (clinic/HUG; rehabilitation/SK) since here requirements are more obvious and system features are easier and faster to be verified and validated. These technically complex solutions can then in later project phases be stepwise (in an adapted and simplified form) transferred into the home care (ZZ and Lyngby) use case contexts and open new markets in this fields for the REACH industry partners.

The overall guiding idea of the REACH project is worth repeating and spelling out: the ambitious and relatively wide-ranging objectives of REACH have a common denominator (described as well in the proposal and Description of Action (DoA)). This is to reduce the risk of functional loss or impairment of elderly citizens (65+) by sensor-based monitoring and promoting physical activity. Thus, by using sensor and detection technologies to support motivational reinforcement of physical activity and, in turn, the functional ability of the older adults this is expected to prolong independent living or, when relevant, speed up physical rehabilitation. (The concept of “functional ability” is a convenient broad term to denote the opposite (negation) of functional impairment or loss), The goal and approach are summed up in the accompanying graphics: **Figure 1-1,** in which we illustrate how activity is both monitored and promoted. We monitor in order to predict and intervene against frailty, and we intervene by supporting and promoting physical (and social, playful and otherwise engaging) activities – for the purpose of preventing loss of function that is interlinked with a wide variety of afflictions characteristic of aging.

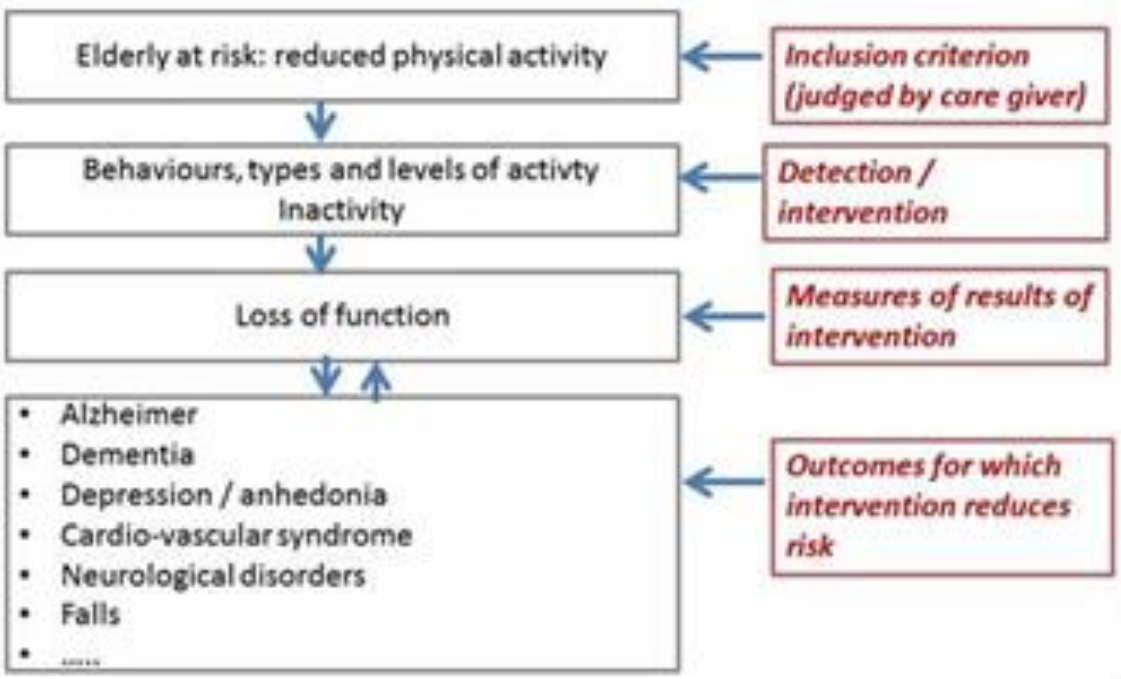

Figure 1-1: REACH objectives and measures of results

This conception of functional ability (prevention or postponement of functional loss or impairment) is reflected in the literature where definitions of healthy ageing include survival to a specific age, being free of chronic diseases, autonomy in activities of daily living, wellbeing, good quality of life, high social participation, at most mild functional impairment, and little or no disability (**Fuchs et al 2013, Kuh 2007**). There is a large body of scientific literature that supports the proposition that “physical activity is medicine for the elderly” (**Taylor, 2010**) – including recent studies cited in the References **Section 7.1** of this chapter.

1.2 Task definition

The task definition of **D1.2** (as per REACH Amendment No. 2) is the following:

Current knowledge of interventions involving sensor-based monitoring and motivational techniques to reduce inactivity and associated risks will be mapped onto a range of older citizen journeys for selected use cases: older citizens at risk of developing frailty either living at home or temporarily at a rehabilitation facility. Associated stakeholder benefits and risks (costs, unintended negative consequences, social isolation, and privacy violation) are analysed.

A separate subtask includes a summary of current evidence behind different methods of activity monitoring and intervention (what is feasible, what has worked, what has not) for physical rehabilitation and associated motivational strategies and techniques. The consequences of implementing the most promising activity engagement (physical rehabilitation) methods and techniques are analysed in terms of benefits and risks/costs for stakeholders (older citizens, close informal care givers, and formal care providers).

A further separate subtask includes results of user involvement and early trials at partner sites involving older users and their caregivers for the purpose of gaining insights into acceptability, activity patterns from the use of wearables and other devices.

Thus, the main body of this report comprises four contributions:

1. Stakeholder Analysis to provide an overview of constraints, incentive structures, interdependencies among stakeholders (input to **T1.4** and **WP2/3** in particular).

2. A review of current knowledge of motivational and persuasive techniques to promote physical activity (input to **T1.4** and **WP4** in particular).

3. A review of current knowledge of sensor-based monitoring of physical activities of elderly citizens living at home or in care-homes (input to **T1.4** and **WP2** in particular).

4. A description of early trials and their objectives for the purpose of planning and executing future user trials (input to **T1.4** and **WP4/6/7** in particular).

1.3 Relation to other tasks

In the first 14 project months, **WP1** will detail (Milestone 2) the REACH concept and system design before the individual subsystems, in **WPs 2-5**, shall be developed and subsequent system integration and testing/demonstration shall be conducted **(WP6). WPs 7, 8** and **9** are concerned with cross sectional topics such as usability, ethics, safety, security, business models and project management.

WP1 consists of four work tasks and will follow a systematic system development approach. First, as part of **T1.1** (outlined in this deliverable report) the as-is situation of the four use cases will be analysed, relevant problems and stakeholders will be identified and initial,

concrete use scenarios will be formulated. Second, **T1.2** will detail the system vision including stakeholder analysis and reviews of early trials, current knowledge of sensor based monitoring and motivational / persuasive technologies. In **T1.3** requirements were prioritized and selected, and the initial value proposition and product-service-system concept was developed together with the stakeholders. Finally, in **T1.4** the overall product-service-system architecture (modularity, standards, software architecture, etc.) will be detailed.

This deliverable report builds upon and expands the results of **T1.1/D1.1**, building upon the use case analysis and the challenges presented therein, and explores the stakeholder context and the current medico-technical and social knowledge relevant for possible solutions, including efforts of the consortium to perform early test of hypotheses. At the same time, **D1.2** is closely tied to the efforts in **D1.3** elaborating the service-system architecture, and it will deliver, together with D1.3, the input for the final requirements to be developed in **T1.4/D1.4**.

2 Stakeholder analysis

We have conducted stakeholder analysis in the four REACH user sites. By utilizing shared formats, the analysis aims at showing stakeholders in figure in the same framework for comparison, and making individual locations comparable. Based on the identification of stakeholders conducted in **T1.1**, an in-depth stakeholder analysis was conducted in **T1.2**. In this section, Stakeholder analysis carried out as a part of **T1.2** deliverable is reported.

Previously, in **T1.1 (2.1 p.12, 3.1.2 p.32, 3.2.2 p.43, 3.3.2 p.55,** and **3.4.2 p.77** in **D1.1)** an initial stakeholder identification was made with basic Actors Maps for each of the four REACH demonstration and test sites. This has been a useful initial step, but a more detailed analysis is required that allows for comparisons across sites and contexts. Therefore, in **T1.2** we have identified and characterized roles, relations and as well the relative distance among stakeholders by utilizing three identical analysis templates in each location so that cross locational analysis could also be possible.

The step stakeholder analysis performed in **T.2** aims at understanding similarities and differences among the four sites to support shared understanding among consortium members of constraints, incentive structures, interdependencies among stakeholders and thus the space in which the REACH solution shall seek to meet unmet needs, both rational-somatic and emotional-social, of the users. The stakeholder analysis should not be expected to provide at future-scenario analysis (e.g., how the REACH system would work in practice 5-10 years in the future on the assumption that the service were to be used by a majority of target users); 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.

2.1 Stakeholder Analysis

There are many ways to analyse stakeholders and a number of methods and associated templates, including the present ones, have been used widely in stakeholder management setting and in user centered system design. The purpose of conducting stakeholder analysis can vary from situation to situation. However, it is typically argued that the analysis is carried out for identifying primary stakeholders who are directly influenced by an action (an intervention, a sociotechnical design or service), secondary stakeholders who are indirectly affected by the action, and key stakeholders who do not belong to the former two groups but who have significant influence on the action (use of the sociotechnical design).

For the REACH personalized prevention and intervention system aimed at 65+ seniors, it is important to identify and characterize their influencing relations (family, friends, caregivers) who may have power to aid and persuade the elderlies, and who may have an interest in care and assistive technologies for both altruistic and selfish reasons - to be identified through the stakeholder analysis. Similarly, establishing mutual understanding in the REACH project team of stakeholder roles and interests is also important.

To ensure maximal benefits from a stakeholder analysis while keeping the scope at a manageable and practical level, we have selected three stakeholder templates. They are (a) the list of stakeholder characteristics, (b) the onion diagram and (c) the stakeholder matrix.

Since each of the local REACH demonstrations sites has had to work independently with the templates, it is fundamental that they are, on the one hand, simple and easy to use even for analysts who are not familiar with stakeholder analysis, and on the other, still sufficiently powerful (expressive, informative) for our purpose. In the following, each template will be explained.

Stakeholder lists (e.g., **Brenner, 1992; Schmeer, 1999**) are a simple table with stakeholder characteristics as shown in **Figure 2-1.** Stakeholder lists are often used as a first step to understand the roles, interests, concerns and influences of stakeholders. The list is made to understand who the stakeholders are and to record relevant, basic information of each stakeholder – not least to support the basic understanding among project members and to interact with stakeholders. The list helps project members to maintain a whole picture of stakeholders over time. From this perspective, it is clear that making the list of stakeholders and their roles, interests etc. is not the ultimate purpose, but utilizing it is critical. The list is used to communicate within project members and other stakeholders over the REACH system development period by reminding one another that stakeholders who are not in the discussion shall not be neglected. Moreover, different sites who are superficially similar may turn out to have either different configurations of stakeholders or different characteristics (interests, powers of influence, incentives).

	Charac-teristics	Role	Interests	Knowledge	Expecta-tions	Influence	Tangible incentives	Intangible incentives	Risks
	Type of stakeholder (some types not relevant at all sites)	Role in relation to end-user	Types of interests relevant to the use of the technology	Knowledge needed to support the use of the technology	Initial motivations for using the technology	Influence om uptake / use of the technology. Scale of 1(No influence) to 10 (Strong influence)	The obvious/ short-term incentives	The long term incentives (typically subconscious)	Potential risks involved in using the technology
S1	Senior								
S2	primary informal care giver								
S3	Professional caregivers								
S4	GP								
S5	Municipality								
S6	System provider								
...									

Figure 2-1: Stakeholder List format

The Onion diagram (**Alexander, 2006; Bourne, 2015**) is a visual and graphical representation which shows a relational map of stakeholders with the target end-users (65 + seniors), in the center as shown in
Figure 2-2. The Onion diagram is widely used in practice to appeal visually physical and mental relative distance and relations in user centered perspective, and expected to be used to consider system design in user centered matter. For example, *Microsoft Visio* offers the onion diagram template in its basic setting, and UN women, and other companies and organizations also use these diagrams (**UN Women, n.d.**) The chosen onion diagram has three layers with the central target, 65 + senior, with information/money flows. The first layer is a business system, where stakeholders with the direct impacts to the core target are

allocated. The second layer is organization, in which stakeholders within the same system are allocated. The third layer is environment, in which stakeholders in the same eco system with the core target are allocated. The information and money flow is additional for the diagram, which are supplementary to understand relative distance and its relations.

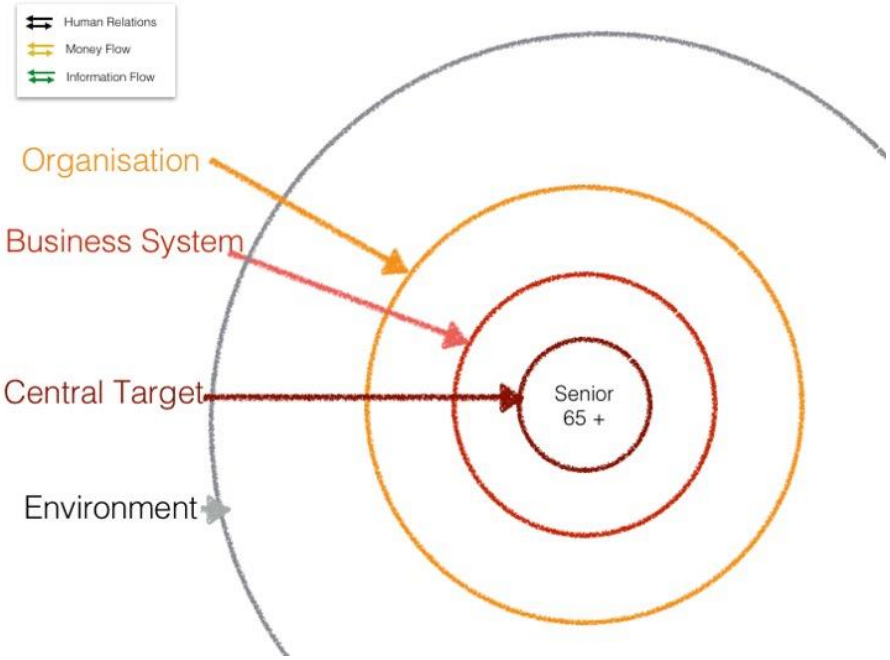

Figure 2-2: Onion Diagram Format

The Stakeholder matrix (e.g., **Polonsky, 1996; Mitchell, R. K et al, 1997**) is a 2 by 2 matrix which indicates relative relations with possible communication strategies to stakeholders. As shown in **Figure 2-3**, the X-axis indicates the degree of power and influence while the Y-axis indicates the degree of interests in using the REACH system. Depending on the allocation of stakeholder within each quadrant, the communication and collaboration strategy would differ (see **Figure 2-3**). This matrix is often used in marketing analysis in order to establish marketing strategy for a new service and products. REACH has different characteristics, however, and this stakeholder matrix is useful for a several reasons, such as a support of making better strategic plan and decisions over designing REACH systems. It is often the case in designing large-scale systems where multiple stakeholders have a different weight in influence/ power/ interests/ involvements. For example, some stakeholders with a strong influence can show less presence in their activity. Nevertheless, they should be keep informed of the critical decision making process. To serve all stakeholders at the desired level and get their supports and collaboration, the matrix is expected to be used as a tool to support good communication over the design process.

Figure 2-3: Stakeholder Matrix format

2.2 Stakeholder Analysis Approach and Process

This section introduces how this stakeholder analysis approach was conducted in each of the four REACH sites (Approach) and how the analysis was processed step by step (Process).

2.2.1 Approach

In the period of September to December 2016, stakeholder analysis with three templates was conducted in four REACH locations: Schön Klinik Bad Aibling, Germany, ZuidZorg, Holland, Lyngby-Taarbæk Municipality, Lyngby, Denmark and Geneva Hospital, (HUG), Switzerland. Key partner participants at each location who have in- depth knowledge about core users, stakeholders and related context performed the task. The responsible persons in four different locations received the three templates as well as an instruction document for conducting stakeholder analysis with self-help. In each location, the key persons would contact core end-users and stakeholders and discuss together with other local consortium members to describe stakeholders in three templates.

2.2.2 Process

The instruction for conducting the stakeholder analysis urged analysts to proceed follows:

- Step 1: List up stakeholders with characteristics (Stakeholder List; Role, Interests, Knowledge, Expectations, Influence, Tangible incentives, Intangible incentives, and Risks)
- Step 2: Prioritize stakeholders in the relative scale with the central end-user, 65 + seniors (Onion Diagram).
- Step 3: Represent each stakeholder and its influences for further strategy planning (Stakeholder Matrix).

2.3 Stakeholder list

To make a stakeholder list requires, first, entering each of the directly involved stakeholders as well as the most important key ones, and next, for each stakeholder describe each of the eight aspects **Figure 2-1**. Role, Interests, Knowledge, Expectations, Influence, Tangible incentives, Intangible incentives, and Risks. The aspects are meant to capture not only the relatively obvious characteristics but in particular also the more implicit ones.

The constellation of stakeholders may be expected to be different from location to location and setting to setting, and the individual properties may also be expected to vary to some extent.

- Role is the stakeholder's role toward the end-user, and is relatively self-explanatory. Interests is meant to describe the stakeholder's interests in the use of the REACH system. The relevant question is that what kind of interests they have in the functions and services afforded by the technology.

- Knowledge is meant to describe the stakeholder's knowledge needed to utilize the REACH system. The relevant question is both what kind of knowledge they need to have and also what kind of knowledge do they already have to support the use.

- Expectations is meant to clarify the stakeholder's initial motivation to utilize REACH system – thus, the relevant question is what is their initial motivations for either engaging in or supporting use of the system.

- Influence is meant to represent the influence of the stakeholder on the use of the system. The relevant question is how much influence do they have on the uptake and acceptance in both the short and long term. This aspect is described in a scale of 1 (no influence) to 10 (strongest influence).

- Tangible incentives are meant to represent the stakeholder's incentive for having the system being used (own use or use by others), and hence the relevant question is what are the obvious and overt incentives.

- Intangible incentives are meant to uncover further and possibly not so explicit incentives for the use of REACH. The relevant question is therefore what are the possibly non-overt and non-concrete and possibly long-term incentives that this stakeholder may have in the system being used. The answer could often be incentives at a subconscious level rather than conscious choice.

- Risks is meant to identify risks of REACH use. Risks can be tangible safety issues as well as intangible issues related to privacy and confidentiality. The relevant question is what could be the risk for stakeholders in using the REACH system.

The list is created in this two-step process:

1. Stakeholders is listed with high proximity on the left column, in the aspect of Characteristics

2. The other eight aspects will be described through discussions with other consortium members and stakeholders

2.3.1 Onion Diagram

An onion diagram (or actors map in **T1.1**) is a template to prioritize importance key stakeholders in relation scale from the center. Putting our target end-user, the senior 65+, in the middle of the diagram the business system, organization and environment layers are arranged as onion shape.

The diagram is created in the two steps process:

1. Stakeholders in relative relations to the central person, 65 + senior are allocated.
2. Information/money flows are described between allocated stakeholders.

As explained before, this template is useful for understanding relative relations among stakeholders in visual format. By visualizing relative relations, the template indicates who could be the key players in relation to our target user, the 65+ seniors.

2.3.2 Stakeholder matrix

A stakeholder matrix is a temple to represent stakeholders' relative power on and interest in the use of the technology. In this 2 by 2 matrix, the x-axis indicates interests or involvements while the y-axis indicates influence or power. For example, the second quadrant is "promoters" space, so that stakeholders allocated to this quadrant should be managed closely in decision making and their ideas should be noted.

The matrix is created in the two steps process:

1. Stakeholders are allocated to their appropriate quadrant.
2. Each stakeholder in the quadrants is compared and defined in relative distance to other stakeholders.

2.4 Findings and Analysis

By utilizing the above three templates, stakeholders, their characteristics relations at four locations, Lyngby (Denmark), ZuidZorg (Holland), SK (Germany), HUG (Switzerland) were described and analysed. Part of local analysis below were reported from the local consortium members while the overall analysis was conducted by **T1.2** Stakeholder analysis consortium members.

In the course of the stakeholder analysis, the templates were filled out and described through discussions with a few local consortium members, promoting as a mutual understandings among local as well as distant consortium members. Many local consortium members reported they had in-depth discussion of the positioning in relative scale and roles of each stakeholders. They re-defined some stakeholders and new stakeholders came in through the process.

Through the analysis, several similarities and differences have been identified by utilizing the same template and visualize relations among stakeholders in the four locations. It is

evident that the analysis achieved in showing stakeholders and their relations in the same framework is needed to allow a further comparison of the context and conditions of use of the REACH sensing and monitoring intervention.

In this section, we first introduce each location and then analyse findings based on the stakeholder maps.

2.4.1 Lyngby Stakeholders

Lyngby, DK, identifies six stakeholders. Since care-taking is carried out at home settings, medical personnel beyond municipal nurses are not included among the stakeholders, and medical services and treatment at the clinics and hospitals are out of scope. While less critical in this setting, however, S4: Municipality and S5: General Practitioners play important roles as well as politicians who determine the financial scope of care services for the elderly. Naturally, there are a lot more supportive but more distant actors in relation to stakeholders such as dentist, podiatrist, supermarket and home delivery around the seniors, which are not listed as stakeholder list. Insurance plays hardly any role at all, since nearly all healthcare costs are covered by tax-based funding. However, they are described in the Onion diagram as a part of the environmental networks.

Table 2-1: Stakeholder List Lyngby

	S1: Senior	S2: Primary informal care giver	S3: Professional caregiver	S4: Municipality	S5: GP	S6: System provider
Characteristics	Citizens 65+, living at home.	Relatives and friends.	SOSU, Professional care givers who has 1-2.5 years professional education.	Municipality is the strategic top management and take leadership on planning, and overall responsibility	General Practitioners.	REACH System provider.
Role	End User.	Supporter for the use in daily life.	Daily operations. Supporter for the use in daily life.	Strategic leadership. Finance provider.	Data users.	System configuration, technical support. Consulting.
Interests	Independence, feeling secure (Tryghed) and Healthy life.	Easier support for my relatives (wife/husband, mother/ father).	Better and more service provision.	Increased citizens' quality of life. Reduce/control costs.	Better understanding on patients. Conduct correct medication treatment.	Cooperation with other companies, services and software.
Knowledge needs	Supports for use of technology.	Occasional technical support.	Training & occasional technical support.	Understand benefits.	Reliability on nature of data.	Understanding about REACH patient's needs.
Expectations	Easy to use, usefulness for my daily life.	Less worries about my relative. Better daily/weekly/frequent overview. (Don't feel guilty due to number of visits and care).	Less work and safety feeling on seniors.	Improved quality of life on senior citizens.	Better understanding on patients.	-
Influence uptake	10	Score 7-8	Score 8-9	2 (In introduction period influence 8-9)	2	2
Tangible incentives	Less anxiety, less burdens on caregivers.	Better overview. Save time (Fewer travels).	Less continuous presence. Work time reduction on one patients (one stay, frequency).	Saved expenses.	Less readmission, less treatments.	Good relations.

Intangible incentives	Feeling comfortable, feeling safe.	Reduce worries. Feeling comfortable, feeling safe.	Less burden on tasks, better treatment on seniors by understanding outlier incidence.	Reputatios, pride.	Better understandin g on patients, and better treatment for recovery.	Better understanding on patients, and better use of IT.
Risks	Private data disclosure. Stress with new technology.	Private data disclosure of my relatives.	My client data disclosure. Stress with new technology.	Private data protection, resistance from seniors and relatives.	Negative impact on using technology; burden, psychologica l pressure.	Usability problem, system problems.

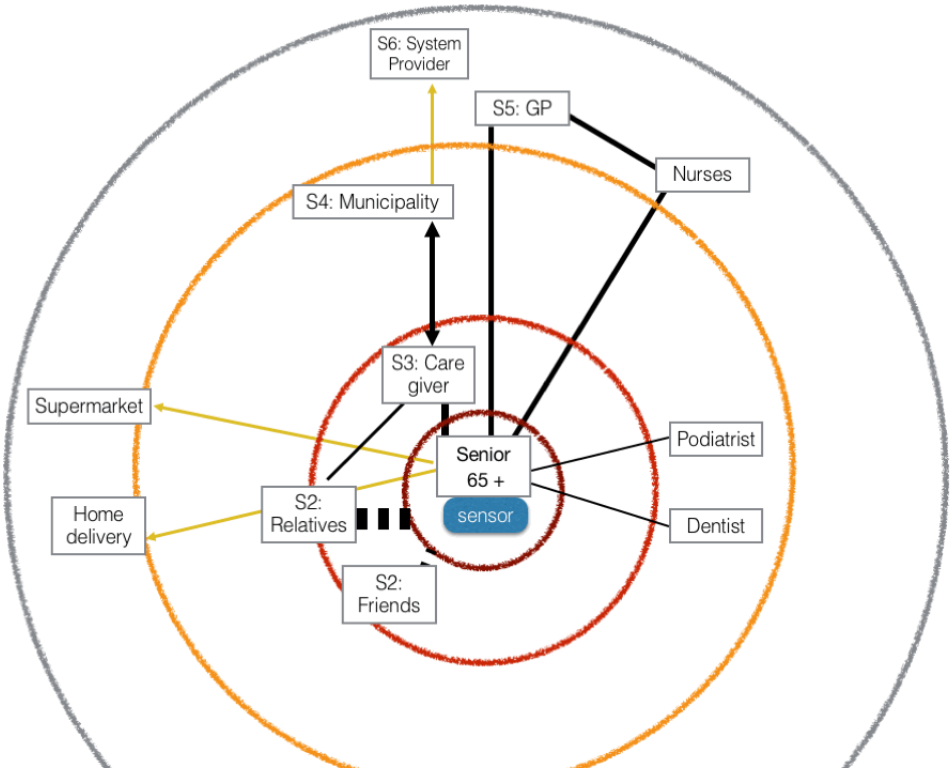

Figure 2-4: Onion Diagram Lyngby

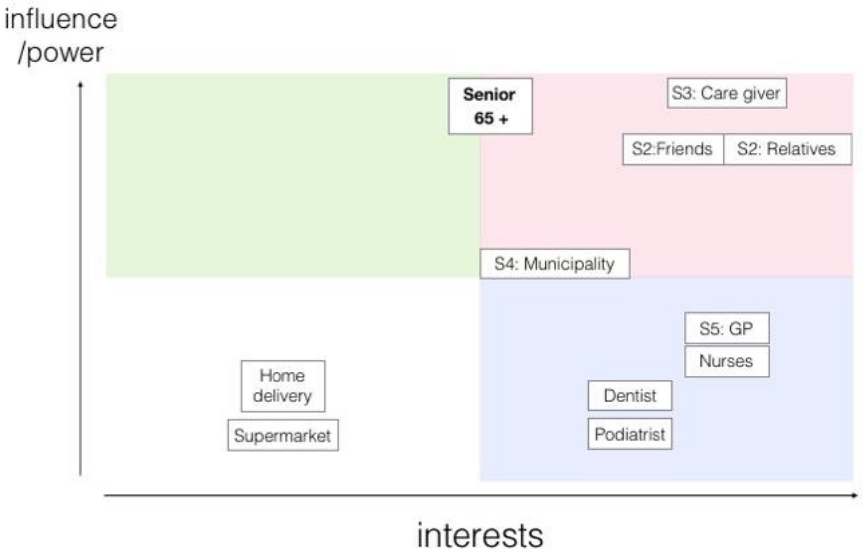

Figure 2-5: Stakeholder Matrix Lyngby

2.4.2 Zuid Zorg Stakeholders

Zuid Zorg, NL identifies seven stakeholders, among which informal stakeholders such as primary informal care givers (relatives and friends) and the Meet and Greet Centre's community hold the biggest and most important roles. S6: Insurance and S5: Municipality are at present outside the circle of care, but it are expected to play an important role in near future.

Table 2-2: Stakeholder List ZZ

	S1: Senior	**S2: Primary informal care giver**	**S7: Professionals and volunteers in Meet and Greet centers**	**S3+S4: Professional caregivers like: GP, social workers, nurses**	**In near future! S5: Municipality**	**In near future! S6: Insurance company**
Characteristics	Citizens 70+, living at home.	Relatives and friends.	Intrinsic motivated people who wants the best for the elderly.	Professional caregivers for their own discipline.	Strategic leadership Responsible for developing more power for the citizens.	Responsible for developing health insurance.
Role	End User.	Supporter for the use in daily life.	To encourage and stimulate. Supporter for the use in daily life and practical assistance.	Daily operations. Supporter for the use in daily life.	Finance provider.	Finance provider Supporter for the use in daily life.
Interests	Independence, Care free and Healthy life.	Easier support for my relatives (wife/husband, mother/father).	Keep them independent, less loneliness and healthy.	Better and more service provision.	Increased citizens' quality of life. Reduce/control costs.	More insured people for themselves.

	Social contact.					
Knowledge needs	Acquainted with technologies and supports for using it.	Occasional technical support.	Training & occasional technical support.	Training & occasional technical support.	Understand benefits.	Understand benefits.
Expectations	Easy to use, usefulness for my daily life.	Less worries about my relative. Better daily/weekly/frequent overview. (Don't feel guilty due to number of visits and care).	Another addiction of the wide range of activities to keep them living independent.	Less work and safety feeling on seniors. Better understanding of seniors.	Improved quality of life on senior citizens.	Improved quality of life on senior citizens. Less costs.
Influence uptake	10	8-9	8-9	3-4	0 at the moment, in future 6-7	0 at the moment, in future 7-8
Tangible incentives	Less anxiety, less burdens on caregivers, low or no costs.	Better overview. Save time (Fewer travels).	Participate in developing and use of new technology.	Less continuous presence. Work time reduction on one patients (one stay, frequency).	Saved expenses.	Reputation. Saved expenses.
Intangible incentives	Feeling comfortable, feeling safe, independent.	Reduce worries. Feeling comfortable, feeling safe.	-	Less burden on tasks, better treatment on seniors by understanding outlier incidence.	Reputations, pride.	Reputation, pride.
Risks	Private data disclosure. Stress with new technology.	Private data disclosure of my relatives.	My client data disclosure. Stress with new technology. Fear for decline personal approach.	My client data disclosure. Stress with new technology.	Private data protection, resistance from seniors and relatives.	Data: resistance from seniors and relatives. Accusation of misuse the data for selection.

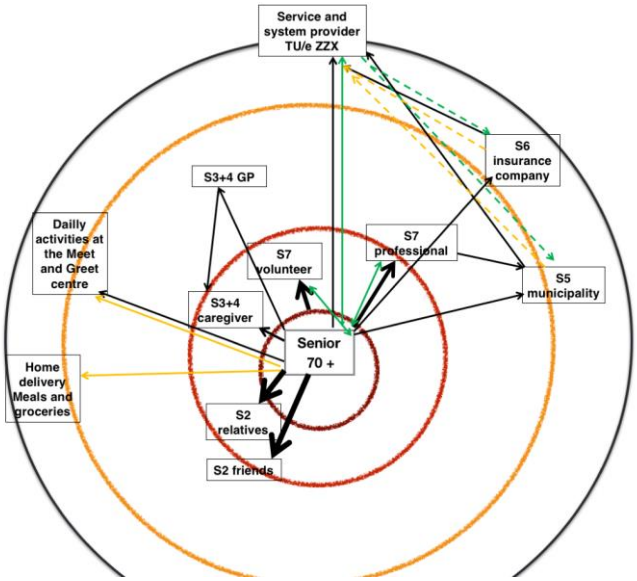

Figure 2-6: Stakeholder Matrix ZZ

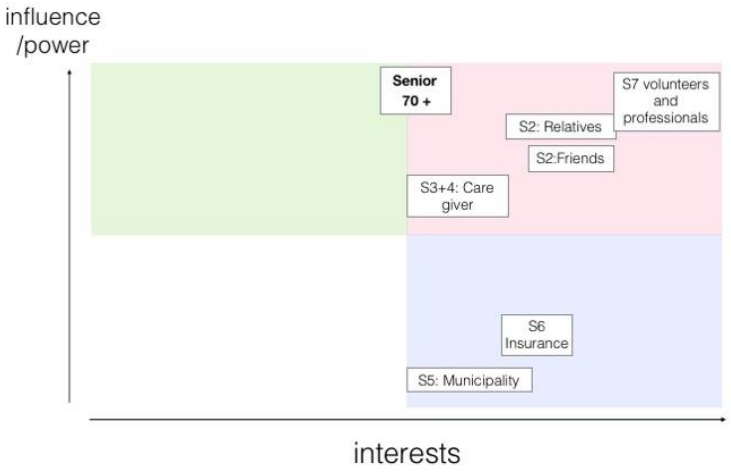

Figure 2-7: Stakeholder Matrix ZZ

2.4.3 HUG Stakeholders, Switzerland

HUG, CH identified six stakeholders, which are more or less similar with the ZuidZorg and Lyngby cases. The informal supporters such as S2: Informal care-givers, as well as formal care givers, S3: Home care-givers and S4: Hospital care-givers have a great influence on the patients. One of interacting characteristics are the importance of S6: Insurance companies, which are allocated in the second quadrant in the stakeholder matrix. Another interesting aspect is the location of S2: Informal care-givers in the Onion diagram, in which S2 is allocated in the further external circle. This indicates that care-taking in HUG can proceed largely within medical care-giving system while informal caregivers are less crucial in spite of their close emotional and social relations to the target users.

Table 2-3: Stakeholder List HUG

	S1: Senior	S2: Primary informal care giver	S3: Home care-givers	S4: Hospital care-givers	S5: Technician	S6: Insurance companies
Characteristics	Citizens 65+ with autonomy impairment, previously hospitalized at the 3C hospital.	Wife, Husband, Children, Friends who provide help and Volunteers.	GP, specialist Doctor, IMAD Nurse, IMAD auxiliary nurses, IMAD nutritionist, town physical therapist, town occupational therapist.	Hospital MD, nurses, auxiliary nurses, physical therapists, occupational therapists, nutritionists, social workers.	REACH SYSTEM technician.	Health insurance people.
Role	End user.	Supporter for the use in daily life. End-user in some ways.	Choose which function of the system to activate with the patient. Daily operations and adaptations. Supporter for the use in daily life. End-user in some ways.	Choose which initial functions of the system to activate with the patient at discharge. Data providers.	System providers and maintenance.	REACH reimbursement.
Interests	Autonomous, socially empowered, help to manage their condition(s).	Facilitated support and safety feeling for relatives (wife/husband, mother/father).	Better care provision based on innovative REACH services. Increase time spent with the patient Limitation of the paperwork time.	Better continuity of care after discharge, Limitation of readmissions, Better rehabilitation.	Getting access to an interesting job.	Decreasing costs of care.
Knowledge needs	Need support for the set-up of the technology, the daily use and the on/off must be easy so that they need no help.	Occasional technical support.	Training & occasional technical support.	REACH training targeted for the hospital user (different modules, how It works, how to use).	Detailed knowledge about the system installation, set-up, management and fixing.	Overview of the system and proof of its efficacy.

Expectations	Autonomy improvement. Easy to use, intuitive. Useful. Fun, motivating.	Feel safe about my relative. Be relieved of some help tasks.	Support in their daily activities, Increase time spent with patient, Limitation of the paperwork Better information transmission between hospital and home (Better continuity of care).	Better continuity of care after discharge Limitation of readmissions, Better rehabilitation.	Market provision.	Decreasing costs of care.
Influence uptake	10	8	8	6	2	6
Tangible incentives	Frequent meetings with kids and grandchildren. Useful for daily activities Fun	Reduce anxiety, time sparing.	Support in their daily activities, Increase time spent with patient, Limitation of the paperwork.	Better continuity of care after discharge, Limitation of readmissions, Better rehabilitation.	Getting access to a job Easy to manage system.	Decreasing costs of care.
Intangible incentives	Improve autonomy, limit hospital readmission, Feeling safe, Reassure family, keep privacy and control, improve physical condition.	Reduce worries, guilt and regrets. Feeling comfortable, feeling safe and reassured	Reduce hospital readmissions. Improve the quality of care, Improve the continuation of care between hospital to home	Improved quality of care.	Better use of the system Improved care to the elderly.	Decreasing costs of care.
Risks	Private data disclosure. Being monitored too much. Stress due to new technology.	Private data disclosure, Limitation of the face-to-face time spent with the elderly, Badly intentioned informal care-	My client data disclosure. Too much time spent on setting-up or debugging the system or training to use the system.	Too much time spent on setting-up or debugging the system or training to use the system New adverse effects.	Wrong usage. Low quality manufacture.	REACH system not performant enough.

		giver: taking advantage of the elderly situation.				

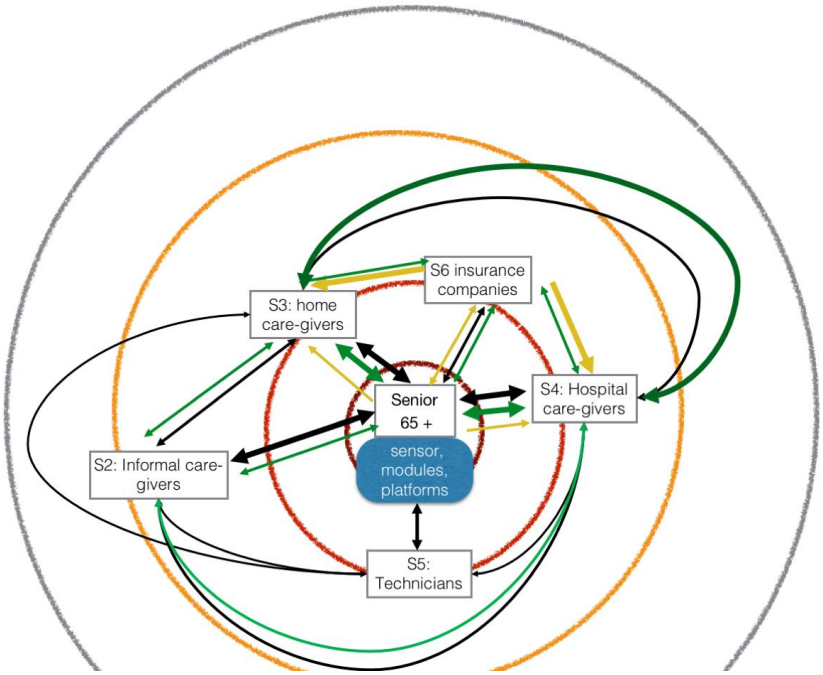

Figure 2-8: Onion Diagram HUG

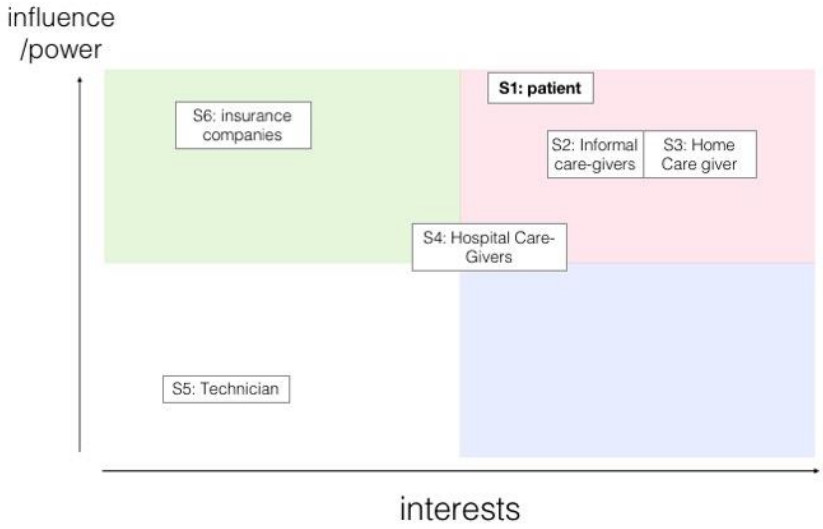

Figure 2-9: Stakeholder Matrix HUG

2.4.4 SK Stakeholders, Germany

Schön Klinik, DE, identified 10 stakeholders - the biggest number among the four locations. This also indicates that there is a complicated support system both in formal as well as informal relations to the patient at the rehabilitation clinic. SK provided three different onion diagrams including the main onion diagram where the targeted user (Senior 65+) is in the

centre. The other two diagrams locate no-user in the center and sensor in the center accordingly. For the comparison, we utilize mainly the diagram with the targeted user in the center.

Although influences are quite limited, there are stakeholders, which the patients interact in the course of medical treatment trajectories, such as S6; Rehab clinic fellow patients, S7; External relations, S8; Insurance companies, S9; Governmental authorities, S10; REACH system providers. This was also oblivious in their Stakeholder Matrix, where S6-9 are allocated in the third quadrant.

Table 2-4: Stakeholder List SK (1)

	S1: Patient in rehabilitation clinic	S2: Primary caregivers	S3:Secondary caregivers	S4: Rehab. clinic: medical treatment staff	S5: Rehab. clinic: non-medical support staff
Characteristics	Patients 65+, hospitalized or undergoing rehabilitation in day-care hospital	Partner, children, grandchildren, parents, close relatives, best friends, legal representatives	Distant relatives, former partner/ family member, close and distant friends	Physicians, therapists, nurses	Administration, counselling, social service, science department, in-hospital transport assistants, diagnostic department, kitchen and service staff
Role	End user	Supporter/consultants for the use in daily life, contact persons in case of problems or in need of system alterations	Supporter (in case of non-availability of primary caregivers)	Data user, trainer, supporter, monitoring of system functionality	Data user, trainer, supporter/consultants, monitoring of system functionality
Interests	More independence in ADL; improvement of QoL; development of positive emotions; mobilization; pain-free living; smooth transition from rehabilitation clinic to home; more security	Easier support and safety feeling for close caregiver; more and timely information about the patient's condition	Better and more service provision; improved social interactions	Better understanding of patient needs; more information about patients' activities or habits between the treatments; earlier indications for changes in the state of health; conduct best individualized treatment schedule; smooth transition from rehabilitation clinic to home;	Better understanding of patient needs; more information about patients' activities or habits between the treatments; earlier indications for changes in the state of health; conduct best individualized treatment schedule; smooth transition from rehabilitation clinic to home;

				easier monitoring of development	easier monitoring of development
Knowledge needs	Recommendation for the suitable system configuration; system training and support for use of technology	System training and technical support	System training & occasional technical support.	System training; options for data output and analysis	System training; options for data output and analysis
Expectations	Individual support in daily life (rehabilitation clinic and after discharge); enhancement of independence level	Feel safe and informed about the person being cared for	System use to contact S1; feel safe and informed about the person being cared for	Better understanding of patient needs; better outcome due to more activity during treatment sessions; objective data to corroborate medical/therapeutic interventions	More patient activities initiated from the patients themselves; better understanding of patient needs
Influence uptake	10	9 - 10	4 - 5	6 - 7	5 - 6
Tangible incentives	More independence; less anxiety (regarding transition and future life); more frequent and positive contacts to family, friends and fellow persons	More time for socializing with the patient; feeling that the patient is under close monitoring (less safety concerns)	Better feeling about the transition to home	Best rehabilitation treatment and more self-determination for the patients; more time for quality contacts with patients	Optimized operational processes; more information about patient's progress
Intangible incentives	Feeling comfortable and safe; reassure children; keep privacy and control; improve physical condition	Reduce worries, feelings of guilt and regrets. Feeling comfortable and safe	Less feeling of insecurity and therefore higher motivation to support the patient after discharge	Rehabilitation clinic is more attractive for patients when offering REACH system; feeling that patient has a sense of well-being in rehabilitation clinic	Feeling that patient is cared for between treatment sessions
Risks	Private data disclosure; reservations and concerns about new technology; financial burden; over-dependent on REACH	Private data disclosure; feeling stressed from technical demands (e. g. when patient cannot cope with technical	My client data disclosure. Stress with new technology. Less contact caused by data collection tools	Reduced interpersonal contacts with the patients	Reduced interpersonal contacts with the patients

	system; under/over-challenge due to modules which do not match the patient's current situation	requirements of REACH system); financial burden (purchase and support of REACH system)			

Table 2-5: Stakeholder List SK (2)

	S6.Rehab. clinic: fellow patients	S7: External relations	S8: Insurance companies	S9: Governmental authorities	S10: REACH system provider
Characteristics	Room- mate, fellow patients, fellow patients' visitors	GP, referring hospital, specialized physician, outpatient therapist, nursing home, nursing service, health care supplier, vocational reintegration center, employer, day-care center, transport services, meals on wheels, bank/financial institutes, self-help organizations, voluntary services	Health insurances, long-term care insurances, casualty insurances, annuity insurances, employers liability insurances	Job center, social welfare agencies, law courts, district administrations	Provider
Role	Members of target group	Data user; communication	Data user, financing; communication	Data user, financing; communication	System configuration, technical support, consulting
Interests	Easier contact to people in the same situation; more contact possibilities after discharge; more possibilities to interact with fellow patients and support and motivate each other	Individualized support; monitoring of progress and/or health status; economic use of resources	Economic use of resources; lower costs due to prevention of readmission; prevention of care dependency	Economic use of resources; data about needs of elderly; prevention of care dependency	Realization of profits; market leadership; cooperation with other companies (synergetic effects)
Knowledge needs	Information about REACH system	System training; options for data output and analysis;	Information about REACH system	Information about REACH system; analysed data	Knowledge about REACH system; Patient needs; user feedback

		occasional technical support		from REACH provider	
Expectations	Co-participation in activities initiated by REACH; easier and more information exchange between the patients	More information about the patient after discharge	Cost reduction and economic use regarding insurance expenses; more information about policyholder	Cost reduction and economic use regarding expenses in the health care system; more information about senior citizens	Profit; high customer satisfaction; support of senior citizen
Influence uptake	2 - 3	3	6	4	2 - 3
Tangible incentives	More social contacts and support from fellows in rehabilitation process	Better coordination between different supporter after discharge	Sound and attractive insurance program	Less expenditure in healthcare sector	Solid company; good relationship between provider and user
Intangible incentives	Knowledge about a system which provides support after discharge and may help to live more independent	Better understanding what kind of support the patient will need after discharge	Shows competence through successful company policy	Shows competence through successful political strategy	Feeling good about supporting elder citizens and caregiver
Risks	Increased need to purchase the REACH system without having the necessary financial resources	Reduction of support portfolio for patients after discharge	Not using the money saved and the data generated with REACH to improve the situation of elderly; reduction of insurance payout to elder citizens; false interpretation of REACH data	Only supporting selected groups of elderly based on standardized assessments/data (neglect of individual cases)	Developing a system that does not meet the market requirements

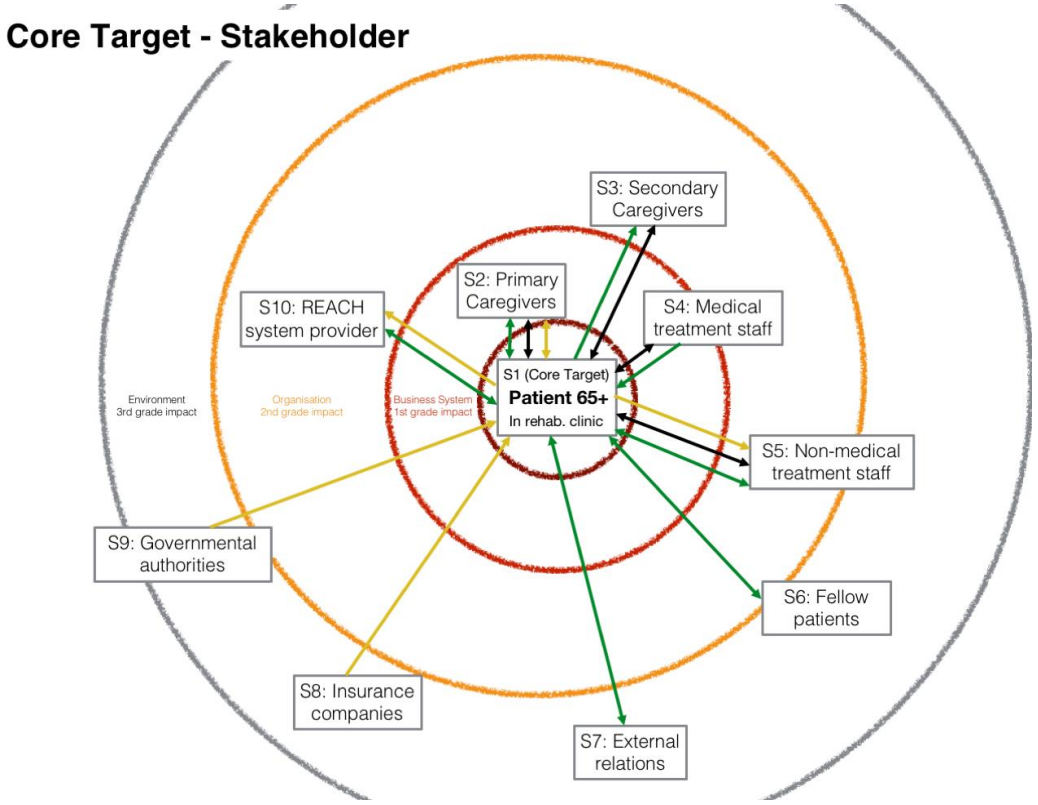

Figure 2-10: Onion Diagram SK

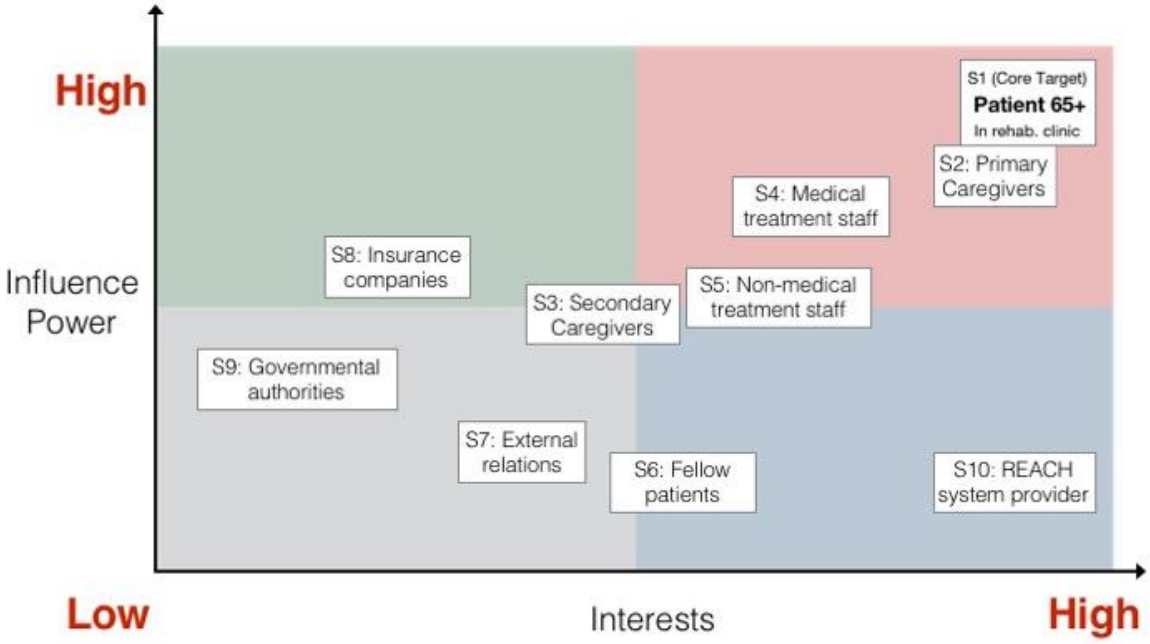

Figure 2-11: Stakeholder Matrix SK

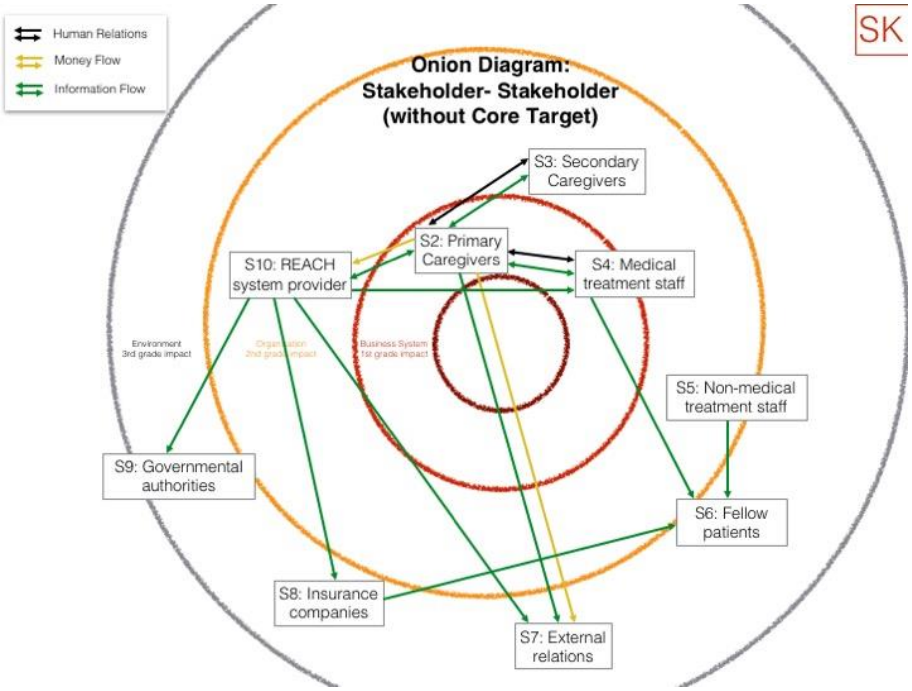

Figure 2-12: Onion diagram: Stakeholder-stakeholder (Without Core Target)

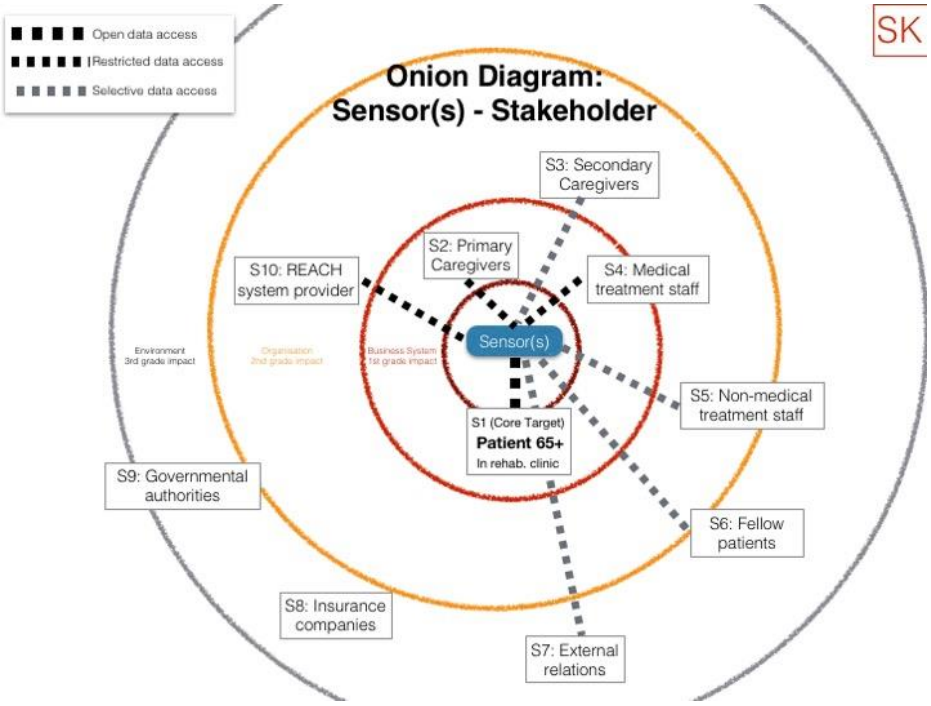

Figure 2-13: Additional Onion Diagrams SK

2.4.5 Analysis across four locations

The four locations have a few similarities as well as differences. In this section, findings about similarities and differences based on the stakeholder analysis across four locations are introduced.

One major difference that was already noted in **D1.1** and which we allude to in the Introduction to this deliverable is that the four sites are easily divided into two types of use contexts: one use context is the clinics (SK and HUG) where professional caregivers are available 24/7 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 user group, professional caregivers (nurses, nurse assistants) are available as well, but besides the scheduled visits they will be called on only for emergencies.

- Different Social Characteristics. Considering stakeholders and their relations mapped out in each location, two important differences are identified which are societal difference and treatment stage differences.

- Societal Differences. Both in ZuidZorg and Lyngby, insurance companies play less critical roles compared to HUG and SK. There are several reasons for this, but the primary one is tied to the socio-political system. As social welfare country, Denmark has considerable senior care already within the national care package for social and health needs, covered entirely by taxes. This covers all citizens – and as was described in **D1.1**, while only 3% of citizens aged 65-69 received regular social/health services from the municipality, it is about half the citizens aged 90 or older. Insurance companies thus play a negligible role, covering mainly dentistry, hearing aids and a small part of medication. For ZuidZorg the role of insurance companies is different, since the Netherlands has a dual-level system. All primary and curative care (i.e. the family doctor service and hospitals and clinics) is financed from private mandatory insurance. But long term care for the elderly, the dying, 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.

- Treatment Stage Differences. HUG and SK are, as mentioned above, clinics where the elderly citizens are formally “patients”, and where more formal medical treatments and treatment related exercises are involved. Lyngby and ZuidZorg settings are, as we noted, care-giving and daily care settings where daily or weekly support and active living are in the central role in its care giving service. According to the treatment stage in the continuum of care, influence and roles of stakeholders differ (cf. description in **D1.1, Section 6.1**, of the concept of continuum of care).

- The Value of Informal and Formal support. Both informal and formal supports are important in the senior health care setting. However, environmental differences mentioned above such as socio-political as well as the treatment stage, influence the level of importance of informal and formal support along the treatment journey. In the four locations, informal caregivers always have a strong impact on the seniors’ daily life while they sometimes have less influence on the formal treatment process, and thus, in the end would have less impact on REACH eco system. Looking at the Onion diagram of HUG, informal care-givers 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, has drastically increased.

- Coordination work vs work for quality of life. In the four locations, one of the challenges of introducing the REACH system will probably lie in its balance of 'coordination work' and 'work for quality of life.' (i.e., work to enhance quality of life). All analyses from four locations indicate the value of independence, free-of-worry and healthy life, which can be supported by the REACH system. At the same time, the stakeholder lists show that stakeholders have concerns of with technical burdens, stress and fear with new technology in using a system such as REACH. This challenge can be interpreted as imposing contradictory requirements, but it is a well-known challenge in the introduction (and in fact also in long term use) of new technology in socio-technical settings. This type of challenge, reducing process work (setting up systems, getting accustomed to the system etc.) and increasing quality of central work (care giving to the seniors, talking more to the seniors etc.) has been discussed for decades in Computer Supported Cooperative Work (CSCW) domain (**Fitzpatrick & Ellingsen, 2013**). This challenge externalized in the process of stakeholder analysis, especially in stakeholder lists, provide good start points in designing REACH system.

2.5 Conclusion: implications of the stakeholder analysis for and applicability in REACH

The Stakeholder Analysis and the process of establishing it at each of the four sites have provided interesting insights which indicate further benefits of REACH project and consortium as well as of the REACH system and sub-systems developed for the future care settings.

We shall begin with a short summary of benefits and risks revealed in this stakeholder analysis based primarily on the information gathered at each of the four sites in Stakeholder List. For the primary users, the elderly citizens, the chief risks and drawbacks are the fear of data disclosure and the stress that the use of the technology may lead to. These risks are similar for relatives and friends (informal caregivers) and, to some extent, for the formal care givers as well. For the latter group and for leaders and managers (e.g., municipality) there is the additional fear of being responsible for inadvertently disclosing data and 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. For relative especially easier support for spouse or parent, and for professional caregivers improved efficiency in care – including better understanding of patient needs; more information about patients' activities or habits between the treatments and visits; early warning and easier monitoring of changes in health; and even a smoother transition from rehabilitation clinic to home, when relevant. Finally, for insurers and funding entities the benefits rest on the prospect of getting an economically sound use of resources; lower costs due to prevention of readmission and hospitalization and transition to (costly) long-term care.

Besides the benefits and risks, there are a couple of evident contributions of the reported stakeholder analysis to the REACH project. Firstly, the stakeholder analysis process has

supported a discussion of not only overt but also implicit challenges for the REACH stakeholders and consortium members. For example, there is a wide variety of stakeholders identified in each location, which were modified, added and erased in the course of the discussion. It was clear from the analysis process and resulting templates that the stakeholder analysis process has helped consortium members to identify potential key stakeholders along the way. In addition, discussions among local consortium members has helped to establish mutual understanding of stakeholders and their inter-relations, contributing toward better communication internally in the project. In this way, the analysis itself helped to clarify key aspects for the REACH project.

More importantly, the similarity of the result of the different locations indicates the shared challenges and potentials across different locations. One of the major challenges is rooted in healthcare eco system. This can be explained as an importance of user journey perspective from a user-centered approach or of healthcare value chain perspective from business model approach (**Lawton, 2002**). Considering the target user (65 + seniors), the future REACH system and subsystem and REACH business model have to deal with care stages of the target user as well as societal medical settings. Thus, there are differences between a care stage involving primarily professional medical and healthcare support, and a care stage which relies more on informal care support, but they may need to be coordinated tightly. Accordingly, the motivation and intervention aspects of the future REACH system could be different from stage to stage but tightly connected. This suggests that the REACH system and its sub-system should be designed with this distinction of care stage of the core user in mind. Similarly, the outputs of this report shall be expanded by the **WP8** business model group.

3 Review of motivational strategies promoting physical health

In this chapter we review current knowledge of motivational and persuasive techniques for promoting physical activity and healthy aging. As we have explained in the introduction, the REACH approach is to seek to promote functional ability (reduce or postpone functional impairment) by motivating and engaging our target population in increased physical activity. In the next chapter we will then review techniques and technologies for monitoring activities, while we focus on motivation and persuasion in this chapter.

3.1 Introduction

In 2009, the World Health Organization (WHO) produced a report drawing attention on the global health risks. They demonstrated that we are living in an era where we live longer to accumulate chronic, non-communicable diseases such as cancer or cardiovascular diseases and die less frequently of malnutrition and infection diseases (**World Health Organization, 2009**). This is especially true in developed countries but it is also more and more the case in developing countries that must cope with the burden of both communicable and non-communicable diseases. Among the main risk factors of non-communicable diseases are lifestyle habits that we can influence such as smoking, unhealthy eating or lack of physical exercise. Although committing to healthy behaviour has been shown to be highly beneficial for the health and well-being of elderly, the challenge remains in motivating the adoption and the long-term engagement in such behaviour.

Multiple researches have been conducted to identify motivational strategies for behaviour change, especially in the physical activity domain. In this report, we plan to have a brief overview of the motivational issues relevant to promote physical activity among the elderly. This review will cover current knowledge about motivational/persuasive techniques and technologies that aim at enhancing physical activity among the elderly (65+ year olds) and seek to identify methods and techniques for which there is evidence of efficacy and effectiveness.

More concretely, we aim at focusing our understanding on:

- the different categories of motivation strategy to promote physical exercise
- the efficiency, cost-effectiveness and the risks associated to each one of these strategies
- the applicability of one or a combination of these strategies within the REACH context and in particular the Touch points and Engine functionality defined in **D1.3, Section 7.3.2.**

To achieve these objectives, we started to explore a comprehensive and standardized behaviour change framework: the Behaviour Change Wheel – which fits well with the REACH approach. From this model, we then reviewed different motivation technics that have been used in various research contexts. We summarize our findings about these strategies in four main categories which are: gamification, social incentives, goal directed behaviour, self-reflection / self-efficacy.

3.2 Behavior Change Frameworks

3.2.1 General overview

Designing effective behaviour change interventions requires identifying the target behaviour and understanding the target behaviour in the user's context. The process should follow an effective, a rigorous and a standardized behaviour change model. In the following section we present a general overview of different existing behaviour change framework, before choosing the approach we are going to follow in this review.

3.2.2 Hedonic principle

The subject of behaviour change dates back to Greek antiquity, who acknowledged the Hedonic Principle. People are intrinsically motivated to move away from painful and towards hedonic, or pleasurable, experiences. Later, in the ninetieth century Herbert Spencer formalized this fundamental principle into a psychological theory (**Bozarth, 1994**), which then expanded by Tronland to describe how please is associated with beneception, actions which support survival, and pain with nociception, the opposite and undesirable (**Bozarth, 1994; Marks, 2011**). This allowed others, like Clark Hull, to build on these theories to create reward learning theories (**Marks, 2011**). From these initial fundamental attempts at understanding the human motivation and how this relates to desired behaviour change, psychology has evolved and developed much since those early theories.

3.2.3 Regulatory focus theory

More recently, the regulatory focus theory (RFT) considers that the way in which people move toward pleasure and avoid pain, changes depending on the needs they are trying to satisfy, based on their individual's self-regulation focus, either promotion or prevention focus. Brockner and Higgins describe that people who are promotion focused are more concerned with growth and development while people who are prevention focused are driven by security. The RFT "distinguishes between promotion focused motivation and prevention-focused motivation" (**Brockner & Higgins, 2001**), but does not absolutely point to either a promotion focus incentive system or a prevention focused incentive system being more effective to motivate the individual. Instead the RFT explains which of these incentive systems is more effective depending on the individual and their "dispositional tendency" to focus on promotion or prevention. (**Higgins, 1997**; **Brockner & Higgins, 2001**). The RFT has the potential to support designers to understand what qualities motivate an individual user once it has been established whether they are accurately more promotion or prevention motivated. However only understanding what motivates an individual is not sufficient to understand what is needed to achieve behaviour change.

3.2.4 Self-determination theory

Motivation can be intrinsic, inherently resulting from an individual's values and feelings, or extrinsic, inherently imposed upon the user. Created by Edward L. Deci and Richard M. Ryan (**Ryan & Deci, 2000**) the self-determination theory (SDT) describes motivation personality and optimal functioning and it addresses various kinds of motivation. The SDT describes three different kinds of motivation respective of three innate needs people have. These three needs are competence, referring to the need to have control over one's situation, relatedness referring to the need people have to feel an emotional bond with others and autonomy referring to the need for free will. Deci and Ryan describe two kinds of motivation. The first is autonomous motivation, which involves the individual drawing on

internal motivation to do a task which is intrinsically satisfying or identified motivation that aligns a task with the individual's internal motivation. The second kind of motivation is led by external consequences, either punishment or reward, or by introjected motivation, which involves the individual feeling appreciated or rejected due to this action.

3.2.5 Fogg behaviour model

B.J. Fogg created a more comprehensive overview of the process of the different elements required to enable behaviour change then that of the regular focus theory and expands our understanding of different kinds of motivation as compared to the self-determination theory. Fogg's behaviour model (FBM) for behaviour change combines the individual's intrinsic qualities of motivation and ability with the external factor of a well-timed trigger (**Fogg, 2009**). Fogg's behaviour model describes three factors necessary for behaviour change; motivation, ability and triggers. These crucial elements are plotted on a graph; ability on the X-axis and motivation on the Y-axis, so the trigger can be place on this two-by-two according to the user's level of ability and motivation (**Fogg, 2009**). On this same graph, Fogg's action line describes the minimum level of motivation an individual must have in relation to their ability to react to a trigger to respond positively to triggers. If the individual is motivated but does not have the ability to complete a task even a well-timed trigger will not move them to react to a trigger and thus perform the targeted behaviour. Conversely, if a task is very easy to complete but there is very little to no motivation to do it then still there will be no change in behaviour.

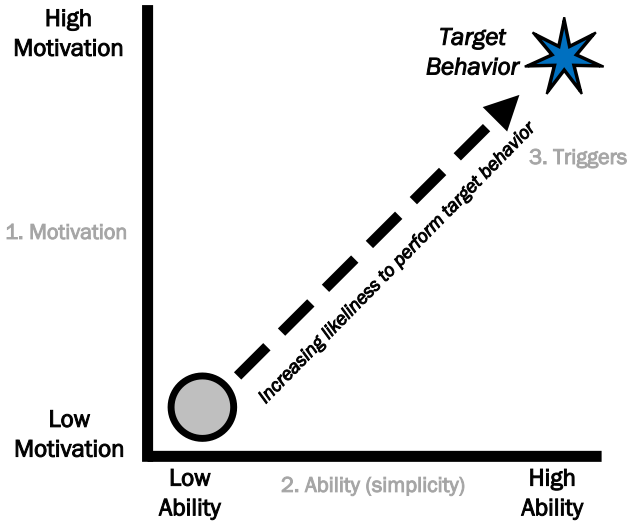

Figure 3-1: Fogg's 3-factor model (redrawn from Fogg (2009)

In his model Fogg outlines three different kinds of motivation as compared to the self-determination theories and regulatory focus theory's two kinds of motivation. Fogg explains that one can be motivated by one of three kinds of motivation; firstly, by the avoidance of pain and pursuit of pleasure, secondly by seeking hope and avoiding fear and lastly, by avoiding social rejection and seeking social acceptance. Fogg's model can also serve as a way to analyse why certain attempts and directed behaviour change failed or succeeded. However, though Fogg's model addresses timing in that triggers need to be designed appropriately to the level of motivation and ability of the individual at that time, it does not give us much insight about how this motivation and ability might change over time.

3.2.6 Trans-theoretical model

The trans-theoretical model (TTM) of behaviour change describes six phases of change through which people move sequentially before and during the behaviour change process.

The first stage the TTM talks about is the Precontemplation stage describing individuals who do not intend to change their behaviour. Several explanations are given for the reason an individual might be in the precontemplation stage including that the individual might be under- or un-informed or the individual might have tried and failed so many times that they have given up trying. Contemplation is the second stage of change in which an individual has decided to change in the future but has not yet undertaken any real steps to change their behaviour. Prochaska and Velicer explain that individuals in this stage weigh the pains from changing with the gains from their improved behaviour and therefore can often get stuck in this stage for long periods of time. When I want to lose weight but always find a reason why now is not a good week to be on a diet because it's Thanksgiving or because it's the week in which we celebrate my co-worker's birthday, I am experiencing behavioural procrastination.

Individuals move on from contemplation to preparation when they decide to change in the immediate future and have a plan of action to do so. The next stage is called the action stage. The trans-theoretical model only defines a modification in behaviour to be 'action' when professional would agree that this behaviour change is significant enough to reduce risk. In the maintenance stage, individuals usually do not rely on change processes like they do in action; however they are working to resist a relapse of their old behaviour. Prochaska and Velicer own that this stage of maintenance can last anywhere from one month to five years. Finally, when the individual does not run the risk of regression, the return to an earlier stage of change, then and only then has the individual reached the termination stage. Prochaska and Velicer worn that not many people ever truly make it to this stage and maintenance becomes the enduring end stage of the journey where many still struggle with their former addictions for a long time.

3.3 Behaviour Change Wheel

The Behaviour Change Wheel (**Michie et al., 2011**) synthetize most of these models nicely. It is a nice approach based on nineteen frameworks of behaviour change identified in a systematic literature review. It consists of three main layers: the sources of behaviours, the intervention functions, and the policy categories (see **Figure 3-2**)**.** In our review, we are mainly interested on the first two layers. Three conditions should be observed to produce a behaviour: the capability, the opportunity, and the motivation (**Michie et al., 2011**). The sources of behaviour are based on this COM-B model (Capability, Opportunity, Motivation and Behaviour). The second layer consists of nine intervention functions, which are education, persuasion, incentivisation, coercion, training, enablement, modelling, environmental restructuring, and restrictions. The choice of the right behaviour change strategy is based on the COM-B analysis and could be one or a combination of these intervention functions.

3.3.1 Sources of behaviour

From the COM-B system, a behaviour change can only occur from the interaction between the three necessary conditions: Capability, Opportunity, and Motivation (**Michie, 2012**).

Capability involves the physical and psychological ability to enact the behaviour. Opportunity is driven by the physical and the social environment that enable the behaviour. Motivation includes the reflective and automatic mechanisms that activate or inhibit the behaviour. This is joining Kahneman's behaviour model (**Kahneman, 2011**) based on two modes of thought "System 1" and "System 2", where "System 1" indicates the fast brain (automatic, intuitive) and "System 2" represents the slower mind (analytical, reflective) when making a decision. In short, for a behaviour to occur, first, the user should be able to perform it; second, the desired behaviour should be triggered adequately and third, the user should be motivated enact accordingly. Since we are especially targeting the elderly, these three conditions should be observed carefully when choosing the appropriate interventions.

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3.4 Intervention functions

The interventions are the activity designed to change the behaviour. Michie and al. conducted a systematic review and identified nineteen frameworks to classify behaviour change interventions.

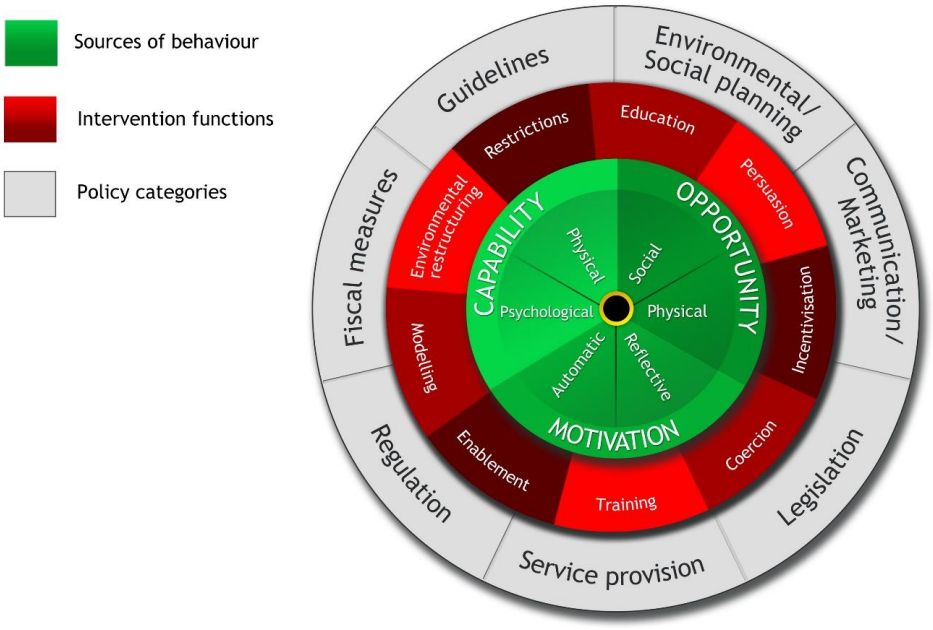

Figure 3-2: Behaviour Change Wheel (from Michie et al, 2013)

The addressed behaviours were not only related to health but also to environment, social marketing, and culture change (**Michie, 2013**). They sum up their results by proposing nine different interventions where each of them includes one or more behaviour change techniques. These nine interventions are summarized in

Table 3-1. We also propose examples according to our context (motivating physical activity) for a better understanding of the concept.

Table 3-1: Intervention functions and examples

Intervention function	Definition	Motivating physical activity: examples in REACH (examples in D1.3, Section 7.3.2)
Education	Increasing knowledge or understanding	Providing information to promote exercise/ asking them to wear a device to make them aware of their daily activity (e.g., touchpoint Active Environment/SK; Nutritional intervention /HUG)
Persuasion	Using communication to induce positive or negative feelings or stimulate action	Using game or metaphor to motivate increases in physical activity. (E.g., touchpoint Rehabilitation gaming; Playware/HUG)
Incentivisation	Creating expectation of reward	Using prizes (real, virtual) to induce a better and a longer physical performance. (E.g., touchpoint Rehabilitation gaming/HUG)
Coercion	Creating expectation of punishment or cost	Some application proposes to do a bet on a physical challenge to motivate physical exercise. (E.g., touchpoint Pattern detection III / ZZ)
Training	Imparting skills	Training with a virtual coach to do regular exercise or rehabilitation exercise. (E.g., touchpoint Cardiovascular workout/HUG)
Restriction	Using rules that limit engagement in the target/competing/supporting behaviour	Limit the access to the TV if the user is too sedentary. (E.g., touchpoint Activity tracker/Lyngby)
Environmental restructuring	Changing the physical or social context	Create more opportunity to exercise at home (adding more stairs, putting things higher step by step for an arm rehabilitation exercise). (E.g., touchpoint WalkStar/HUG)
Modelling	Providing an example for people to aspire to or to imitate	Involving the user in a social network where they can share their goals and their experience. Induce competition and collaboration. (E.g., touchpoint Pattern detection I & II/ZZ)
Enablement	Increasing means/reducing barriers to increase capability or opportunity	Prostheses to promote physical activity. Safe equipment for rehabilitation at home. (E.g., touchpoint Dynamic stander/HUG)

Based on: (**Michie, 2013**).

3.5 Motivational strategies

Several motivational strategies can be derived from these intervention functions. We conducted a literature review to identify strategies that combine one or more of these intervention functions.

3.5.1 Approach to analysing motivational strategies

To collect relevant articles, we conducted searches in an iterative manner on PubMed, ACM digital library and Google Scholar. Search terms included “physical activity,” “motivation,” “behaviour change intervention” and “elderly”.” From the title of each paper, we excluded the ones that are not relevant to our analysis. After reading the abstract, we identified 57 relevant papers. We then reviewed in detail the reference lists of each article to find additional relevant papers and ended up with 82 articles.

Included articles described intervention functions that promote physical activity for elderly and the general population. The strategy used along with its efficiency was recorded. A set of 4 key themes emerged from the intervention analysis: gamification, social incentives, goal-directed behaviour and self-reflection/self-efficacy.

In line with our behaviour change model, social incentives would include persuasion, incentivisation (approval), coercion (disapproval) and modelling (observational learning). Gamification would be a combination of persuasion, education and incentivisation. Goal-directed behaviour would involve training, education. Self-reflection and self-efficacy would be a combination of education, training, incentivisation.

3.6 Selected strategies

3.6.1 Gamification

Gamification which is defined as “the application of game principle into non-game context” (**Huotari & Hamari, 2012**; **Deterding et al., 2011**) is being widely used in various domain such as work, marketing, education and health. The goal is to induce user engagement in performing certain action. A plethora of researches investigate the use of gamification to motivate physical exercise among people with chronic disease, cardiovascular risks and the aging population (**Hamari, et al., 2014**).

Researchers have been actively designing persuasive technologies that motivate moderate physical activities. To motivate people to walk more, activity monitoring devices are coupled with a virtual rewards system and allow users to collect badges and points (**Skriloff, 2016**). Another common area of research is the use of metaphor to help people visualize in a playful and easy way their progress towards their goal. Many studies have been trying to map the number of steps achieved to the growth of virtual character like animals (**Lin et al., 2006**) and plants (**Consolvo, 2008**). In addition to that, we observe a real interest in using serious game to engage people in performing physical exercise. Playing games that involve subtle physical movement are widely explored (**Rice et al., 2011**) not only for moderate activity like walking or running but also for rehabilitation exercise. Immersing the user into a virtual world does not only procure a feeling of pleasantness but also has the potential to increase user self-efficacy and confidence in doing the required exercise.

3.6.2 Social incentives

Social interaction counts numbers of benefits regarding multiple domains such as reducing stress level, improving people’s mood, or increasing life expectancy (**Sasidharan, 2006**). Belonging to a society and interacting with others are proved to influence positively elderly’s quality of life (**Grosinger et al., 2012**).

Moreover, social incentives have been shown to have a significant impact in motivating people to reach certain behaviour. Researches in psychology and neuroscience have demonstrated that people easily mirror others' behaviour (**Iacoboni, 2009**) and could be influenced by what others are doing. We thus observed many studies (**Roelof et al., 2016**; **Keyani, et al., 2005**; **Brox et al., 2011**) that involve sharing goal and achievement on social platform to motivate people to engage in healthy behaviour like doing physical exercise or eating healthy meals. They could receive social support in different format such as

instrumental support, informational support, emotional support, and appraisal support (**Uchino, 2004**). Besides, most of the existing applications to promote physical activity involve a way to foster competition and challenges (**Pyae et al., 2016**). If the partners or the group are chosen carefully (**Chen & Pu, 2014**), competition has been proven to be an efficient way to motivate people surpass themselves and reach their goal. However, some studies (**Chen et al., 2016**) started to investigate the incentives of collaboration in doing physical exercise together. Fostering collaboration has shown promising results in engaging users to perform physical activity together in the long term.

3.6.3 Goal-directed behaviour

Goal setting has been widely studied as a technic for behaviour change, especially regarding diet and physical activity (**Pearson, 2011**). We all went through the process of setting goals to lose weight at the beginning of the year but end up failing to meet our objective at the end of the year. In fact, setting goals for behaviour change involves more specificity than just saying it at New Year's Eve. Defining a goal is laudable but how to make it happen remains a challenge.

In the domain of physical activity, many researches (**Shilts, 2004**) have come to understand the role of goal-setting in motivating people to exercise more. Different steps were proposed to efficiently reach the desired behaviour. Firstly, the user would need to be as specific as possible in defining their goals (**Consolvo et al., 2009**), such as "walking 8000 steps each day for two consecutive weeks". Then, the use would need to define the method that would help them to reach this goal, such as "going for a walk every day after work" or "running 10 minutes a day every morning". By creating circumstances that would help them exercise more, they will be closer to their objectives. Many studies (**Baerta et al, 2011**) pointed out the importance of setting realistic goals depending on user's needs and capacity. Especially, for elderly, it is a key point to consider their ability to perform when helping them setting their goal. From a research point of view, one way to do this would be to split a bigger goal into smaller goals and perform baby tasks one at a time (**Khatri et al., 2016**). This would improve the user's confidence and will motivate them to do even more.

3.6.4 Self-reflection/Self-efficacy

Self-reflection strategies would be defined as a method to put people in a situation where they should reflect about their behaviour. This reflection could be a way to drive motivation to change certain behaviour and adopt new habits. Many studies involving self-reflection have been carried out and have shown that asking people to log their activity everyday could trigger an awareness of their current behaviour (**Maitland & Chalmers, 2010**). Studies involving activity monitoring device have discussed the effectiveness of showing people their activity level such as the number of steps and the walking distance (**Randriambelonoro et al., 2015)** they perform every day. Using metaphor and visualisation could also be a good vector to induce self-reflection. The study where they use the growth of flowers in a garden to motivate physical activity was a nice way to prompt self-reflection (**Consolvo, et al. 2008**). The more they walked, the more the garden flourished. As they didn't want to end up with an empty garden, they tried to increase their activity level.

On the other hand, encouraging self-efficacy has also been proved to have a positive impact in doing more physical activity (**Güldenpfennig et al, 2015**). One big challenge in setting big goals is that people have difficulty to assess their improvement over time and start to

give up in the middle of the process. This is one reason why splitting goals into smaller tasks and giving baby feedback are important to drive motivation. Researchers have proposed to deliver simple and meaningful feedback of the user's improvement as he is moving towards his goal (**Maitland & Chalmers, 2010**).

3.7 Efficiency, cost effectiveness and risks associated to these strategies

Multiple studies show the efficiency of gamification in different level, not only in term of motivation to exercise more but also in term of increasing elderly's confidence about themselves (**Hamari et al., 2014**). Performing activities together at remote locations has been shown to be possible (**Kadomura et al, 2016**) using an intelligent mirror and haptic devices. A time-based rewards game involving 180 participants increased their physical activity, and decreased the amount of sedentary playing time, without reducing the perceived enjoyment while playing the game (**Berkovsky et al. 2010**). Besides, positive reinforcement like encouragement has been shown to be more efficient than negative reinforcement to promote long term behaviour change (**Lin et al., 2006**). However, it is important to note that the effects of gamification are greatly dependent on the context in which the intervention is being implemented, as well as on the users using it (**Hamari et al., 2014**). If not adapted and too complex, it can easily become a barrier that affects elderly's motivation to interact with the game, the application, or the technology (**Styliadis et al., 2014**). Social engagement with friends has been shown to be a strong motivator. Nevertheless, the content of information chunks needs to be carefully tailored to the participant (**Grosinger at al., 2012**). Furthermore, being paired with a buddy has been proven to increase user engagement in doing physical exercise but few conditions should be ensured such as the choice of adequate partner (**Chen et al., 2012**). Mutual support between partners participating as a couple or friends facilitated increased walking (**Victor et al., 2016**). Many studies have shown that people who increased their walking considered goal-setting components intervention to be very important. Offering continuous measurement of walking time, a daily goal, and real-time feedback on progress toward a personalized goal facilitates reflection on activity (**Zuckerman, 2014**). These reflections and goal setting support is needed to compose goals that accurately reflect these intentions to change (**Saini & Lacroix, 2009**). A combination of these interventions has the potential to significantly increase walking time. However, to ensure the long-term behaviour change, each intervention should be tailored to the elderly's needs and living context.

3.7.1 Applicability of these strategies within the REACH context

One or a combination of these strategies could be applicable within the REACH context, depending on the exact target behaviour that we would like to change. There is much potential in REACH to use this strategies that are summarised in the touchpoints described in **D1.3**. At the same time, industrial partners Alreh Medical, Philips, Smart Cardia, and ArjoHuntleigh have an interest and the capabilities to implement these strategies in REACH. In this review we describe on example involving games developed by one of the REACH partner at Center for Playware (DTU).

3.7.2 Games: Center for Playware

When we want to understand how to motivate people to do things they would otherwise not do it can be beneficial to understand games and play. We can learn from the computer game

industry where the development of games for motivation to learning or improve health has long been a theme.

In the 80'ies a development within the education industry was seen, with learning games, also called edutainment. The ambition was to utilize the motivational aspects of games to get children to learn better and faster by playing games. A lot of games were created where the game elements was used to make the learning fun. They did have some effect, but the idealistic concept of harnessing the motivational aspects of game to create learning didn't happened. Recent research on games have shown, that a part of the problem was the lack of understanding of what games do (they create play), and the understanding of what play is and how it works (**Jessen & Jessen, 2014**; **Jessen & Lund, 2016**). While the games were used in educational settings and to some extent also in other settings (e.g. games for health) the games simply weren't good at creating play (e.g. fun) compared to other games. Further, the learning was often detached from the game, and it was often just an extra layer, that was put on to make the learning appear fun.

So, why is this relevant when we want to motivate elderly people to be more physical exercise?

First, if we understand motivation as something that we can just "add" to a product, we end up in the same situation as the games industry did with edutainment. In that situation, the motivation is detached from the actual exercise and it is less entertaining than other entertainment types, which requires less exercise.

In this view, two different strategies appear on how to motivate behavioural changes. The first is trying to change certain behaviour within people; the second is to adjust exercise opportunities to the behaviours already present within people. In other words, we can choose to convince people to change their behaviour (e.g. move more) using different strategies (i.e. gamification, social incentives, goal directed behaviour and/or self-reflection) or we can create technologies that allow people to exercise their natural affinity for play, social interaction, accomplishment and reflection. This would require that the touchpoints be designed to support certain target behaviour and that the motivational aspect is tailored to the user and their context for behaviour change and well integrated in the design. This is important because games make us play, and play is something we all seek. Thus creating games where you exercise allows the target behaviour to be a result of a user's natural motivation to play, turning the motivation upside down. Games have the potential to utilize the benefits of different behaviour change strategies (gamification, social incentives, goal directed behaviour and self-reflection) along with many others ways to create play.

3.8 Conclusion

We presented an overview of the motivational strategies relevant to promote physical activity among the elderly. To structure our review, we based our analysis on the Behaviour Change Wheel model, an approach based on nineteen frameworks of behaviour change frameworks. We then conducted a literature review to identify common interventions to motivate physical activity, in line with this model. We focused here on four behaviour change technics to motivate physical activity among elderly, which are gamification, social incentives, goal-directed behaviour, and self-reflection. One or a combination of these

strategies could be applicable within the REACH context depending on the exact behaviour we would like to change. Techniques to engage elderly in being more physically active are diverse. They can complement each other to increase their efficiency. How we could personalize these interventions to fit the REACH target population needs is an essential question to be addressed.

Results of this review in combination with the touchpoints identified in **D1.3** will be used in WP4: Motivation and intervention (Subsystem 3) for the planning and implementation of motivational strategies and techniques to be integrated into the REACH system.

4 Sensor technologies to monitor daily activities

In this chapter we review current knowledge of sensor-based monitoring of daily activities of elderly citizens living at home or in care centers. As explained in the introduction, the REACH approach is to promote functional ability (reduce or postpone functional impairment) by motivating and engaging our target population in increased physical activity. In the previous chapter we reviewed motivational techniques while we will focus on sensor technologies in this chapter. The present review, which continues and integrates the review of wearable sensors by EPFL in **D1.1** that reported on acceptance and the phases of uptake, will be taken further in **T1.4** on system architecture and will serve as input to **WP2/WP3** on sensing monitoring

4.1 Introduction

In this review, we will investigate current R&D trends on sensor technology for the elderly (65+ years old). Some sensors and related R&D for the elderly utilize for monitoring moderate physical daily activity, mainly light activities such as lying, sitting standing, walking, other house chores and outdoor walking. By differentiating such light, the sensor will have a large potential to identify normal patterns of activity (daily, weekly) and to detect irregular activities by distinguishing normal variations from critical deviations. In this review, we focus understanding the current sensor researches on.

1. How to detect light physical activities characterized with seniors such as lying, sitting, standing, lying in bed, sleeping, walking and other house chores?
2. How to identify normal patterns of activity, normal variations in such patterns and distinguish these from critical deviations in activity?
3. What is the status and likely development (near future: 1-2 years) of algorithm and approaches to developing algorithms to detect deviations?

The types of sensors and technologies to be surveyed are both wearable and ambient sensors, including indoor sensors often utilized in smart houses. The ability to identify indoor location is important, for example, when the elderly falls, it is critical to identify the falling position are; on floor or staircases, e.g. As a first step, it is important to comprehend correct behaviours and normal variations, and secondly, it is important that the sensor could help to detect critical deviations. Since the ultimate purpose of understanding physical activity level for the elderly in REACH are to provide feedbacks and alerts to the seniors based on the activity levels, identifying each activity accurately such as differentiate walking to vacuuming the room, might be less relevant. In order to support elderly's active living, it is critical to detect daily light activities with decent granularity, and detect deviations on time.

Sensor data support three different functions: First the detection of unintended sudden events or inactivity (falls; remaining in bathroom for x hours). Second, and overlapping with the former: detection of critical deviation in activity from ordinary pattern. Third, utilizing data to support physical activity via feedback or monitoring.

4.2 Background

Traditionally the sensor technologies for objectively measuring physical activity have sought for improvements of its sensitivity, range, accuracy and precision, and the sensors have been developed and tested mainly targeted to active younger and healthier generations (**Schrack et al, 2016**). The majority of the traditional sensor researches do not categorize light activities such as casual walking, stair climbing, and household tasks as activities. They focus on high intensity activities (**Matthews et al., 2012**), rather than differencing sitting and lying in spite of the fact, which is of critical importance for the use on the elderly (**Harris et al., 2007**; **Owen et al., 2010**).

Currently many societies have faced to the challenges relate to aging population. The sensors, which have targeted mainly the active younger generation, get some attentions for the use of understanding and detecting unexpected events on the elderly. Thus, we need to redefine the roles of sensors in physical activity monitoring depending on the emerging target characteristics, the seniors (65+ years old).

However, in order to apply current sensor technologies to detecting seniors' way of living, identifying normal patterns and outliers patterns, there are still many challenges and limitations in the existing studies. Before consumer wearable devices such as iWatch and Fitbit, have widely accepted in the international market, more expensive and high quality sensor devices with higher sensitivity, range, accuracy and precision have been the main target of research in analysis and validation. Such professional sensors are not only costly and difficult to set up in private, but quite limited to apply to the elderly's daily life as their physical activity is more moderate and rather low strength such as walking.

In **Section 4.2**, we started to review different sensor types and ways to detect typical activities in the elderly life. In **Section 4.3** we investigate sensor technology researches in depth. The section covers varied techniques in data collections, data combinations, as well as analysis methods in identifying normal patterns of activities and distinguishing ordinary from critical deviations in activity. Lastly, we discuss the potential development of algorithm and approaches to detect deviations for protecting the elderly's better living.

4.3 Detecting Elderly Activities with Sensors

As key measurements for elderly's healthy living, good sleep (**Landry, 15**), appropriate meals every day, physical activities such as walking, standing and stair climbing, and liquid intake are known as simple but critical measurements. Identifying changes in utilization of cooking, watching and toilet facilities could also be a clue for functional health statues. For understanding elderly's healthy living, sensor technologies which can detect daily way of living, have attracted attentions. (These results are of particular interest in the REACH context and the touchpoints identified in **D1.3**)

A number of sensors have been utilized to measure elderly's daily health statues and conditions. The sensors are used to detect living environment, daily routine and elderly's daily activity level. Chen et al. (**Chen et al, 2012**) categorized sensors in three types; movement sensors, physiological sensors, and contextual sensors. Movement sensors, such as accelerometers and infrared light are good examples among the most widely used

sensors in detecting human physical activities (**Yan & Hsu, 2010**). Physiological sensors are used for more clinical purposes such as taking blood pressures, body temperatures, and blood chemistry. Contextual sensors such as GPS and RFID measure qualitative environment data instead of measuring quantity

In 90s and 2000s, many studies investigated a single or a few sensors, and majority was conducted laboratory-based setup to detect elderly's ordinary patterns. To name a few, temperature sensor, light sensor, gyroscope and magnetometer sensor or infrared light, magnetic sensors in doors (Demongeot et al., 2002; Ohta et al., 2002; Yamaguchi, 1998) have been investigated. Sensors attached household electric appliances such as smart kettle [Guardian, 2016], sensor toilet (**Kumata et al., 2011**), magnetic switches, or combined of varied sensors at home (**Celler et al., 1995**; **Yamaguchi et al., 1998**) have provided earlier studies of smart houses. Smell sensor, gas sensor and visual sensor are also used in the elderly household domains, while microphone sounds with a low transmitting power mobile phone (W-SIM) (**Matsuoka, 2011**) are used in the elderly physical activity environment. Comprehensive services such as home security have also utilized sensor and related technologies to detect outlier events.

Obviously, mobile phone and smart phones these days are one of the biggest sensor sources, which include all three sensor types of movement, physiological and contextual sensors, such as motion sensors, accelerometer and GPS, and used in combination. For example, Ghose et al. (**Ghose, 2015**) utilized accelerometer and GPS of smart phone to detect human physical activities, while Landry et al (**Landry, 2015**) investigated wrist-worn watch to understand and promote better sleep quality and physical activity. Not only ordinary smart phone, but also special system such as a novel shoe-based sensor system for stroke detector (**Fulk, 2012**) has been suggested. Different from sensor set up in rooms, wearable sensors have additional challenge such as locations. An analysis of wearable sensor placement locations for the human body has been investigated in depth (**Atallah et al., 2010**; **Yang, 2010**), among which researches over fall detection (**Kangas et al., 2009**; **Özdemir & Turan, 2016**) have provided intensive analysis.

In addition to the automatic data collection through sensors, subjective inputs such as the elderly and care-givers self in-put, interview data and reports can also be used as supplements in some studies (**Celler et al., 1995**).

Despite the long research on sensor technologies on elderly activities, detecting light activities, which are unique for elderly, are more difficult than it was thought in the 90's due to lack of sensitivity for sedentary behaviours such as sitting, standing and lying [Chen, 12]. In addition, interpreting its meaning from multiple parameters and signals of movement data are also challenging task, as we need to define which properties of human behaviours should be considered to detect a particularly dangerous movement. By identifying key elderly activities, collecting key functional data for detecting particularly light activities have gradually been investigated and validated. Oner et al. (**Oner, 2012**) suggests algorithm, which accurately distinguish between walking and running, while, Li (**Li et al., 2009**) introduced a system where algorithm can distinguish different postures such as standing, bending, sitting and lying, by using accelerometers and gyroscopes.

4.4 Identify irregularity

There are two categories in an elderly's irregular patterns or behaviour:

- Unexpected sudden irregularity (e.g., a fall, resting for hours in the bathroom)
- Unexpected long term progressive irregular patterns (e.g., greatly reduced number of daily steps).

The unexpected irregularity is emergency events such as stroke, physical deconditioning, falling, accidents cf. in bath rooms while long term irregular progressive patterns are events such as gradual decrease in activity level and wondering behaviours. The former unexpected irregular behaviours could be defined as below four categories. First, unexpected irregularity such as falling or find yourself in irregular place. Secondly, irregularity in time such as staying in bed during a whole day, getting out from the bed in the midnight, or walking around irregular patterns. Thirdly, detecting no motion for a long time such as no toss and turn in bed.

In order to identify such the elderly's irregular behaviour through sensor data, the base data such as normal behaviour patterns are needed. Practically speaking, when it comes to elderly's behaviour, only regular patterns could be collected and become a target of machine learning except identified elderly's daily life risks such as falls (**Kangas et al., 2009**). When it comes to low-complexity falls, data can be acquired through false fall experiences and varieties of algorithms are suggested (**Brown 2005**; **Brownsell et al., 2000**; **Brownsell & Hawley, 2004**; **Doughty et al., 2000**; **Kangas et al., 2009**; **Li et al., 2009**; **Luukinen et al., 1994**; **Oner, 2012**; **Ozcan et al., 2005; Shi et al., 2015**). However distinguishing real falls from fall-like activities is difficult and can result in false alarm. Other irregular patterns in the future are not prepared so that machine will learn only with regular data, and assess other patterns as irregular patterns, which is one kind of outlier detection approach.

The previous studies typically collect and use their normal behaviour patterns as comparison. Some use general statistical data (ex. **Kangas et al., 2009**) or a set of participants' data (ex. **Fulk, 2012**) as basic foundations as common normal behaviour, however, it is getting more evident that individualized data ought to be used as comparison with their irregular patterns. Since normal healthcare patterns could vary from person to person at wider degrees, it is challenging to generalize individual patterns precise enough to detect irregularity. Sometimes based on the data from learning period, statistical analysis on each person's individual behaviour and activity are conducted, and the mean and standard deviation and its distributions are calculated (**Demongeot et al., 2002**). A combination of statistically calculated indexes with human analysis on unusual state detections are also commonly reported for improving the credibility of the unusual stated detection system (**Ohta et al., 2002**). Instead of using general or statistical data, recently more and more research utilize machine learning and optimization techniques. By utilizing and combine varied sensors data from smart house sensors to wearable sensors, Fujitsu and CASALA (**Fujitsu, 2015**) measures individual value, relate individual activity with, and optimize individual reference value automatically. By collected real-time data, irregularity detection through hybrid statistical and knowledge-based technique is also suggested (**Riboni, 2015**).

Applicable machine learning technique could be for example, the k-nearest neighbour (k-NN) classifier (**Atallah et al., 2010**), Bayesian decision making (BDM) (**Atallah et al., 2010**), support vector machines (SVM) (**Mannini et al., 2012**), least squares method (LSM), random decision forest (**Ghose, 2015**), artificial neural networks (ANNs), rule based algorithms (**Kangas, 2009**) and others. The research on fall detection through 63 different combinations of sensors and machine learning technique, concluded the best sensitivity was achieved on body by using the k-NN classifiers (**Özdemir & Turan, 2016**). For rehabilitations purpose among people with stroke, SmartShoe with feedback utility is suggested with a function of utilizing artificial neural network (ANN) using data from a different set of participants (**Fulk, 2012**).

(The above results on identification of activity patterns shall be used in further work in **WP2/3** where Frauenhofer, EPFL, TUM and SmartCardia shall utilize results when further detailing the REACH engine and the platform functionalities).

4.5 Comparing off-the-shelf sensors

We performed a survey of the existing sensors that may address our needs. More concretely, we would like to collect: steps, cadence, calories, stairs, sleep data, body weight, fat mass, muscle mass, water mass, bone mass, heart rate, heart rate variability, breathing rate and breathing volume. We performed a comparison of off-the-shelf products based on a number of criteria. These criteria include safety certifications, measurement accuracies, ease of use (wearability, battery life, data storage, ease of use of the software interface), usefulness (the range of information collected via the sensor), seamlessness of data transmission, data accessibility (using public **API**, manual download, or lack thereof), and affordability – see below **Section 4.8** for the summary. The full data sheet is available as a separate document as well.

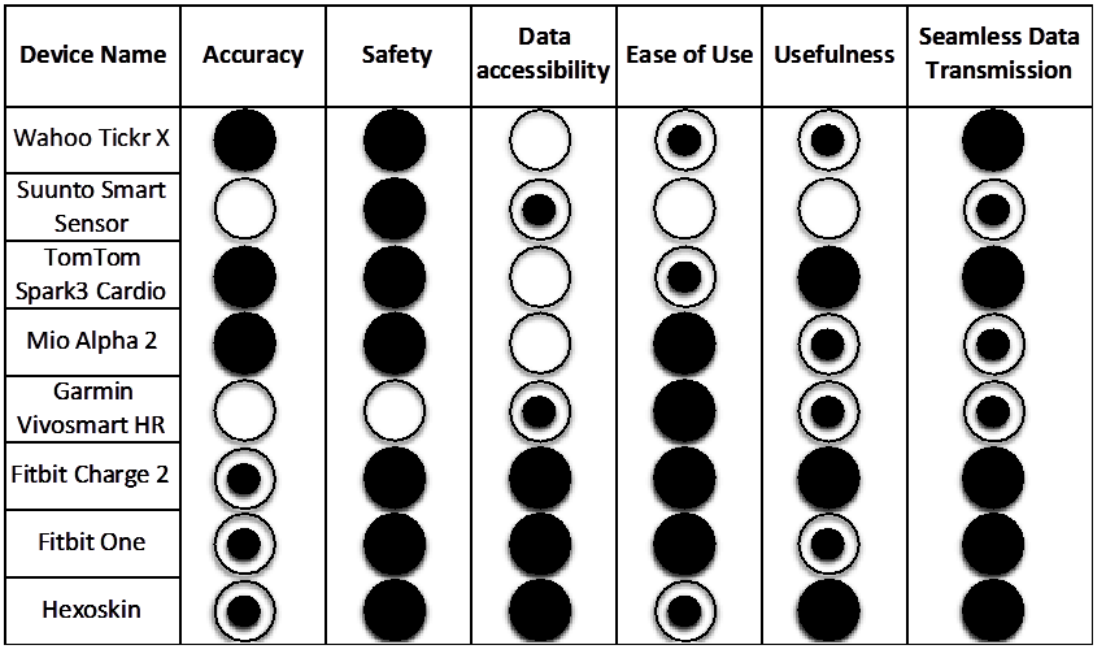

Figure 4-1: The summary of our sensor evaluations

4.6 Risks and benefits - privacy concerns

Issues about privacy and confidentiality are necessarily key issues in the context of sensor-based monitoring. Privacy is about people's right to keep their personal matters and relationships to themselves including their right to determine whether, when, how, and to whom, their personal information can be shared. Confidentiality is the right of an individual to have personal, identifiable medical information that is given to a health care provider kept secret and not disclosed to others unless the individual has given specific permission for such release (confer **D43**, **Chapters 3 and 4**; see also **AMA (no date**)). Few studies have explored in-depth how extensive monitoring and surveillance might affect users more broadly, although protection of privacy is frequently mentioned as a cause of concern. For instance, in their recent review of 16 articles on electronic technology aimed at supporting aging in place by monitoring and tele-medical solutions, **Peek et al (2013)** find that half of them articulate concern over privacy issues. Still, **Al-Shaqi et al (2016, p. 17)** also note in their conclusion of an overview of ambient assisted systems based on 133 papers that "most of the research appears to ignore and assume that users will accept the system in the way they design it. User acceptance depends on how users experience the balance between possible loss of privacy and the perceived benefits of having trusted family members and care providers monitor critical deviations from daily activities. In their extensive interview study of the views of elderlies about privacy issues **Mortenson et al. (2016)** find that while participants associated monitoring technologies with an unpleasant sense of being watched, they were willing to make the trade-off between intrusion and security in the hope of avoiding nursing home placement. Similarly, in their interview study of elderly citizens living alone, **Pol et al (2015)** found that their interviewed older persons positively valued sensor monitoring and indicated that the technology served as a means to enable independent living.

In summary, much of the literature on sensor-based monitoring contains expressions of concerns about the protection of privacy but there is no generally accepted framework for guiding design of these technologies, although the "privacy by design" method (**Cavoukian 2009**) does suggest a general approach, described in **D43** (**Chapters 4/5**).

4.7 Future Direction

There are many ways to direct future studies on sensors for elderly. First important direction is to apply individualized and personalized data of normal living, rather than general statistical data, to the irregularity detection algorithms. More and more researches (**Fujitsu**; **Ohta et al., 2002**; **Riboni, 2015**) have reported algorithms, which collect individual daily life data and apply irregularity detection. In spite of the fact that the general approach nowadays utilize accumulated general data as base data for detecting outliers, more and more customized data should be applied in near future. Since it is gradually known that each individual has their own specific daily patterns of movements and particular personal characteristics in durations on stay in a particular room, it is less appropriate to utilize general data to detect emergency events on elderly.

In addition, together with data collection, irregular identification, varied feedback functions will be suggested. Currently, only a few suggest functions are used in real world settings

(There are already many in laboratory settings), the tendency will have developed more along with the personalized data analysis functions.

When it comes to identification of normal patterns and irregularities and its algorithms, not only elderly's physical conditions but also other environmental conditions such as seasonal fluctuation of weather and temperature should also be studied as critical data input (**Ohta et al., 2002**). By taking seasonal fluctuation into consideration, it becomes more precise in creating algorithms for calculating elderly's normality and irregularity of their health condition.

Lastly but not least, intervention, which is one of the emerging topics to support healthy living should be investigated along with sensor technologies (**Landry, 2015**; **Martin et al., 2015**).

4.8 Conclusion: Benefits/risks analysis and outline of implications for and applicability in REACH

Further application of results of the sensor analysis and its implications for REACH will be made in **T1.4** and reported in **D1.4** on the product-service-system architecture and as well in **WP2/WP3** on sensing and monitoring. However, a summary of the implications include the following points:

1. At the level of technologies, wearable activity sensors are widely used by younger populations; they are widely available and have been shown to be relatively robust and reliable in sensing physical activity. The sensors under development by REACH partner SmartCardia are expected to provide further value by providing as well physiological data.

2. Sensor-based monitoring plays a crucial role in several of the touchpoints identified in **T1.3** (**Section 7.3.2**) and in particular in the clusters.

3. The state of the art with respect to identifying concrete activities – in contrast to tracking and recording physical activity (number of steps in time and place) – is still not at a stage where robust algorithms have been developed and validated. However, the primary goals of the REACH system may be satisfied, since most critical irregularities may captured by physical activity tracking combined with positioning.

4. For the design of the REACH system it is crucial that users are able (and feel they are so) to control the balance between privacy and monitoring level. Procedures and guidance documents to support this are described in **D43** and at public presentations of the approach to privacy protection of the REACH project (**The ISG 2016 Conference on Gerontechnology, 28-30/09/2016, Nice, France; Japanese Ergonomics Association, Tokyo Inst. Technology, 20/10/2016**). In these presentations the REACH position is made clear: the system design must ensure that the user can freely determine the types of data that the user wants not to share with others.

5 Early trials

The project has initiated early trials at the four demonstration sites in order to (a) obtain early data from primary users with "early" versions of the planned technologies and interventions, (b) acquire experience with technologies and techniques in the areas of sensing and motivation; (c) collect data on the deployment and use of relevant technologies.

The process of obtaining approval from ethical review boards or data protection boards will take up to 6 months or more (as expected), and therefore only one of the planned trials has been conducted at the time of writing (Lyngby). We report in this chapter on the plans for the trials and reproduce the summary protocols for each of the trials along with a short statement of current status (December 2016).

The protocols of the planned/ongoing studies of HUG and Lyngby are available to partners at the REACH project website and for the Lyngby trial the approval of the local data protection office is also available.

5.1 Lyngby

Table 5-1: Test Lyngby

Name/Location of test case/setting	Lyngby / DTU & CPH Univ
Version number and date	V.2.0 (2016-12-12)
Short description: Purpose of test (e.g. whether and how X affects Y for population Z)	Primary purpose: - examine to what extent) daily feedback from wearable activity tracking is accompanied by changes in activity Secondary purposes: to examine … - acceptance/ tolerability of wearables over time (9 weeks) by target group; - whether changes in subjective activity reports match changes in sensor records; - pilot full scale logistics of daily visits over long periods time; - sensor recording and data upload robustness/reliability.
Demographics of test persons (age group, health/mobility status ….) Relatives (?) Planned number(s) recruited	Stage 1: Recruit citizens 65+ who receive personal/healthcare service and are judged by nurses to be in need of physical activation: Screened N=42; Included in trial: N=26 Participants wear a Fitbit for 5 days (battery time); those who most tolerate/accept wearables eligible for Stage 2 Stage 2 Stratified randomization divide participants into two groups A and B, each 13 persons Stage 2a Group A daily feedback about yesterday's activity Group B same amount of feedback but about previous night's sleep Stage 2b Vice versa: Group A receives daily feedback about sleep; Group B about activity.
Planned start and finish dates (approx.)	Detailed logistics Recruitment August – Sept. Stage 1: Early September 5 days Stage 2a: October-Nov. 20 days Stage 2b: Nov. – Dec. 20 days

Clinical setting (home/clinic, extent and type of assistance; rehabilitation … other type of intervention etc.	Home, elderly receiving modest amount of personal and or healthcare support Exclusion: elderly using rollator/walking frame (because Fitbit does not record physical activity with rollator
Type of test design (cross-over; cohort-before/during/after; RCT …. …)	Structured: Criterion + Cross-over design
Sensors and equipment to be used (SmartCardia, Fitbit Surge ….)	Fitbit Charge HR Smartphones to pick up and transmit data
Other equipment/materials used in trial (e.g. Playware tiles, AlrehMedical equipment, Arjo Huntleigh equipment …)	Measures of mobility/functional ability (to be determined)
Specific conditions to be detected/recorded (health states, frailty, activity/inactivity, diseases, motivational aspects, usage and usability ….)	Physical activity; heart rate variations; personal acceptance; usability
Optional link to patient profiles/personas identified in T1.1	Similar to Personas identified by Lyngby
Data collection, storage and processing approach (e.g. data will be stored first locally at test site, anonymized and then transferred to the analytics partners)	Data collection at DTU or Copenhagen Univ.; local data pseudonymisation; anonymization of data for analysis and transfer to collaborating partners
Ethics application necessary (yes/no; if yes please specify associated procedures and time frames; if no, please specify why the data are not personal health-related or sensitive data)	Ethics approval (personal data registration for research purposes) has been obtained via CPH Univ. Data Registration Board, June 4th
Potential risks/harm to trial participants (discomfort, injury, unintended disclosure of private data …. …) Insurance issues	• Risk of privacy violation controlled by: (i) strict security protocol of CPH Univ. (ii) informed consent procedure • (iii) detailed written and oral instructions to staff involved • Minor discomfort of wearer due to hard bracelet

Update 18 December 2016

We will conclude the trial on the 22nd December, which therefore is the last day of data collection which began with the first participants late October. We managed to recruit 26 citizens into the trial, mean age 85.

Two of our participants fell ill during the trial, one found the armband too uncomfortable to wear and one passed away – so data from 22 participants. We have collected data on sleep and steps from the 22 participants over 6-8 weeks. For some participants, we lack data for some of the days due to repeated problems with Bluetooth pick up of data from the Fitbit to a smartphone.

One of the unexpected observations was that some (3 out of 10) of the participants who began with feedback about the previous day's walking activity had become so happy with this feedback (which they received by a phone call from a research assistant) that when we switched them to feedback-about-sleep they told us they very much wanted to continue receiving feedback about the previous day's physical activity and that they had in fact begun to share this information among themselves. So for some participants the feedback has clearly led to a wish for increasing physical activity and for monitoring this. We will follow up on this.

Data will be analysed Jan-Feb. 2017 and results will be shared with partners, and a summary is planned for inclusion in **D1.4**.

We are planning follow-up qualitative interviews (open questions) with each of the participants (January – February). The objective is to elicit their views, concerns and preferences concerning sensor-based monitoring and tracking, privacy, confidentiality, security, motivational issues, willingness to share etc.

5.2 ZuidZorg

Table 5-2: Test ZuidZorg

Name/Location of test case/setting	Eindhoven
Version number and date	V0.3 (2016-12-21)
Short description: Purpose of test (eg whether and how X affects Y for population Z)	Understand whether and how different persuasive strategies such as social support and dialogue support affects the degree of physical activities for the target elderly personas at ZZ meet and greet center with different attitudes towards physical activities and at different stage of behaviour changes towards being physical active.
Demographics of test persons (age group, health/mobility status ….) Relatives (?) Planned number(s) recruited	Elderly people, 65+, about 60 people in total
Planned start and finish dates (approx.)	9 Jan 2017 - 30 April 2017
Clinical setting (home/clinic, extent and type of assistance; rehabilitation … other type of intervention etc.	Activity centre, home
Type of test design (cross-over; cohort-before/during/after; RCT …. …)	RCT with two parallel groups
Sensors to be used (SmartCardia, Fitbit Surge ….)	Mi-Band
Other equipment/materials used in trial (eg Playware tiles, AlrehMedical equipment, Arjo Huntleigh equipment …)	Not at this stage
Specific conditions to be detected/recorded (health states, frailty, activity/inactivity, diseases, motivational aspects, usage and usability ….)	activity/inactivity, motivational aspects
Optional link to patient profiles/personas identified in T1.1	Personas from ZZ and Lyngby
Data collection, storage and processing approach (e.g. data will be stored first locally at test site, anonymized and then transferred to the analytics partners)	Data will be stored locally and anonymized and then transferred to the analytics partners
Ethics application necessary (yes/no; if yes please specify associated procedures and time frames; if no, please specify why the data are not personal health-related or sensitive data)	We will prepare a consent form. No personal health data will be collected but activity/inactivity data. The “client raad” approved our test proposal on Dec 19 2016.
Potential risks/harm to trial participants (discomfort, injury, unintended disclosure of private data …. …) Insurance issues	We do not foresee this with the sensor that we aim to use.
Status per 21 Dec. 2016: We have just received the approval from the ethic committee at ZZ (the client raad). We are purchasing the Mi-Band and preparing necessary questionnaires and cultural probes and data visualisation. The participants have been already recruited. We expect to start in Jan for a small month pilot and the real RCT will start from Feb onwards for three months.	

5.3 HUG

Table 5-3: Test HUG

Name/Location of test case/setting	Safety and proof of concept study of Alreh equipment and smart cardia sensors / Hôpital des Trois-Chênes / In-hospital setting
Version number and date	V.1.0 (2016-07-06)
Short description: Purpose of test (e.g. whether and how X affects Y for population Z)	This trial aims at assessing the safety and the functionality of Alreh equipment and smart cardia sensors
Demographics of test persons (age group, health/mobility status ….) Relatives (?) Planned number(s) recruited	Inclusion criteria according to the HUG use-case: 65+ year old AND hospitalized at the Trois-Chênes Hospital AND planned discharged with the help of the IMAD AND 20<MMSE<28 OR 63<MIF<121. Exclusion criteria: non capable of discernment, impossibility to interact with a human-computer interface. Demographics to be determined precisely with the conclusion of our first study but probably 75-100 years old with predominant problematics of metabolic syndrome and associated complications, falls, cognitive impairment, cancer, COPD, i.e. all frequent conditions in geriatric internal medicine… Variable mobility status. Sample size: 20 (5 patients with intervention, 5 without and 10 healthy adults)
Planned start and finish dates (approx.)	Start: January 2017 End : End of march 2017
Clinical setting (home/clinic, extent and type of assistance; rehabilitation … other type of intervention etc.	In patient setting in the geriatric hospital
Type of test design (cross-over; cohort-before/during/after; RCT …. …)	Safety and proof of concept study. 5 patients corresponding to the inclusion criteria will be recruited and will train their transfers with Alreh equipment with the occupational therapists (30min) under monitoring of SC and Fitbit sensors (48 hours). 5 other patients will train their transfers according to the standard of care without Alreh equipment or sensors. Finally, 10 healthy adults will follow the same protocol as the first group. The design is thus adapted from the RCT methodology.
Sensors to be used (SmartCardia, Fitbit Surge ….)	SmartCardia + Fitbit
Other equipment/materials used in trial (e.g. Playware tiles, AlrehMedical equipment, Arjo Huntleigh equipment …)	Alreh equipment
Specific conditions to be detected/recorded (health states, frailty, activity/inactivity, diseases, motivational aspects, usage and usability ….)	Alreh equipment and SmartCardia sensors and Fitbit : - Safety (questionnaire to be determined) - User-friendliness and functionality (NASA questionnaire +/- specific questions ?)
Optional link to patient profiles/personas identified in T1.1	Cf. inclusion criteria
Data collection, storage and processing approach (e.g. data will be stored first locally at test site, anonymized and then transferred to the analytics partners)	Data collected and anonymised on site with the code stored at campus biotech. Then, Data will be shared with technical partners in Switzerland. Data destroyed at the end of the project.

Ethics application necessary (yes/no; if yes please specify associated procedures and time frames; if no, please specify why the data are not personal health-related or sensitive data)	Yes Timeline: - End of august : submission - Answer (often negative) expected end of October - Re-submission: mid-November - Approval: end of December / beginning January
Potential risks/harm to trial participants (discomfort, injury, unintended disclosure of private data …. …) Insurance issues	Low-risk: - Consultation of the medical records by the research team - Injury with the equipment or sensors (very unlikely)
Status December 2016: Awaiting approval from the ethics review board.	

The documentation produced for the trial activities at HUG may be found in **D43, Appendix 8.1**.

5.4 Schön Klinik

Table 5-4: Test Schön Klinik

Name/Location of test case/setting	Schön Klinik Bad Aibling
Version number and date	V.1.0 (2016-06-10)
Short description: Purpose of test (e.g. whether and how X affects Y for population Z)	
Demographics of test persons (age group, health/mobility status ….) Relatives (?) Planned number(s) recruited	Persons associated with members of the REACH team, age 40 +, healthy adults, male and female
Planned start and finish dates (approx.)	July 18, 2016 – Sept 12, 2016
Clinical setting (home/clinic, extent and type of assistance; rehabilitation … other type of intervention etc.	Home/Work/Leisure environment
Type of test design (cross-over; cohort-before/during/after; RCT …. …)	
Sensors to be used (SmartCardia, Fitbit Surge ….)	SmartCardia combined with Fitbit
Other equipment/materials used in trial (e.g. Playware tiles, AlrehMedical equipment, Arjo Huntleigh equipment …)	
Specific conditions to be detected/recorded (health states, frailty, activity/inactivity, diseases, motivational aspects, usage and usability ….)	Activities, personal motivation, concerns,
Optional link to patient profiles/personas identified in T1.1	
Data collection, storage and processing approach (e.g. data will be stored first locally	Data collection at SK Aib, pseudonymized transfer to partner

at test site, anonymized and then transferred to the analytics partners)	
Ethics application necessary (yes/no; if yes please specify associated procedures and time frames; if no, please specify why the data are not personal health-related or sensitive data)	Ethics vote not necessary for this first stage of the data collection Full application for stage 2 with patients.
Potential risks/harm to trial participants (discomfort, injury, unintended disclosure of private data …. …) Insurance issues	Personal experience will be collected in with interviews. Participants have to sign an agreement which allows us to use the data and releases SK Aib from liability.
Status December 2016: Awaiting approval from the ethics review board	

6 Conclusion

We conclude this report by summarizing the outcomes of this task and pointing forward to the WPs and other tasks in which these outcomes shall be used as input.

In the last part of **Section 1.1** we have referred back to, and spelled out in more detail, the overall guiding idea of the REACH project – viz. to reduce the risk of functional loss or impairment of elderly citizens (65+) by sensor-based monitoring and stimulation of physical activity. By using sensors and recognition of changes in physical behaviours motivational techniques shall nudge our target users to engage in greater physical activity. The positive goal of REACH may therefore be said to be the preservation or restoration of functional ability (prevention or postponement of functional loss or impairment). At the same time, this suggests that a set of common measures of success of the REACH system will centre on selecting appropriate measures of functional ability. (A catalogue of such measures was described in **D1.1**, **Section 2.2**). These considerations are input to **T1.4** and in particular **WP6** which will lay down the methods and concrete techniques for measuring the success of the progress and achievements of the REACH.

Besides the brief conceptual re-analysis, this task has performed three substantial investigations:

First, in **Chapter 2** we have provided at Stakeholder Analysis, using three templates to capture constraints, incentive structures, interdependencies among stakeholders as well as chief benefits and risks. The results will be used in particular by **T1.4** and **WP2/3**. An important outcome of the stakeholder analysis is that across all sites the primary users, the older citizens, have a chief risk and drawback in, first, their fear of or discomfort with possible data disclosure and second, the stress that the use of the technology may lead to. These risks are similar for relatives and friends (informal caregivers) and, to some extent, for the formal care givers as well. Another important outcome is the reinforcement of the distinction between care stages: between primary users in rehabilitation care in clinics (who thus have the status as "patients"); and those who live independently at home with more or less assistance (and who are “citizens” unless they have a visit from a healthcare professional or receive care in a facility). Finally, the Stakeholder analysis has helped making explicit differences in the influence and interest that different stakeholders have in different national contexts.

Second, in **Chapter 3** we have provided at review of current knowledge of motivational and persuasive techniques to promote physical activity. We have observed that a few of the structured taxonomies and models, including in particular the Behavioural Change Wheel, may be of particular value to REACH and may be adapted to the project. The results of this subtask will be used in **T1.4** and in **WP4** in particular, but will also be of relevance to **WP2/3/6**. A selection of strategies have been selected and described, that also proposes how specific intervention functions may be applied to the touchpoints identified in **T1.3/D1.3**.

Third, in **Chapter 4** we have presented a review of sensor-based technologies to monitor physical activities of elderly citizens living at home or in care-homes. The review indicates that the identification of critical (health-threatening) deviations from normal pattern of activity (i.e., capturing non-sudden irregularities in patterns of activity) is a research challenge that

may not be solved in the near future. On the other hand, current developments in activity trackers show that it is possible to capture variations with high reliability in number of steps per day, and hence, a marked drop in activity can be captured with great certainty. Results of this chapter will be input to **T1.4** and **WP2** in particular.

Finally, we have wanted to present an overview of the experimental efforts that are being currently spent on assessing how users react and respond to (early versions of) the technologies to be developed. One and possibly two early trials will have results that will be summarized in **D1.4**, whereas the trials that take longer to complete will be reported in **WP6**.

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