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D1.2 Narratives booklet for rehabilitation assistance

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EXECUTIVE SUMMARY

The deliverable, D1.2: Narratives booklet for rehabilitation assistance, is the outcome of Task 1.2: Narratives for virtual coaching. It is considered by the clinical partners of the project to be the logical application and follow-up to Task 1.1: Healthy, Behavioural & Well-being models.
D1.2 investigates the Virtual Coaching interaction scenarios with frail persons in the context of specific narratives in the selected rehabilitation pathways, accompanied by some related use cases. The descriptive process used with this document re-uses the results of D1.1 and examines the different conditions of the patient populations that will be considered when validating the *vCare* platform.
Narratives derived from medical practice and patients are a source of knowledge for treatment evidence: they are regarded as a useful resource for understanding the individual, patient-specific meaning of an illness (Kalitzkus & Matthiessen 2009). In particular, the use of narratives enables a better definition and coverage of the core components of the rehabilitation model, and therefore addresses a major patient need. The approach used in this document ("booklet") is based on the *vCare* clinicians' practically gained knowledge. The narratives represent the most common and debilitating disease conditions and reflect a collection of symptoms and complications observed in clinical practice and in this sense they can be considered as an "indirect" bottom-up approach.
Moreover, choosing the narrative approach as specific qualitative research approach, and underpinning these with distinct use cases, addresses a major technical requirement of the project: essentially, it identifies the needed rehabilitation pathway support by the patient.
The final definition of the strategies to be used and implemented in *vCare* will be based on the narratives described in this document, together with the related use cases. They will be discussed and represented by other means in detail in Task 1.3 and its related deliverables, D1.3 and D1.4. Furthermore, this document provides important input that feeds into the technical requirements and the virtual coaching architecture definition in WP5 and WP7.

Table of Contents

List of Figures

List of Tables

ABBREVIATIONS

ADL – Activities of Daily Living
BP – Blood pressure
CR – Cardiac rehabilitation
DoW – Description of Work
ECA – Embodied Conversational Agents
HADS – Hospital Anxiety and Depression Scale
HF – Heart Failure
HR – Heart Rate
IADL – Instrumental Activity of Daily Living
NA – Not applicable
NYHA – New York Heart Association (NYHA) [classification system]
OFF – motion status (stop) of a Parkinson's Disease patient
ON – motion status (movement) of a Parkinson's Disease patient
PD – Parkinson's Disease
TV – Television
UC – Use Case
VC – Virtual Coach

1 INTRODUCTION

This document provides a set of narratives about how patients can be helped and supported by *vCare*. Its introduction has two main purposes. It outlines the document's objectives and basic approach, and it describes the variability among patients to be treated by the outcomes of the *vCare* project.

1.1 OBJECTIVE AND BASIC APPROACH OF THE DOCUMENT

In this document, clinical partners have been requested to propose narratives (and related use cases) in order to further substantiate the desired virtual coaching functionalities and to facilitate the derivation of technical implications. The basis for this work was a preliminary analysis of the clinical needs, as presented in deliverable D1.1.
To elaborate the content of D1.2, each clinical partner reviewed and summarised the current situation regarding clinical management and rehabilitation strategies for each of the pathologies proposed by *vCare*. This review/summary illustrates examples of the missing gaps in traditional clinical pathways. On that basis, the needs/services for each condition, are outlined from an initial clinical point of view; they aim to address the missing gaps in order to improve traditional rehabilitation pathways thought innovative *vCare* services.
Being aware that the narratives reflect changes in the person's status (DoA, p. 13), task 1.2 "Narratives for virtual coaching" builds the basis for the set of requirements of the solutions related to the patient's high priority needs. It does so according to two different perspectives (see DoA (part B, p. 23)):

- the first perspective can be labelled as "unstructured" and is named a "**narrative**". It is based on the analysis of the patient's profile from a clinical perspective, providing the actions foreseen in an extended rehabilitation programme, focused on the home setting;
- the second perspective can be labelled as "structured" and is named a "**use case**". This perspective is based on the description of specific actions, as a sequence of steps within a process (including the supporting services). Use cases are presented according to the level of interaction between the VC and the patient affected, which was defined in D1.1.

The narratives were chosen to represent two purposes: paradigmatic prototypes of patients, and the variability of the clinical spectrum in the context of each disease. Narratives derived from medical practice and patients are a source of knowledge for treatment evidence, that goes beyond the gold standard of randomised controlled trials of evidence-based medicine. Narratives can be understood as the bridge between the evidence of large-scale randomised-controlled studies and the medical practice of applying this knowledge to a single case (Kalitzkus & Matthiessen 2009).
Consequently, the current work identifies **eight narratives representative of paradigmatic individual cases**, which address **14 use cases representative of needs of the patients**. Thus, starting from a patient's needs collected in a narrative, the use case represents a description that specifies the useful services needed to provide his/her rehabilitation programme. Each use case is described according to the three levels of interaction foreseen by the *vCare* model. In particular, the three technological dimensions of the *vCare* model (see again D1.1), which addresses the continuum between the "intrusiveness" and the "interaction", are addressed by the possible interaction scenarios between the Virtual Coach and the patient use cases. They are handled at three different levels:

- at the lowest level of interaction, a "silent" and non-intrusive virtual coach may be particularly supportive to risk factor reduction, adherence to the care plan, and for

rehabilitation purposes. The Virtual Coach should work like a reminder (i.e. notification), by offering very light feedback to the patients. This interaction is defined as "context-driven", as the communication is driven by events (automatically) detected in the context where the user lives;

- at the medium level, the future solution should be more participative, by implementing verbal messages or providing information, in order to support the rehabilitation programme. The Virtual Coach should act like a "trainer", able to provide recommendations on the way to perform a particular action foreseen by a specific pathway; this interaction is defined as "content-driven", as the communication is driven by a set messages associated to the patient's profile;
- at the highest level, the Virtual Coach involves various emotional and motivational aspects. For example, at this level, the Virtual Coach could "listen" to the user's messages and provide support. this interaction is defined as "engagement-driven", as the communication is driven by a reasoner detecting the involvement of the patient to the care plan, from different perspectives.

The Virtual Coach should recognise and consider the patient's actual status and adapt rehabilitation activities and interactions in a personalised way. The activities presented in this deliverable will help:

- clinical partners, in order to detail the use cases by the in the next two deliverables (D1.3: Narratives representation for automatic reasoning and D1.4: Natural representation for clinical pathways), with the aim of defining ontologies, rules and designing clinical pathways;
- technical partners, in order to prioritise the use cases and identify functionalities and services in order to define an implementation plan.

Finally, each clinical partner investigated the patients' needs (and related treatments) which could be enhanced through technological actions (see section 3.5), and provided prioritised needs. Needs with the highest priority were consequently analysed, identifying a list of potential domains of application.

1.2 TACKLING VARIABILITY OF PATIENTS

Variability is an important phenomenon, in terms of its predictability or lack of it. This variation can be seen in D1.2 in the use cases used to describe scenarios/narratives. Handling the notion in this way enables the *vCare* consortium to deal with the degree of variation seen among patients in Europe.

The characteristics of the use cases presented in this document are based on clinical practice: they reflect representative examples of typical outcomes for each of the four diseases covered in *vCare*. For each narrative, the most common variations are outlined in the brief descriptions outlined below. In addition to the proposed prototypical features of the use cases, every disease embodies some degree of predictable and unpredictable variability in terms of clinical presentation and evolution, risk association, and response to pharmacological and non-pharmacological treatment. However, in some diseases the variability of the severity of how the disease is manifest is proportionally higher by definition. Stroke and Parkinson's disease belong to these types of diseases. Major aspects of this variability are introduced below.

Regarding **stroke patients**, the vascular territory covered by ischemia or haemorrhage is variable and can have different consequences on the patient's clinical signs and clinical

manifestations. Timely treatment in an emergency, and “etiological” factors also influence the clinical outcome. In addition, a residual hemiparesis in a stroke patient can determine different levels of spasticity and pain on the side of the body affected. However, variability in stroke is mostly due to the primary and secondary prevention of risk factors (Guzik & Bushnell 2017). Overall, stroke can cause five types of disabilities (Kim & Caplan 2016): paralysis or problems controlling movements (faciobrachiocrural hemisyndrome with major involvement of upper limb; faciobrachiocrural hemisyndrome with major involvement of lower limb); sensory disturbances (pain, localized hypoesthesia; localized dysesthesia); problems using or understanding language (aphasia), problems with thinking and memory (amnesia, deficit of executive functions); and emotional disturbances (depression, anxiety). These five disabilities can occur and be combined, with varying degrees of severity, in a single patient. Epidemiologically, outcomes show that more than 70% of individuals experience upper limb weakness after a stroke (Nakayama 1994), and 30% of these patients have a permanent paresis (Nichols-Larsen et al 2005). Six months after a stroke, 35% of survivors can experience depression, 30% experience important ambulatory disabilities, and 26% are dependent in terms of their activities of daily living (Ovbiagele 2011). Dysphagia and dysarthria can both be present in up to 28% of the population (Flowers et al, 2013). According to the American Stroke Association, pain is one of the four common medical complications in stroke survivors. Turning to risk factor modification, it is of fundamental importance for stroke prevention (Romero et al 2008). Among risk factors, Obstructive Sleep Apnea (OSA) is a common risk factor for stroke (Valham et al 2008). Morbidity and mortality from stroke is strictly linked to the pathogenesis and risk factors (Hankey 2017, Huang et al 2018, Kim et al 2017, Mirzaei et al 2018).

Regarding **Parkinson’s disease (PD),** variability is very evident. The duration of daily OFF motor status, the degree of motor fluctuations, and the occurrence of freezing of gate, dyskinesia or neuropsychiatric manifestations can vary in the short term, even from one day to the other. In the long term, instead, variability is less evident: patients with PD go through a relatively stereotyped clinical course of development, with increasingly disabling stages.

Regarding **cardiological patients**, the variability comes from the diversity of the risk factors to which they are exposed. These risk factors can either be reversible e.g., those related with lifestyle (sedentariness, smoking, obesity, diet, excessive alcohol consumption, increased stress levels, high blood pressure, and social status) or irreversible (sex, age, genetic background). Depending on their number, and the intensity of the patient’s exposure to them, these factors affect the appearance and onset of ischemic heart disease or heart failure.
In order to tackle the variability in patients, once the diseases are diagnosed, the management of secondary prevention programmes is concentrated on fighting all the reversible factors through personalised actions.

The variability of actions that will be performed by the virtual coach will be centred around the risk factors that must be adjusted for a healthy life style. Actions include: in the neurological domain, physical/motor activity, emotional recognition, risk factor modification (falls) and cognitive enhancement; in the cardiological domain, physical/motor activity, emotional recognition (anxiety, depression), risk factor modification (smoking, weight) and adherence to therapy (pharmaceutical). Risk factors include: physical activity, low fat-salt diet, no smoking, blood pressure control, medication adherence, weight control and signs and symptoms of heart disease such as dyspnoea, angina, palpitations, and peripheral oedemas.

2 MATERIALS AND METHODS

This section covers the definition of the narratives developed in the preparatory work for this document, the structure of the narratives and use cases, and the prioritisation method selected.

2.1 DEFINITION

The approach presented in this document is based on the concept of a "*narrative*". The narrative connects a patient's characteristics that are related to his/her clinical history with the manifestation of impairments, unexpected needs, and bad feelings. It explains a carefully selected set of supposedly true events, experiences, or similar occurrences, intended to support the rationale for rehabilitation treatment. In *vCare*, as raw material, the starting point for the description of these narratives' was a selection of the most common needs and aspects encountered by the *vCare* clinicians during their daily clinical practice or reported directly by a patient during a visit.

The narratives reproduce the needs of the target group: this is defined as elderly citizens with existing or emerging chronic diseases, impairments, and showing frailty in the rehabilitation setting. In this document, the medical aspects of the narratives are addressed first and foremost. At the same time, the sociological implications of these factors will be considered, because of their potential positive impact on patients' quality of life. In the context of a societal situation of limited rehabilitation care resources, in which *vCare* can offer an effective way of managing services for this population, the ethical aspects of the narratives must also be satisfied.

It is appropriate to emphasise the importance of defining typical profiles and collecting data in a biographical (narrative) format, documenting fragments of people's lives and providing insight into their life stories and daily routines. In the description of the narratives, comorbidities, complications from treatments and consequent disabilities are taken into account as part of the patient's profile (Kumar et al 2010).

Each narrative represents, in an exemplary way, a type of patient. Starting from a general description, a more specific characterisation is pursued that takes into account the virtual coaching interaction modes and the specific environmental setting (i.e., the patient's home). In addition, the narratives are adapted to the evolution of the person's status or any changing external factors based on health, behavioural, and environmental monitoring, situational perception and awareness, and changes in care objectives.

From the patient's needs described in the narratives, a list of virtual coaching services is suggested for the patient's rehabilitation in section 3.5 (e.g. motor impairments will be treated through a rehabilitation programme made up of e-learning procedures for correcting postures, movement prescriptions, and physical interactive exergames). Moreover, each need and its associated service offered by the Virtual Coach is described in detail in the different use cases.

2.2 NARRATIVE STRUCTURES IN THE *vCARE* FRAMEWORK

Each narrative has been classified into the following three parts:

- **Patients profile overview**: The person's profile describes clinical characteristics of the person and his/her limitations and everyday problems related to his/her pathological condition. In this section, the individual medical history is provided, including background information and details about the disease and related impairments of the patient. The patient's profile overview is used to provide a first glance of the patient by using individual

clinical features that are realistic, and will help in the screening process for the selection of candidates for which *vCare* would be indicated .

- **Variability of patient**: Signs and symptoms, associated risks and their management are reported in order to offer information concerning the possible evolution (in positive or negative directions) of the described patients. Particularly, when an unexpected and potentially harmful event happens, the *vCare* system will intervene to guarantee the patient's well-being. Methodologically, a library of critical events, requiring exceptional procedures, will be included in the Virtual Coach platform in order to ensure the patient's safety.
- **Needs description**: The principal needs related to the patient's support and treatment on a daily basis in the home environment are described. For each need, services to address it are proposed.

Following this information, the next step is fashioning these tailored descriptions:

- **Personalised home rehabilitation pathway**: This pathway contains the rehabilitation programme prescribed by a physiatrist or medical staff member. It includes the results of hospital rehabilitation treatment and the activities planned for the period of rehabilitation at home that will be carried out by the *vCare* system.
- **Matching of patient's needs to the *vCare* model:** The *vCare* model, described in D1.1, is characterised by two domains: one related to the "social interaction" and the other to "interaction" and "intrusiveness". Once the previously defined patient's needs are mapped into the *vCare* platform, the system will automatically configure and modulate its "social interaction" and "interaction/intrusiveness" domains to provide the most individualised, effective and least intrusive rehabilitation strategy for the patient, assuring him or her with the highest possible security, comfort and adherence to treatment.
- **Use cases:** Directly linked to the personalised home rehabilitation pathway (including the services used by the Virtual Coach), the use cases will be introduced as descriptive rationales of the use of the system at the organisational level. Use cases are a type of textual requirements specification: they capture how a user will interact with a solution to achieve a specific goal. They describe the step-by-step process that a user goes through to complete that goal using the system or a service.

Each narrative was explored in one or more use cases. Therefore, the use cases addressed different Virtual Coach domains and are intended to show that the *vCare* approach can span a wide range of situations and conditions, i.e., their capacity to cope with variability. Thus, starting from a person's specific need or needs, each use case has determined the appropriate services required according to the three intrusiveness/interaction levels (see e.g. Figures 1 and 2).

Each use case includes services and processes:

- **Services:** Desirable features of the *vCare* system for taking care of needs previously identified. Each service is composed of a technological setup, sensing environments, and modes of adaptation (where possible/reasonable) accomplishing users' needs and requirements from the proposed use cases.
- **Processes:** Descriptions of the identified services. Like a screenplay, these processes encompass the possible interactions between users and the *vCare* system. The aim is to exemplify and, at the same time, predict variables in the process of sensing data and establishing a dialogue and an interaction with the data.

2.3 PRIORITISATION PERSPECTIVE

Prioritising of different elements of the *vCare* approach is important in order to address implementation and deployment plan. It also helps to minimise overload (since providing too many services could be overwhelming for the patient and lead to a reduced compliance) and to choose which services are more appropriate in a specific clinical context. For these reasons, the clinical partners have set priorities, presented in the section 3.5.

3 RESULTS

In the following parts of this section of the document, narratives are presented: they illustrate the main needs of the typical patient for the envisioned Virtual Coach solution. They are written from a medical/clinical perspective, using largely medical/clinical terminology. A set of exemplary patient profiles are defined to assess a typical situation for a Virtual Coach-based rehabilitation solution. In addition, narratives are defined by the use cases so as to enable an examination of how the needs are covered by basic interaction patterns for Virtual Coach scenario. Therefore, the Virtual Coach model is matched to show its interaction with the different use cases.

3.1 STROKE NARRATIVES

3.1.1 Introduction of exemplary patient profiles

This table provide an overall introduction to the stroke narratives, depicting main characteristics of the patient profile, primary impairment and rehabilitation needs and the related use cases. Four stroke narratives are introduced, referred to as use cases 1-4 (UC1-4).

Table 1 Narrative items for the Stroke case

Narrative	**Maria**	**Giuseppe**	**Rosa**
Characteristics	Right hemiparesis caused by left-sided cerebral stroke	Sensitive and motor deficits following right-sided ischemic stroke.	Slight residual left hemiparesis caused by right-sided stroke
Primary impairments and rehabilitation needs	• Right-sided functional motor impairment. • Problems in managing indoor and outdoor activities. • Difficulties in using her right hand. Needs: • Recovery from paresis and reduction of functional disability • Fall risk reduction, home hazards reduction	• Deficits in the neuropsychological domains for attention-executive functions and long-term memory. Need: • Improvement of memory and attentional-executive function	• Mild attentional and amnesic deficits • Depression/anxiety Need: • Monitoring and management of anxiety and depression
Related UC	UC 1 + 2	UC 3	UC 4

3.1.2 First Narrative: Mrs. Maria – Use cases #1 and #2

- **Patients profile overview**: Mrs. Maria suffered a left-sided cerebral stroke that caused a right hemiparesis. This deficit causes functional motor impairment and Mrs. Maria has serious problems in managing her life both in domestic environments and in open spaces. She is still able to walk, but simple, everyday activities, such as eating, answering the phone or logging on to the computer, are compromised in some way by her right arm paresis. Mrs. Maria complains about difficulties in using her right hand and often says "*I feel maladroit and useless*", "*I am disappointed about not being able to cook like before*". She is also worried about the risk of falling during her daily life, and she says "*I am afraid of falling when I have to go to the toilet*".
- **Variability of patient**: Maria's variability can be moderately related to her motor impairment. One day she complained of pain in the right upper limb and cramps in the right lower limb due to an increased spasticity. To face this possible complication, the *vCare* system can be set up to send appropriate reminders to encourage Maria to continue her exercises in order to ease the spasticity and to continue taking her medications for pain and/or spasticity. No other significant fluctuation in symptoms is part of Mrs. Maria's "syndrome".
- **Need description**: two principal needs are evident: i) the recovery from paresis and reduction of functional disability (Use case #1); ii) fall risk reduction, home hazards reduction (Use case #2). Therefore, the Virtual Coach solution should provide a service to Maria that supports her recovery on a daily basis in her home.

After gathering this information, we identified the following next steps:

- **Personalised home rehabilitation pathway**: Maria does not have access to outpatient rehabilitation after her discharge from the hospital. *vCare* gives her the chance to perform a personalised home rehabilitation programme, and so hopefully maintaining/improving her functional status. The physiatrist prescribes an eight week-long session of motor rehabilitation treatment using **serious games**. In addition, the physiatrist suggests slight motor activities during the day, the use of an aid (walker/cane) whenever she walks and, to reduce the risk of falling, the avoidance of complex tasks while she is in a standing position. Maria is worried about the risks related to walking outside her home when the weather conditions are bad. The Virtual Coach should provide information about the weather forecast in order to help her better plan her daily activities. On her discharge from the hospital, the physical therapist suggests some safety tips to help her cook, dress and move in indoor locations. *vCare* will coach Maria to improve her adherence to her drug prescription. Thus, Virtual Coach offers motor rehabilitation treatment through serious games, informs her in real time the patient about the weather conditions (to encourage better daily planning) and suggests safety measures to reduce risk behaviours.
- **Matching of patient's needs with the *vCare* model**: The management of Maria's needs transposed within the *vCare* model is described in Figure 1 and Figure 2.
  Use case #1 (Figure 1) (the recovery from paresis and the reduction of functional disability) is represented as follows: the healthy domain (the rehabilitation) in the personal sphere is entirely included and covered by the system at all the interaction levels of the vertical axis, from a silent mode to a participative Virtual Coach. The other *vCare* domains, "life-style" and "proactive life" are both covered by the system at a high Interaction level, which is

"patient's engagement-driven". This level includes not only rehabilitation activities but all the Virtual Coach suggestions, corrections and motivational feedback for the improvement of daily living and proactivity (walking, practicing slight exercise, cooking, dressing, moving in an indoor location).

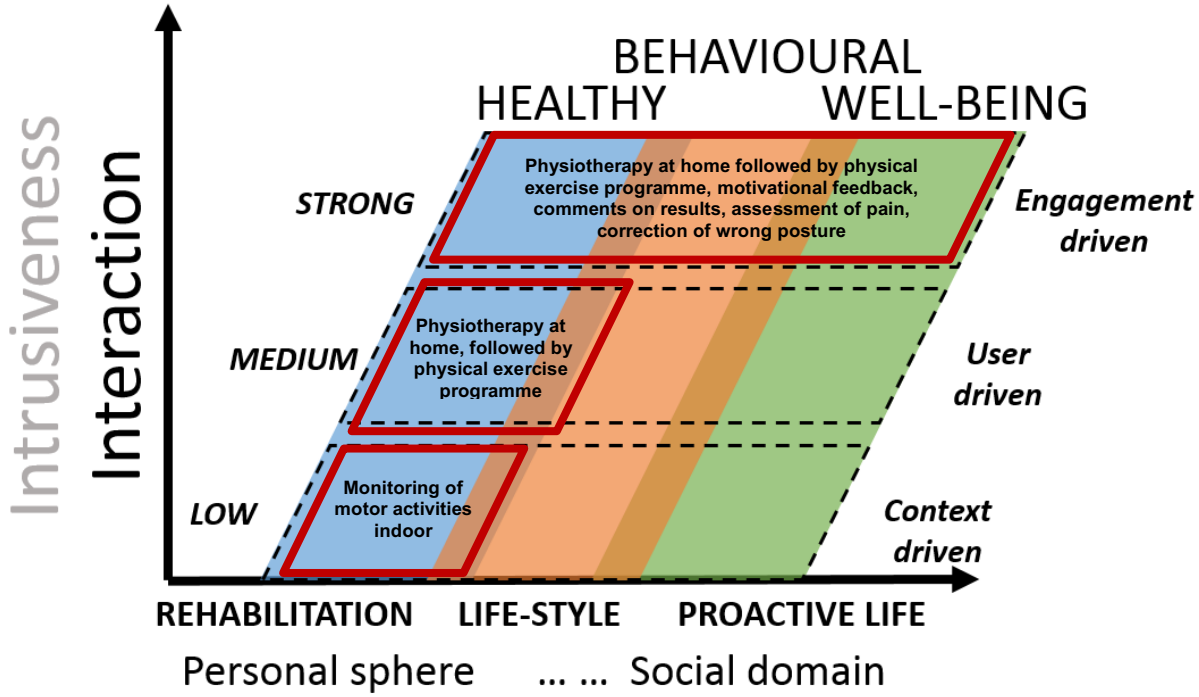

Figure 1 Graphic representation of use case #1 matched to the vCare model. Fields for a possible intervention by the *vCare* system are emphasised in the red boxes.

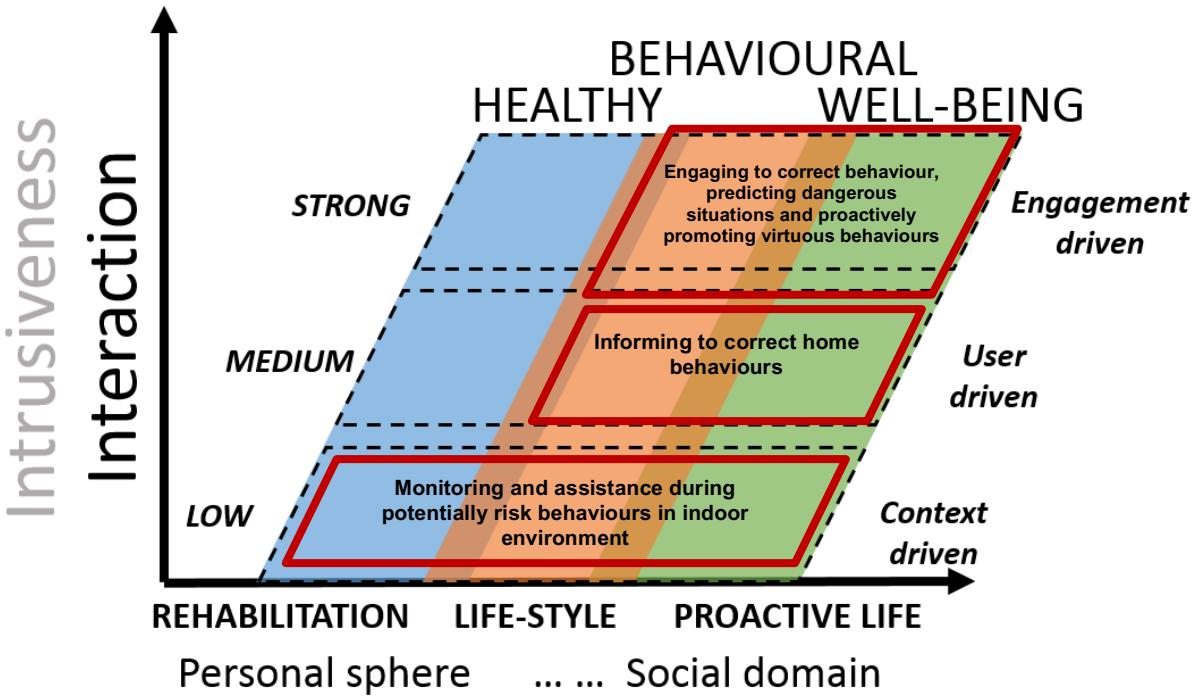

Figure 2 Graphic representation of use case #2 matched to the vCare model. Fields for a possible intervention by the *vCare* system are emphasised in the red boxes.

Use case #2 (Figure 2) (the reduction of fall risk and home hazards) is represented as follows: the first has been presented by covering both the three interaction levels in the "proactive life" domain, from a silent mode (just alerts) to a more personalized one (motivational, with activities suggestion and keen risk monitoring). "Rehabilitation" and "life-style" domains foresee that the Virtual Coach acts only at a low level of intrusiveness, providing reminders or simply locating the assistive object localization (aid/walker/cane) when it is lost or forgotten in a room by the patient.

UC1-1	
Need	Recovery from paresis and reduction of functional disability
Interaction level	**Low**: Monitoring of motor activities indoors

Services: Monitoring of indoor activity/inactivity and feedback (low level of intrusiveness)
Processes: Maria is sitting on the sofa doing crosswords: An hour has passed since she has been inactive. The Virtual Coach detects Maria's inactivity and notifies her of the need to perform physical activity through an acoustic feedback.
Maria decides to ignore the feedback and continues to stay on the couch.
15 minutes later, since Maria has not moved, the Virtual Coach sends her further acoustic feedback.
At that moment, Maria follows the advice and decides to go to water the plants on the terrace.
The Virtual Coach keeps track of Maria's activity/inactivity and resets the "inactivity" timer. The notification is recorded and made available for consultation at any time.

UC1-2	
Need	Recovery from paresis and reduction of functional disability
Interaction level	**Medium**: Physiotherapy at home, followed by physical exercise programme

Services: Motor rehabilitation programme – serious games (medium level of intrusiveness)
Processes: Maria, while reading the newspaper, is informed by the Virtual Coach that a session of motor exercises is scheduled at 10:30 a.m. In order to complete her reading activity, Maria postpones the scheduled session for 15 minutes later.
At 10:45 a.m. the Virtual Coach notifies her again of the appointment and remains on hold.
Maria moves herself in front of her TV screen.
The sensors recognise that Maria is ready to start exercising and then automatically turns on the screen, starts the suite of exergames / serious games, and shows the exercises available to the user, in accordance with her personalised motor training programme.
At the completion of each exercise, the Virtual Coach provides a graphic video-report on the activity performed by Maria, on the screen.
The Virtual Coach evaluates Maria's results and compares this performance with the rehabilitation goal designated by the physician. According to the cut-off levels established for her training programme, the Virtual Coach will propose evolving levels of performance to be reached (e.g., if Maria's performance has a trend over a pre-defined threshold, the Virtual Coach increases the challenge of the next level, otherwise it proposes the same level).
At the end of the session, when Maria leaves the field of view of the serious game suite, the Virtual Coach starts the procedures for ending the rehabilitation session:

1. updates Maria's physical activity report;
2. saves the data of the motor rehabilitation session;

3. synchronises the daily goals achieved with Maria's profile at the reference healthcare facility;
4. records data on the *vCare* platform and makes it available for consultation at any time;
5. turns off the system.

UC1-3	
Need	Recovery from paresis and reduction of functional disability
Interaction level	**High**: Physiotherapy at home followed by physical exercise programme, motivational feedback, comments on results, assessment of pain, correction of inappropriate posture

Services: Motor rehabilitation programme – serious games (high level of intrusiveness)
Processes: Maria moves herself in front of her TV screen in order perform the daily session of motor exercises.
The sensors recognise that Maria is ready to start and then automatically turns on the screen, starts the suite of exergames / serious games and shows the exercises available to the user, in accordance with her personalised motor training programme.
At the completion of each exercise, the Virtual Coach provides a graphic video-report on the activity performed by Maria, on the screen.
Maria asks the Virtual Coach about her efficacy in performing the rehabilitation exercises through vocal feedback/recognition. The Virtual Coach should establish a dialogue, providing Maria with some reporting data on her performance, showing her current score or the evolution of past results, and eventually suggesting to her to perform better or dynamically adapting the desirable score.
As a feedback, the Virtual Coach shows or speaks motivating and/or correcting messages such as "*try to increase your movement spreads*" or "*you're doing well Maria, try to stretch a bit more your left arm and your score will increase*".
As an advantage of this interaction, Maria could ask the Virtual Coach to give her a video tutorial on the exercise performed in order to increase her performance.
At the end of the session, when Maria leaves the field of view of the serious game suite, the Virtual Coach asks her some questions in order to assess (if any) her musculoskeletal pain and/or motor rehabilitation related pain.
Then, the Virtual Coach starts the procedures for ending the rehabilitation session:

1. update Maria's physical activity report;
2. save the data of the motor rehabilitation session,
3. save information about additional issues raised by Maria herself (if any);
4. save information about pain (if any);
5. synchronises the daily goals achieved with Maria's profile at the reference healthcare facility;
6. records data on *vCare* platform and makes it available for consultation at any time; turns off the system.

UC2-1	
Need	Fall Risk Reduction
Interaction level	**Low**: Monitoring and assistance during potentially risky behaviours in an indoor environment

Services: Domotics, alert remainder, localisation (low)

Processes: Maria is alone at home, sitting on the sofa in a state of quietness when suddenly the doorbell rings.
Maria moves from her position with the purpose of going to open the door.
According to her medical prescription, Maria must use an aid to walk, but – in order to move faster – she starts walking without a cane.
The Virtual Coach monitors the body movement and the new postural Maria's condition. In addition, the Virtual Coach detects that Maria is walking without the walking aid.
The Virtual Coach sends acoustic/audio feedback suggesting to her to take the cane.
Despite the the Virtual Coach alert, Maria ignores it and goes to the door without any assistance.
The Virtual Coach records Maria's motor behaviour, updates the potential risks, and records the event to make it available for consultation at any time from the *vCare* platform.
Moreover, the Virtual Coach should be able to detect in which room Maria is and if she is by herself or not.

UC2-2	
Need	Fall Risk Reduction
Interaction level	**Medium**: Informing to correct home-based behaviours

Services: e-learning (video tutorial), informative multimedia elements (medium).
Processes: Maria is spurred on by her interactive caregiver to improve her behaviour in order to reduce the risk during the daily activities.
Maria accepts this advice and switches on the tablet in order to access the *vCare* e-learning tool, a collection of videos, and information on the correct way of performing her most common daily activities.
Since Maria's behavioural potential risks are recorded, the homepage of the e-learning app from the Virtual Coach, shows a playlist based on the Maria's major deficits, which have potentially been recorded by sensors.
The Virtual Coach makes sure that the multimedia e-learning tool is appropriate for Maria's needs, according to medical prescription.
Maria watches the video tutorial on her tablet. The e-learning contents show her some educational instructions, in order to help Maria to reduce her fall risk, through informative multimedia; for example, "*how to climb stairs properly*", "*how to sit and stand up properly from a chair*", "*the best tips for avoiding falls*".
On completion of the e-learning video: the Virtual Coach asks Maria if she has some questions about the contents of the module or if she needs to play it again. If Maria has some questions, she could look for them within an internal interactive list of questions with associated respective answers.

UC2-3	
Need	Fall Risk Reduction
Interaction level	**High**: Engaging the user to correct behaviours, predicting dangerous situations and promoting virtuous behaviours in a proactive format

Services: educational dialogue, e-learning, domotics, alert remainder, localisation (high)
Processes:
At 8.00 a.m., Maria is in her bedroom standing in front of the wardrobe.
Maria is still wearing her pyjamas and she is planning to get dressed for the day.

According to the medical programme/prescription, it is best to avoid to dressing in a standing position. The home smart sensors system, detecting the patient's movements, recognises the possible dangerous situation.
At lunch time, Maria is in the kitchen and she is cutting some vegetables to prepare lunch, when unfortunately a spoon falls down on the floor. The sensors system recognises this event. In accordance with Maria's medical condition, in this situation she is at a potential risk of falling: Maria must pay attention and must not pick up the spoon from the floor. The Virtual Coach, with a low level of interaction modality, warns her and collects the information.
At 4.00 p.m., After Maria's daily nap, the Virtual Coach proposed the scheduled motor training session to Maria. Before starting the motor activities, the Virtual Coach establishes a dialogue with Maria.
The Virtual Coach warns Maria about the set of potential risks of falls that occurred during the day.
Based on the home hazards detected that day, the Virtual Coach tells Maria to pay attention during her personal activities and when some objects fall on the floor. The Virtual Coach suggests to her how to do these potentially dangerous activities in a safe way – for example, suggesting this strategy instead of that. The Virtual Coaching provides corrective feedback, advises the use of body support (e.g. a walking stick), and suggests in-home fall-prevention training exercises.
Maria shows interest on this topic and asks for a playlist of the available video tutorials.
The Virtual Coach proposes a set of e-learning videos directly to her tablet. Maria accepts these suggestions, and watches the e-learning video(s).
The Virtual Coach updates Maria's "e-learning profile". These activities are recorded on the *vCare* platform to make it available for consultation at any time.

3.1.3 Second Narrative: Mr. Giuseppe – Use case #3

- **Patients profile overview**: Mr. Giuseppe is a 75 years old man, right-handed, with 8 years of education. Giuseppe acquired left facio-brachio-crural hemisyndrome with sensitive and motor deficits following right-sided ischemic stroke (frontal and semioval centre). A neuropsychological examination showed a cognitive profile characterized by deficits in the neuropsychological domains for attention-executive functions (selective attention, executive planning, cognitive flexibility) and long-term memory (learning and recall of structured information). Moreover, slight uncertainties of temporal and autobiographical orientation have been observed. While the motor-sensitive deficits of Mr. Giuseppe are mild and they don't significantly influence his quality of life, the cognitive disabilities are troublesome features for his daily life. Mr. Giuseppe complains of difficulties at the cognitive level, claiming "*I often forget where I put things*" and "*I have difficulties in managing how to perform activities that I was completely able to do before*".
- **Variability of patient**: Giuseppe's variability can be specifically related to the cognitive status. To face this possible complication, *vCare* can monitor the patient's routine and can send appropriate reminders to continue physical and cognitive exercises in order to ease the memory deficits.
- **Needs description**: the main need for Giuseppe is the improvement of memory and attentional-executive function (Use case #3). VC provides cognitive support and treatment adherence control for Giuseppe in his home on a daily basis.

After this information, we identified the following next steps:

- **Personalised home rehabilitation pathway**: By considering the improvement observed during the cognitive treatment and the patient's levels of compliance and motivation, at the hospital discharge the physician recommends Giuseppe to remain active trough adoption of functional behaviours aimed to stimulate his cognition, to promote engagement in self-care and a socially satisfying everyday life. In addition, the physician suggests a home-based rehabilitation treatment specifically addressed to improve the impaired cognitive domains. The exercises will be targeted for stimulation of memory (learning, retention and recall of verbal and visual spatial information), attention (visual search tasks) and executive functions (by using tasks requiring increasing levels of cognitive flexibility, planning and monitoring, problem solving).
- **Matching of patient's needs on *vCare* model**: Figure 3 emphasizes the matching of the specific use case within the *vCare* model. Particular attention is given to the improvement of memory and attentional-executive functions placed at the strongest interaction level, which drives the engagement of the patient, for all the three social domains (from personal-rehabilitation to proactive life-social domain). VC interacts with the patient in his daily living by delivering cognitive serious games in order to improve his executive functions, attention and memory.

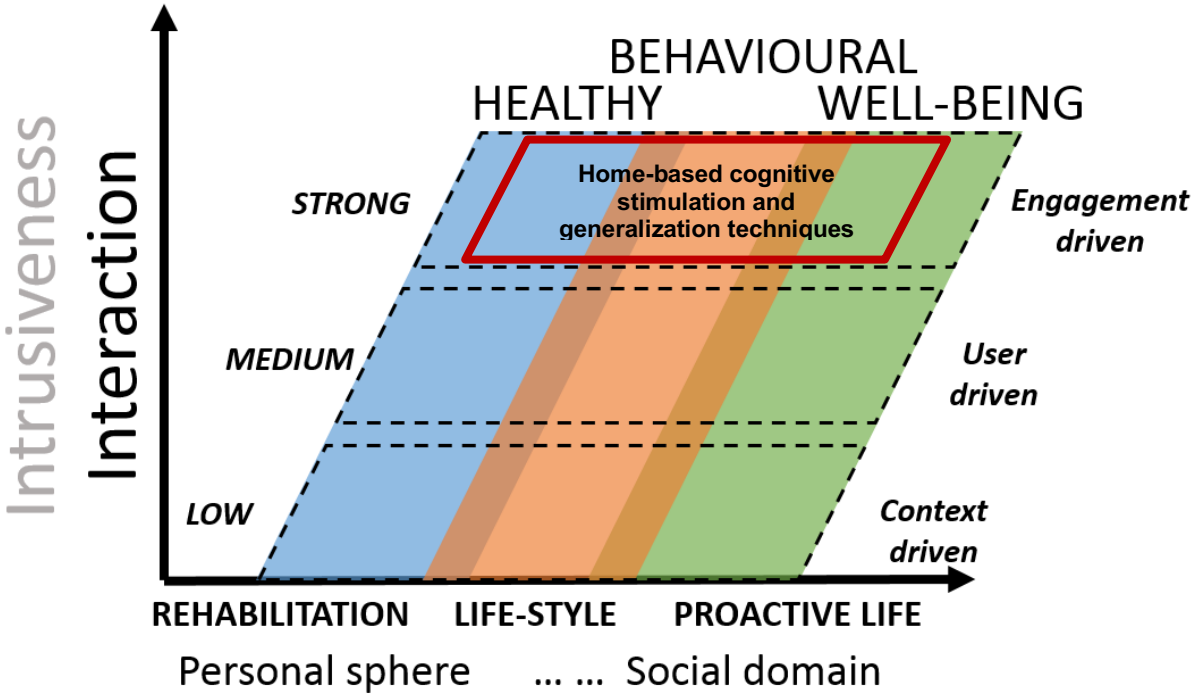

Figure 3 Graphic representation of use case #3 matched on the vCare model. Fields for a possible intervention by *vCare* system are emphasised in the red box.

UC3	
Need	Improving memory ability and attentional-executive functioning
Interaction level	**High***: Home-based cognitive stimulation and generalization techniques

(* = Lower levels not applicable since cognitive rehabilitation entails a certain degree of intrusiveness of the intervention)

Services: cognitive stimulation programme – serious games/virtual reality – Information sharing regarding possibilities of generalization in everyday life.

Processes: Giuseppe, while watching the TV, is informed by the Virtual Coaching that a session of cognitive exercises is scheduled at 9:30 a.m., for 45 minutes. Giuseppe switches on the tablet in order to perform the daily session of exercises. When the user is ready to start, the VC establishes a dialogue with him: the VC asks Giuseppe how he feels and tries to understand if the users is motivated to start a new rehabilitation session or, rather, whether he feels tired or indifferent.
In the latter case the VC explores the reasons of this negative attitude by asking to the patient for further explanations (e.g., presence of cognitive or physical fatigue, activities performed before the cognitive session, presence of concern). The VC further describes and motivates the importance of the training programme for improving those abilities.
The VC describes the exercises planned for the day, based on home rehabilitation pathway, explaining which cognitive abilities are targeted to (attention, reasoning-executive functions, and memory). The VC also specifies the relevance to work on different aspects of cognition since several abilities are involved in complex everyday activities and the improvement of a cognitive function promotes the enhancement of other cognitive domains.
For each exercise, the VC asks for Giuseppe's opinions on his previous performance and how he could face the task in order to overcome such difficulties, by providing feedback and suggestions. The VC proposes strategies in order to perform each exercise for different cognitive domains.
Throughout the session, the VC dialogues with Giuseppe and monitors if the user is tired or bored (from facial expressions and verbal content) in order to adjust the path of the session (e.g., by planning to perform the easiest exercises at the end of the session). This flexibility ensures more engagement from the patient.
The VC adapts the content and terminology used in the dialogue according to the information detected from Giuseppe's verbalizations and emotional behaviour, both in terms of verbal content and facial expressions exhibited.
At the end of the session, the VC dialogues on the results obtained that day, trying to understand Giuseppe's awareness of difficulties and to provide feedbacks. The VC explores Giuseppe's knowledge of strategies which may help him to overcome such difficulties and explains how they can be functionally implemented in everyday life.
At the end of the session, the VC starts the procedures for ending the rehabilitation session:

1. updates user's cognitive activity report;
2. saves the data of the cognitive rehabilitation session;
3. synchronizes the daily goals achieved with user profile at the reference healthcare facility.
4. records data on *vCare* platform and makes available for consultation at any time.

3.1.4 Third Narrative: Mrs. Rosa – Use case #4

- **Patients profile overview**: Mrs. Rosa is a 70 years old woman with a right-hemisphere stroke and a slight residual left hemiparesis, mild attentional and amnesic deficits. Therefore, she performs both motor and cognitive rehabilitation. At the discharge, motor evaluation showed still slight difficulties in the fine movements with the fingers of the left hand and in stepping with left leg, causing Mrs. Rosa to feel slightly embarrassed when she walks; nevertheless, the ADLs are intact. From a cognitive point of view, the neuropsychological evaluation showed residual slight disturbances of attention and memory. However, as the date of discharge approaches, Rosa is worried about her return to home. Sometimes she feels confused, and a wave of strange and unknown emotions

invades her. She does not know if she will manage to return to her previous activities such as watching her grandchildren, an activity she found tiring even before. She feels that the expectation of her family members is too high, as they have seen her get back "so well" and probably expect her to start doing all the things as before. Above all, she does not want to be a burden to her children, who being close to her are at the same time so busy with their lives. The more she thinks of it, the more she worries and she comes to think that if things had gone differently, it would have been better for everyone. Mrs. Rosa complains about difficulties on using her hand and often says, *"I will never be the same as before",* and *"I'm worried about what my husband thinks I will be able to do".*

- **Variability of patients**: Rosa's variability can be specifically related to her mood. To face this possible complication, *vCare* can monitor the facial expressions of the patient, and send appropriate reminders to take her depression/anxiety medication as prescribed during the inpatient recovery and provide encouragement feedback when the patient achieves an expected goal. In addition, validated questionnaires for Depression and Anxiety are administered by VC such as Hamilton Depression Rating Scale (HDRS). Occasionally, Rosa might decide not to have any kind of interaction with *vCare* because she wants a rest.
- **Needs description**: Rosa's needs are related to the monitoring and management of new concerns (anxiety) and negative and ruminative thoughts (depression) (Use case #4). VC provides the services required for Rosa's emotional support and treatment on a daily basis in her home. In addition, VC stimulates Rosa's social interaction to avoid the worsening of her status.

After this information, we identified the following next steps:

- **Personalized home rehabilitation pathway**: The pathway should respond to the patient's needs for acquiring awareness of emotional states and modify them through exercises focused on the body.
- **Matching of patient's needs on *vCare* model**: in Figure 4 the management of anxiety and depression is matched with the *vCare* model part consisting in services interacting with the patient at all levels, from a low level (sending alerts or reminders) to a high level (complete engagement of the patient such as asking to start a conversation with the VC). Considering the "social" domain (*horizontal-axis*), use case #4 is committed to cover the system at a high interaction level, acting directly on patient's lifestyle and suggesting her a proactive lifestyle comprising the interaction with other people.
  The management of the emotional status, including facial recognition, movement and breathing analysis matches the following VC activities: the low interaction level should consist of only monitoring the emotional state; the medium level foresees the interaction of VC with the subject providing her cues about pains/body postures; finally, at the high level the system directly suggests exercises for managing anxiety and changing the emotional state.

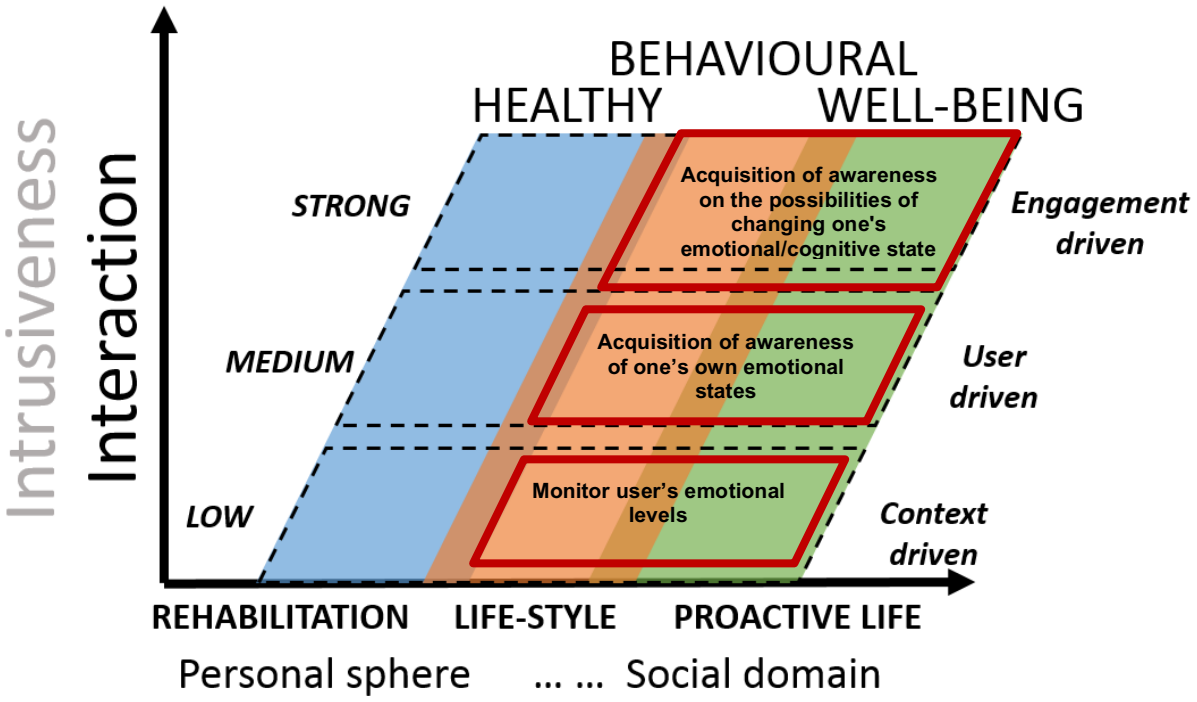

Figure 4 Graphic representation of use case #4 matched on the vCare model. Fields for a possible intervention by *vCare* system are emphasised in the red boxes.

UC4-1	
Need	Managing new concerns (anxiety) and negative and ruminative thoughts (depression)
Interaction level	**Low**: Monitor user's emotional levels

Services: monitoring different parameters: facial expressions, movement, postures, breathing, dialogues (quantity, length, speech rate, contents through the identification of specific keywords etc.)
Processes: Every day the VC monitors and tracks the type (anxiety vs. depression) and the level of emotional activation, making a grading of them, through the reading of different parameters: facial expressions, movement, postures, breathing, dialogues (quantity, length, speech rate, contents through the identification of specific keywords etc.). In addition, VC reads Rosa's parameters and couples them with other information (e.g., movements, dialogues, activities).

UC4-2	
Need	Managing new concerns (anxiety) and negative and ruminative thoughts (depression)
Interaction level	**Medium**: Acquisition of awareness of one's own emotional states

Services: monitoring and elaboration of different parameters related to emotional state alteration (facial expressions, movement, postures, breathing, dialogues (quantity, length, speech rate, contents through the identification of specific keywords etc.), simple cognitive games).
Processes: Two or three times a day VC asks Rosa to mark on a thermometer on the tablet screen her current level of anxiety-tranquillity, the level of sadness-serenity and the degree of

tolerability. The tolerability parameter refers to a "tolerance window" of Rosa's perceived emotional states. When one or more parameter recorded is outside of the tolerance window, the VC signals this to Rosa, suggesting the possibility to observe her emotional state and to modify it through the execution of brief exercises.
The VC is able to offer very simple and fast exercise (duration 10 minutes). For example VC suggest to pay attention to her posture or to control the breath, providing simple cue: e.g., <*Try to breathe more deeply, relax your shoulders, sit as straight as you can, open your shoulders, lift your chest, lean well both feet on the ground*>.
At the end of the exercise, it detects and records any changes to the parameters previously recorded and updates data on *vCare* platform making them available for consultation at any time.

UC4-3	
Need	Managing new concerns (anxiety) and negative and ruminative thoughts (depression)
Interaction level	**High**: Acquisition of awareness on the possibilities of changing one's emotional/cognitive state

Services: monitoring different parameters: facial expressions, movement, postures, breathing, dialogues (quantity, length, speech rate, contents through the identification of specific keywords etc.). Cognitive games, interaction to perform exercises to be conscious or aware regarding the disabilities.
Processes: The VC has detected some parameters changes out of the tolerance window in the last two days.
VC, after matching scheduled activities and current state of user (i.e., state of inactivity), interacts with Rosa in order to analyse, together, her emotional state.
After a brief explanation, VC proposes to Rosa to make an exercise that encompasses breathing and posture modification depending on the degree of activation recorded.
VC asks Rosa to write her thoughts on the tablet about emotions and pains/bodily sensations before and after the exercise.
VC can explain to Rosa some modes of thought to avoid such as generalizations, identification with one's own thoughts or use prejudices in thinking about oneself and others (see table below for an outline of the situation).
When the exercises is completed, the VC starts the procedures of profile updating:

1. updates Rosa emotional profile report
2. synchronizes the daily activities with Rosa's profile at the reference healthcare facility;
3. records data on *vCare* platform and makes available for consultation at any time.

3.2 PARKINSON'S DISEASE NARRATIVES

3.2.1 Introduction of exemplary patient profile

This table provide an overall introduction to the Parkinson's disease narratives, depicting main characteristics of the patient profile, primary impairment and rehabilitation needs and the related use cases. Two Parkinson's disease narratives are introduced, referred to as use cases 5-6 (UC5-6).

Table 2 Narrative items for the Parkinson's disease case

Narrative	Alvarez
Characteristics	Advanced Parkinson's disease, stage IV of Hoehn and Yahr [1]
Primary impairments and rehabilitation needs	• Impairment of gait • Mild cognitive deterioration Needs: • Improve motor, fluctuations and gait • Fall risk reduction • Management of impulse control disorder and apathy
Related UC	UC 5 + 6

3.2.2 First Narrative: Mr. Alvarez – Use cases #5 and #6

- **Patients profile Overview**: Mr. Alvarez is 75 years old and he has advanced Parkinson's disease (PD), stage IV of Hoehn and Yahr. He suffers from PD since first motor manifestations (tremor) started 8 years ago. In the course of 2 years, motor abnormalities became bilateral and 5 years after clinical onset, gait became significantly impaired. He has a bilateral disease, with severe impairment of gait and mild cognitive deterioration which makes him a dependent patient. This situation is further aggravated by orthostatic hypotension and increasing cognitive deterioration. Mr. Alvarez is dependent for most instrumental activities such as writing, using his mobile phone, home appliances and his computer. He is also partially dependent for basic daily activities such as personal hygiene and dressing, for postural changes and moving around, requiring one or two supports for walking. All these manifestations make Mr. Alvarez a dependent 75-year-old man at risk of suffering severe complications (falls, dementia, depression and social isolation), which could be clearly improved by personalized motor, cognitive and instrumental rehabilitation. In addition, this patient has speech problems (dysarthria and hypophonia). He subscribed to the local Parkinson's disease patients' association where he started some motor, cognitive and speech rehabilitation activities. However, the association is too far from his home so he has not been able to attend the rehabilitation activities.
- **Variability of patients**: The main source of clinical variability for Mr. Alvarez is related to motor manifestations. He experiences motor fluctuations (levodopa-related fluctuations, including wearing off and on-off fluctuations) and long periods in OFF situation during the day that may improve with monitoring of motor status and with adjustment of medication. In the last two years, Mr. Alvarez suffers of freezing of gait 2 to 6 times a day, with frequent falls, at least 2 every month. Mr. Alvarez has also dysautonomia with orthostatic hypotension, which frequently makes him dizzy and further increases the risk of falling. During the day, Mr. Alvarez suffers frequent unpredictable and invalidating dyskinesia in his right hand.
- **Needs description**: Three principal needs are related to Mr. Alvarez conditions: Improve his motor situation, particularly fluctuations and gait disorders and decrease the risk of falls (Use case #5), reduce risk of complications associated to cognitive impairment, risk of

[1] The **Hoehn and Yahr scale** is a commonly used system for describing how the symptoms of Parkinson's disease progress. It was originally published in 1967 in the journal *Neurology* by Melvin Yahr and Margaret Hoehn and included stages 1 through 5. https://en.wikipedia.org/wiki/Hoehn_and_Yahr_scale

behavioural (impulse control disorder and apathy) and emotional problems (depression and anxiety) (Use case #6), and improve his speech problems (Use case #5).

After this information, we identified the following next steps:

- **Personalized home rehabilitation pathway**: The neurologist prescribes 12 weeks of sessions for motor and cognitive rehabilitation using serious games, cycling and Nordic walking, following the same rehabilitation care already performed by Mr. Alvarez in patient's association. The daily personalized home rehabilitation pathway includes 45 minutes of serious games in the morning and 30 minutes of Nordic walking or cycling (alternating days) in the afternoon. During OFF periods, Mr. Alvarez cannot do his rehabilitation exercises. From the cognitive point of view, *vCare* performs *serious games*, plans routines for basic and instrumental activities with motivational rewards. The facial expression recognition, motor activity detection or physical location of the patient (time spent on the sofa, in bed, or in the kitchen) may indicate depressive mood or apathy, which can activate in *vCare* a protocol for engagement in leisure or social activities. The level of interaction for Mr. Alvarez is medium, so it includes screens and tablets that interact with the patient. In this sense, *vCare* can improve his quality of life, identifying risk factors from environment and risk behaviours, acting on the walking and gait through in-door serious games and promoting out-door activities, educating the patient and caregivers on the management of complications and reducing OFF time, motor fluctuations, dyskinesia and freezing of gait by improving the control of medication regimens.
- **Matching of patient's needs on *vCare* model**: The management of Mr. Alvarez´s needs integrated within the *vCare* model are described in Figure 5. Use case #5 includes improvement of motor fluctuations and speech, and decrease of risk of falls. It is represented as follows: rehabilitation can be covered at the low level of interaction by means of *messages or warning* devices that organize and structure the rehabilitation tasks of most independent patients according to their motor situation (starting *Nordic Walking* at the time when the system detects that the patient is in ON motor situation). In the case of medium level of interaction, the patient can perform specific rehabilitation exercises through serious games guided by *vCare* through a screen or tablet focused on the most affected limb or on the trunk. Other aspects such as "life-style" and "proactive life" are both covered by *vCare* system at a low interaction level through motivational *messages. vCare* reminds the patient of the medication timetable and feeding schedules and motivates the patient to get involved in the rehabilitation process and in following a proactive and social life indoors and outdoors, sending corrections and motivational feedback for the improvement of activities of daily living and proactive activities (walking, practicing slight exercise, cooking, dressing, moving in indoors location). Fall risk reduction has been represented covering low interaction level in the "proactive life" aspect, using alerts that warn the patient of obstacles or detect a bad motor situation (OFF) that increases the risk of falls.

  Figure 6 reports the needs and the actions that *vCare* should provide, highlighting the correspondences to each specific interaction level. Mr. Alvarez's patient profile is characterized by a consistent impairment of motor and cognitive symptoms which require the management of his needs. Therefore, on the right we enlisted the corresponding actions with a bottom-up approach which goes from the low to the high level of intrusiveness/interaction. Hence, the figure represents different *vCare* features, from the object localization and alert reminder to the suggestion to perform motor and cognitive programmes (serious games) and monitoring the variations of motor situation (off/on,

dyskinesias) to advise the patient. Regarding rehabilitation, *vCare* detects stability problems and encourages the patient to do specific exercises (i.e., serious games) and avoids other activities that increase the risk of falls.

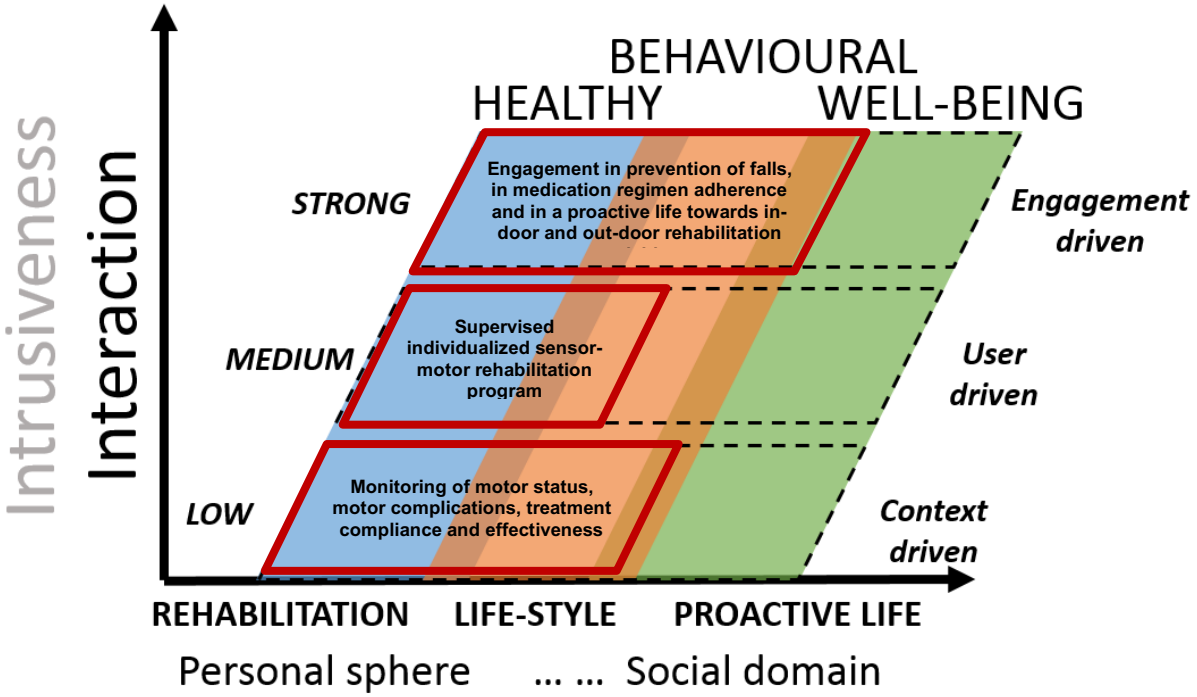

Figure 5 Graphic representation of use case #5 matched on the vCare model. Fields for a possible intervention by *vCare* system are emphasised in the red box.

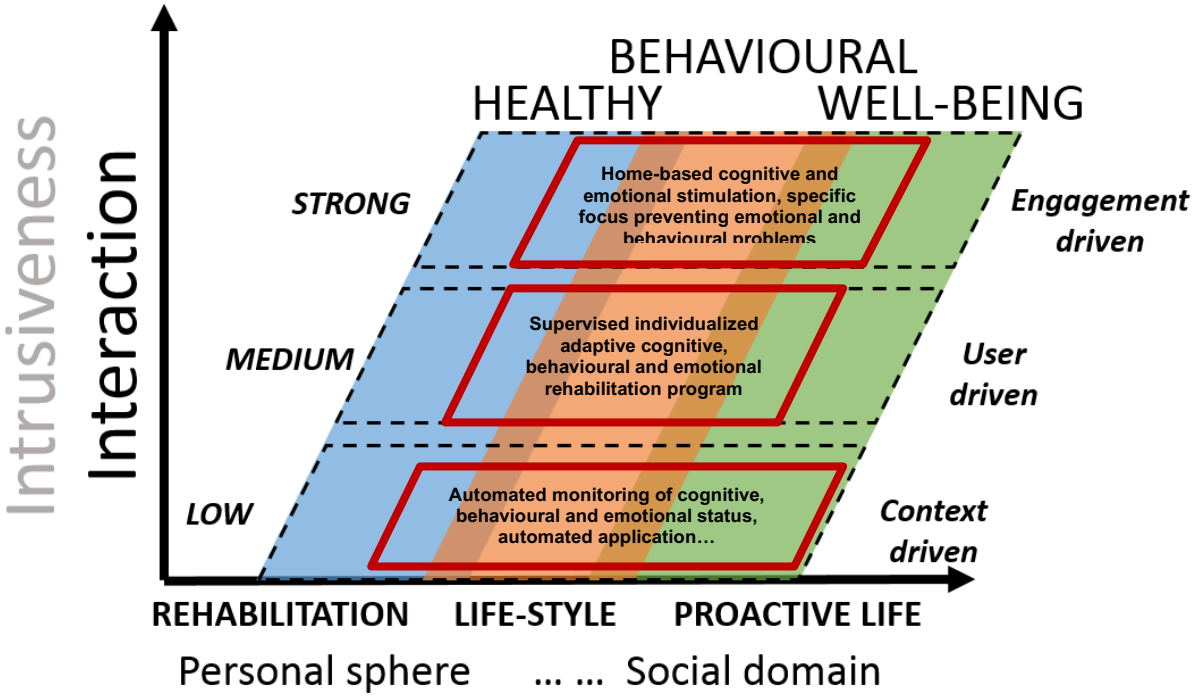

Figure 6 Graphic representation of use case #6 matched on the vCare model. Fields for a possible intervention by *vCare* system are emphasised in the red box.

UC5-1	
Need	Motor functioning
Interaction level	**Low**: Monitoring of motor status, motor complications, treatment compliance and effectiveness

Services: Continuous monitoring of motor status, motor complications and treatment compliance & effectiveness, using wearable motion sensors, electronic pillboxes and patient's electronic diaries.
Processes: Mr. Alvarez carries a wearable motion sensor that is able to detect OFF motor states, motor fluctuations and dyskinesia. This information is complemented by patient reported electronic diaries on his motor status and complications.
Electronic pillboxes and patient reported diaries provide real-time information on treatment compliance. The VC system has an in-built alarm and messaging system to remind missed medication and its artificial intelligence is able to provide suggestions to dynamically adapt under clinical supervision dosing of treatment in relation to motor status and complications.

UC5-2	
Need	Motor functioning
Interaction level	**Medium**: Supervised individualized sensor-motor rehabilitation programme

Services: Individualized sensor-motor rehabilitation (oriented by patient's motor profile) with different types of exercises (dual-task exercises, Nordic walking, yoga, motor imaginary, complementary physical exercises, mind-body exercises, global postural re-education, respiration therapy exercises, loudness and speech treatment) to be conducted based on VC system (software platform, wearable/mobile devices, in-home screens or virtual reality, serious games).
The design and training of the individualized rehabilitation protocol should be supervised regularly (every 2-7 days) by motor rehabilitation clinical team (nurse, physiotherapist and neurologist).
Virtual coaching system (software platform, wearable/mobile devices, in-home screens or virtual reality, serious games), wearable motion sensors + plethysmograph (motor status + heart rate and blood pressure monitoring).
Processes: Mr. Alvarez has gotten out of bed and has correctly taken the medication for his Parkinson's disease (100 mg of levodopa). The motor status monitoring system detects a good motor situation, so VC system sends an acoustic message to initiate the rehabilitation exercises. However, Mr. Alvarez despite being in a good motor situation is dizzy. The plestimography and heart rate sensor detect orthostatic hypotension in standing with a 20 mmHg drop in systolic blood pressure when standing up from the chair. The VC sends an order to the patient to sit down or lay down waiting for the recovery of blood pressure. When the sensor detects that the patient is in ON situation and in the absence of orthostatic hypotension, VC gives instructions to begin the rehabilitation of the gait according to his individualized rehabilitation programme. The sensors recognize that the user is ready to start and then automatically turns on the screen (wearable device, virtual reality system or TV screen), starts the suite of exergames and shows the exercises available to the user to improve gait.
At the end of the session, when Alvarez leaves the field of view of the serious game suite, the VC starts the procedures for ending the rehabilitation session:

1. Updates Alvarez's physical activity report;

2. Saves the data of the motor rehabilitation session;
3. Relates the goals reached in the rehabilitation programme with the falls and parameters of the gait obtained from the sensor in the last 24 hours.
4. Turns off the system.

The recordings of the performance in the rehabilitation programme from VC system and wearable sensors are reviewed by motor rehabilitation clinical team regularly (every 2-7 days) to evaluate the adaptation of exercises to the current motor status of the patient and to modify the program if necessary.

UC5-3	
Need	Motor functioning
Interaction level	**High**: Engagement in prevention of falls, in medication regimen adherence and in a proactive life towards in-door and out-door rehabilitation activities

Services: text messages on phone/watch/tablet/TV screen, continuous motor status monitoring technology (OFF status, motor fluctuations), continuous blood pressure and body position monitoring technology (orthostatic hypotension monitoring), electronic pillbox.
Processes: After being discharged from hospital (phase 1, stage 1), the VC platform and rehabilitation programme is configured and set-up according to the motor profile of Mr. Alvarez (see D 1.1 for further details). After that, in subsequent phases monitoring of motor functioning of Mr. Alvarez will be based on automatically obtained measures from wearable sensors and patient's diaries. The system will focus in high interaction level activities related with engagement to prevent falls (warning patient and relatives of prolonged OFF situations or orthostatic hypotension, avoid obstacles and risky activities, use of walking aids), to improve adherence of medication regimen (through messages and electronic pillbox alarms) and to perform speech exercises such as cycles of inspiration/expiration or breathing exercises. Wearable sensors, home-based sensors will be used to record the human voice and to detect the decibels and the frequency of the voice. The treatment will be delivered during hour-long sessions, given four times a week. Through video, the patient's loudness will be measured through a series of voice exercises using a decibel sound meter".
The system will focus in high interaction level activities related with engagement to perform physical proactive activities for motor rehabilitation in-doors (e.g., yoga) or out-doors (e.g., Nordic walking).

UC6-1	
Need	Cognitive and behavioural rehabilitation
Interaction level	**Low**: Automated monitoring of cognitive, behavioural and emotional status, automated application and difficulty adaptation of cognitive training and alarms for behavioural and emotional risks

Services: Automated continuous monitoring of cognitive, behavioural and emotional status, automated application of cognitive training, adaptation of cognitive training difficulty and alarms on major behavioural and emotional changes (impulsive-compulsive, risky or aggressive behaviour, apathy, major depression or anxiety symptoms); Electronic neuropsychological test batteries & questionnaires, serious games, VC platform (including voice and touch responsive portable and in-home TV screens)
Processes: Mr. Alvarez is sitting in is couch after having breakfast and his morning pills. The VC platform sensors recognize that he is in a situation of rest, in ON medication and ready to

start cognitive evaluation and training. Then VC automatically turns on the screen, starts the serious games and shows the exercises available to the user, working different cognitive domains (attention, visual and verbal memory, executive functions) in accordance with his personalized cognitive training programme. At the completion of each exercise, the VC provides a graphic (on the screen) video-report on the activity performed by the patient. Virtual coaching evaluates the patient's results and compares this performance with the cognitive rehabilitation goal designated by the neuropsychologist.

UC6-2	
Need	Cognitive and behavioural rehabilitation
Interaction level	**Medium**: Supervised individualized adaptive cognitive, behavioural and emotional rehabilitation programme

Services: Supervised individualized cognitive, behavioural and emotional rehabilitation (oriented by patient's profile) with computer-based cognitive training, cognitive behavioural exercises and serious games adapted to patient's profile. Supervision and programme adaptation will be conducted periodically by clinical team using virtual coaching platform. The design and training of the individualized rehabilitation protocol should be supervised regularly (every 2-7 days) by rehabilitation clinical team (neuropsychologist, neurologist and nurse).
Computer-based cognitive training and cognitive behavioural exercises, serious games, VC platform (including voice and touch responsive portable and in-home TV screens
Processes: Based on the functional profile of Mr. Alvarez, the clinical team has already designed a cognitive, behavioural and emotional rehabilitation programme with specific computer-based exercises and serious games Once the VC platform is ready and Mr. Alvarez is trained, cognitive-behavioural-emotional rehabilitation is set up to be activated automatically once a day in the morning. The clinical team can search the rehabilitation performance remotely. The performance of the training corresponding to the first 2 weeks is recorded and transmitted remotely for supervision of the clinical rehab team, who may modify the protocol or solve potential issues.

UC6-3	
Need	Cognitive and behavioural rehabilitation
Interaction level	**High**: Home-based cognitive and emotional stimulation, specific focus preventing emotional and behavioural problems

Services: questionnaires and instrumental and non-instrumental evaluations of cognitive, behavioural and emotional status. The VC describes the exercises planned for the day, based on home rehabilitation pathway, explaining which cognitive abilities are targeted to (attention, reasoning-executive functions, and memory). The VC also specifies the relevance to work on different aspects of cognition since several abilities are involved in complex everyday activities and the improvement of a cognitive function promotes the enhancement of other cognitive domains. The VC also provides emotional stimulation using motivational strategies from cognitive behavioural therapy such as positive rewards or music therapy.
Processes: After being discharged from hospital (phase 1, stage 1), the cognitive, behavioural and emotional functional profile of Mr. Alvarez is further characterized at home by rehabilitation clinicians daily during 14 days using questionnaires and instrumental and non-instrumental measures. The VC platform and rehabilitation programme is configured and set-up according to the profile of Mr. Alvarez (see D1.1 for further details). After that, in subsequent phases

monitoring of cognitive, behavioural and emotional functioning of Mr. Alvarez will be based on automatically obtained measures from computer-based neuropsychological tests and questionnaires and from face-recognition and in-door localization technologies for mood and behavioural monitoring. The system will apply accordingly an individualized cognitive, behavioural and emotional rehabilitation plan with specific focus on high interaction for patient stimulation, that will be automatically modulated according to the clinical situation of Mr. Alvarez.

3.3 HEART FAILURE NARRATIVES

3.3.1 Introduction of exemplary patient profiles

This table provide an overall introduction to the Heart failure narratives, depicting main characteristics of the patient profile, primary impairment and rehabilitation needs and the related use cases. Four heart failure narratives are introduced, referred to as use cases 7-10(UC7-10).

Table 3 Narrative items for the heart failure case

Narrative	Elena	Gheorghe
Characteristics	Acute heart failure event	Myocardial infarction complicated with valvular disease
Primary impairments and rehabilitation needs	• Hypertension • Dyslipidaemia • Obesity grade I • Type two diabetes Needs: • Improving medication control • Improving weight control	• Development of heart failure • Rapid heart rate • Hypertension Needs: • Supporting his cardiovascular fitness • Counselling on smoking cessation
Related UC	UC 7 + 8	UC 9 + 10

3.3.2 First Narrative: Mrs. Elena – Use case # 7 and #8

- **Patients profile Overview**: Mrs. Elena is a 64 years old woman who, due to a poor diet and to bad medication adherence that lead to excessive high blood pressure values, suffered an acute heart failure event. She was known with hypertension for 20 years, dyslipidaemia, obesity grade I, and type two diabetes with antidiabetics for 6 years. She was hospitalised for 5 days, time in which she was cleared of excess fluids and her blood pressure was controlled. Then she was discharged in New York Heart Association – NYHA II class compensated heart failure. She is at the 3rd episode of acute heart failure in the last 2 years. She seems to have troubles in managing her diet and medication. Short after discharge she is enrolled in the rehabilitation programme and starts interacting with the virtual coach for her heart failure rehabilitation.
- **Variability of patients**: this is the typical case of heart failure with systolic ejection fraction. Variability is covered by the VC analysis of different variables in isolation or in association that can impact patient's general evolution:

  - blood pressure management - less than 140/80mmHg during rest and less than 210/100mmHg during physical activity
  - weight evolution: weight gain/loose speed, body composition (water retention)
  - diet: salt intake, caloric intake, water intake
  - cardiovascular signs: leg swelling, oedemas, body position (not breathing properly when in supine position)
  - cardiovascular symptoms: dyspnoea, palpitations
  - flue signs: cough, fever, chills
  - comorbidities: ischemic heart disease, atrial fibrillation, pulmonary hypertension, diabetes, stroke, renal disease, anaemia,
  - urinary infection signs: frequent urination, dysuria,
  - medication intake, additional medication intake
  - family support
- **Needs description**: Elena's needs are related to the monitoring of her vital signs and symptoms, the medication adherence level, and promotion of actions by the VC for the reduction of the risk factors. *vCare* will provide the services required for Mrs Elena`s support, treatment and rehabilitation on a daily basis at home. These services will have to address two principal needs: Improving medication control (Use case #7); Weight control (Use case #8).

After this information, we identified the following next steps:

- **Personalized home rehabilitation pathway**: Based on the patient's general cardiovascular risk, the rehabilitation team prescribes a personalised rehabilitation plan consisting of medication, dietary and physical activity recommendations, social activities. It is important for patients with heart failure with preserved ejection fraction (normal pumping function of the heart-but abnormal relaxation of the heart muscle) to maintain adherence to the prescribed medical therapy in order to keep the blood pressure values under control to decrease the progression of the disease and to prevent future decompensations. Weight control is also very important in heart failure rehabilitation on one side due to the fact that an increased bodyweight increases the work that a weakened heart has to do and also because it is an important indicator of poor management of the patient in some situations.
- **Matching of use case and *vCare* model:** Figures 7 and 8 present the type of approach aimed to improve medication and weight control for the patient. The accent will be placed more on the behavioural component for the medication adherence through the virtual coach ability of high level interaction. For the weight control use case there will be a high level of engagement of the VC both in terms of the healthy rehabilitation but also in terms of the behavioural adaptation of the patient because there are many interconnected variables that need to be assessed in order to produce valid recommendations for the management of patient's weight in heart failure.
  The type of interactions that will take place:
  - Low level interaction: the VC will notify dynamically depending on the patient's previous status (previous values in conjunction with signs and symptoms) and the need to monitor the blood pressure, heart rate, weight.
  - Medium level interaction will be provided by the VC by verbal interaction for monitoring weight and the medication intake, verbal coaching and counselling towards taking the medication, choosing appropriate foods, reducing the salt intake

- High level interaction will be provided by the VC using free speech in order to detect any possible related signs and symptoms, other medications, external factors that could lead to abnormal patient status/un-adherence to medication. Also, as a high level interaction the VC will provide motivation and support as a positive reinforcement.

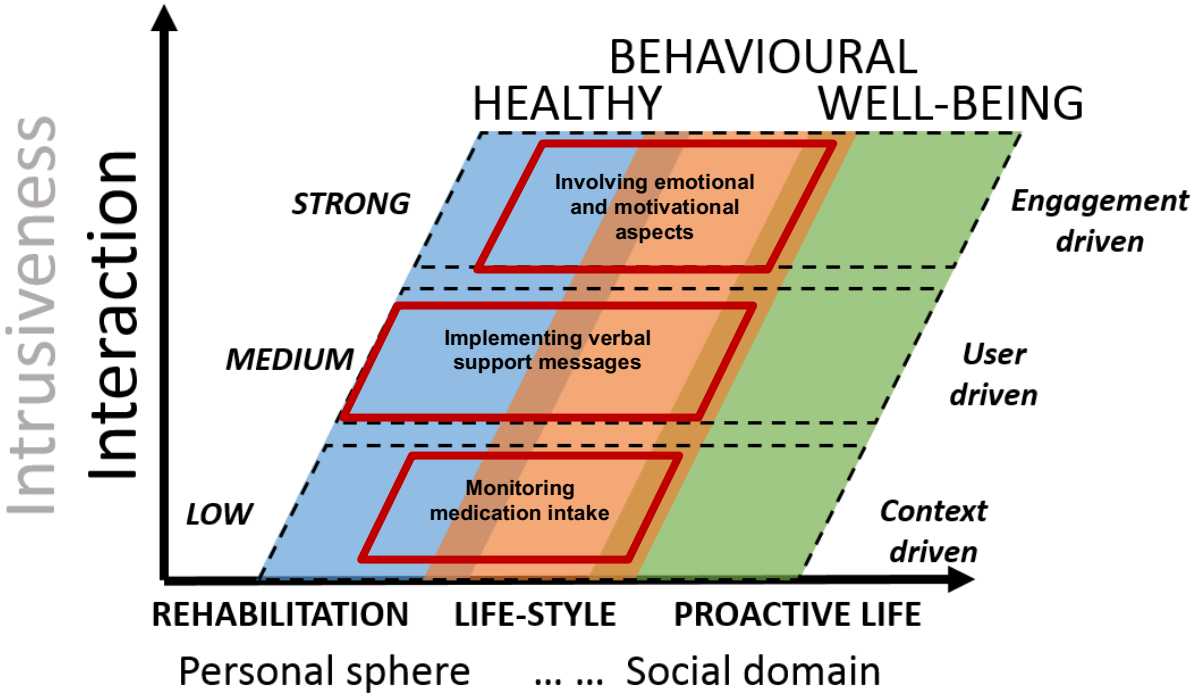

Figure 7 Graphic representation of use case #7 matched on the vCare model. Fields for a possible intervention by the *vCare* system are emphasised in the red boxes.

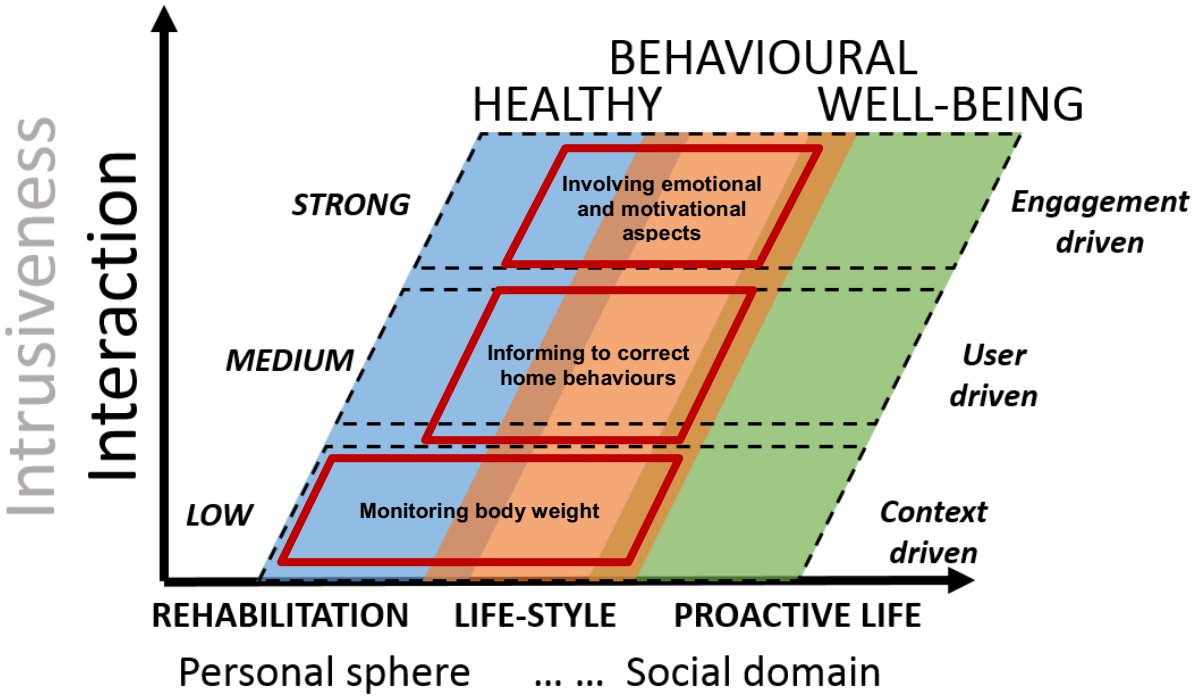

Figure 8 Graphic representation of use case #8 matched on the vCare model. Fields for a possible intervention by the *vCare* system are emphasised in the red boxes.

UC7-1	
Need	Improving medication control
Interaction level	**Low**: Monitoring medication intake

Services: Electronic Pillbox
Processes: Mrs Elena has been prescribed a complex heart failure medication that needs to be taken permanently at three moments within the day, in the morning, at noon and in the evening, at established time intervals (usually 08:00/14:00/ 20:00). The medication is prepared each week for the following week in an Electronic Pillbox in order to ensure proper administration.
It is 08:00 am and, according to the doctor's recommendation, Mrs. Elena should take her morning medication. By 08:30 am, the VC detects that she has not taken the morning medication and it sounds a reminder for Mrs Elena. Mrs. Elena snoozes the alarm and continues her activity as she was heading to the market.
Mrs. Elena is going at the market for buying groceries at 09:00 am: 30 minutes have passed since the last alarm notified her that she should have taken her morning medication. The VC detects Mrs. Elena's ignorance and notifies her again the need to take the medication.
At that moment, Elena follows the advice and decides to open the pillbox and take the medication.
The VC keeps track of Elena's reactions to the notifications and based on the level of adherence expressed by the number of daily notifications triggered to take the medication. During the following days, it triggers' alarms with shorter snooze intervals (less than 30 minutes).
As the adherence increases, the snooze interval gets prolonged to max. 60 minutes.
All notifications are recorded and made available for evaluation at any time.

UC7-2	
Need	Improving medication control
Interaction level	**Medium**: Implementing verbal support messages

Services: Virtual coach – verbal support
Processes: During the last three days, Mrs. Elena has taken her medication after more than two snoozed notifications. The VC initiates a dialogue to see if there are any internal setups that can influence the low adherence such as asking:

- Do you have problems hearing the notification?
- Would you prefer a louder notification?
- Would you prefer another hour for medication intake?

The VC system detects that she needs increased support in this direction and for further support it activates the notification alarm to take the medication as Elena is sensed to leave the house. In the 4th day at 08:00 am, she forgets to take her medication and prepares to go out. At 08:20 am, while leaving her home going at the market, she is verbally informed by the Virtual Coach that she should go back and take her medication.
As the adherence indicator measured by the Virtual Coach goes towards poor adherence it also decreases the snooze time between notifications on taking medications.
Throughout the day as she misses/delays taking the medication the VC emits supportive messages on finding why is she not taking properly the medication.

In the evening at 08:00 pm she needs to take the evening medication. She snoozes the low response alarm. The sleep sensor detects at 08:15 pm that she has fallen asleep and it verbally notifies her calmly that she needs to wake up to take her medication.
If she misses taking the medication during two moments within a day (e.g., morning and afternoon) automatically the virtual coach transmits a message to the closest family member/caregivers to ask for support during the process.
At the end of each day the virtual coach transmits a verbal feedback to Elena to let her know how adherent she was to the rehabilitation recommendations related to medication intake and how much it has improved from the beginning of the process in terms of adherence.

UC7-3	
Need	Improving medication control
Interaction level	**High**: Involving emotional and motivational aspects

Services: Virtual coach verbal support – involving emotional and motivational aspects, blood pressure measurement, heart rate measurement
Processes: Blood pressure (BP) and heart rate (HR) will be monitored at regular times during the rehabilitation process but if Elena will have difficulties in taking her medication the VC will initiate to monitor emotional and motivational aspects:

- Recommendation of measuring BP and HR more frequently.
- If following this recommendation Elena discovers that the BP or the HR are over the normal range. She will also receive verbal feedback from the virtual coach that because the adherence to the medication is low the BP values are not controlled and she should pay more attention at this aspect because increased BP could lead to:
    - another acute heart failure event in combination with a poor diet,
    - a stroke,
    - memory problems,
    - headache.
    - Play, with Elena's approval, short audio materials related to the impact of low medication adherence on the long run related to the patients' evolution.
    - Share the low adherence situation with the close family members and the supervising medical personnel.

In addition, if Elena is performing well the VC will congratulate Elena for her adherence, transmit the situation to the family members and to the supervising medical personnel to increase her support.

UC8-1	
Need	Weight control
Interaction level	**High**: Monitoring body weight

Services: Weight measurement
Processes: At base during rehabilitation depending on Mrs. Elena cardiovascular heart failure class she will need to monitor her weight regularly. If she is NYHA (New York Heart Association) Class II heart failure, at least twice per week weight monitoring will be needed.
Therefore, for example on Monday morning and on Thursday she will have to perform weight measurement.

At 08:00 am, she will receive notification to get on the weight scale.
Elena can perform the task or ignore the first notification by pressing a button "*I'll do it a little bit later*" or "*I'll do it tomorrow*".
If she presses "*I'll do it a little bit later*" at 8:30 another short alarm appears. If she presses "*I'll do it tomorrow*" the notification will pop up the next day at the same hour.

UC8-2	
Need	Weight control
Interaction level	**Medium**: Informing to correct home behaviours

Services: virtual coach – implementing verbal support messages.
Processes: Elena is monitoring her weight as prompted by the application and it is stationary, the VC tracks and presents messages of well evolution to her.
In case Elena is gaining weight between measurements, different processes come into place. At identifying an increase of more than 500 grams in weight over a 2 times per week measurement, 2-3 days' distance, or more than 1,5 kg over one week, the VC automatically transmits to Elena the message to measure more frequently the weight because she is heading in the wrong direction.
In addition, VC starts communicating with Elena based on the recommendations that were performed during the nutritional assessment related to:

- how many meals per day she had during the last 3 days in which the weight status has changed,
- any additional salt intake to foods,
- any nonsteroidal anti-inflammatory medications or other new medication,
- frequency of daily urination decreased,
- swollen ankles.

VC updates Elena's "Risk management profile", and also records data on *vCare* platform to make it available for consultation at any time.

UC8-3	
Need	Weight control
Interaction level	**High**: Involving emotional and motivational aspects

Services: educational dialogue, e-learning
Processes: During the morning Mrs. Elena is in the kitchen. The VC based on the previous assessments determines that she needs additional support and motivation to eat regularly and without salt.
If the VC detected irregular meals it activates the monitoring when Elena is in the kitchen, between the scheduled times for meals, and provides suggestions on different types of foods.
At the end of the day in which Elena has increased in weight, the VC will ask for the foods that she has ate during the day and the amount of additional salt that was used.
VC proposes to Elena to watch some descriptive video material related to decompensation of heart failure.
The VC records all the inputs that Elena provides and transmits it to the medical professional which will decide if it will intervene directly.

3.3.3 Second Narrative: Mr. Gheorghe – Use case #9 and #10

- **Patients profile overview:** Mr. Gheorghe, 61 years old known with a previous myocardial infarction 2 years ago complicated with valvular disease refused to perform at that moment cardiac rehabilitation. He adhered to the medication schema but still he continued to smoke, to be physically inactive due to the fear that by performing physical activity he would risk developing another myocardial infarction. Unfortunately given his continuous exposure to the risk factors his disease progressed towards heart failure. Recently he has been discharged from the hospital following an acute heart failure that appeared on the development of atrial fibrillation with rapid heart rate. He was compensated hemodynamically and he started performing the ambulatory cardiac rehabilitation programme due to the fact that he understood that he needs to do more for his health.
- **Variability of patients:**
  - the possible evolution of blood pressure values throughout the rehabilitation (low blood pressure<90/60mmHg, normal values 90-140mmHg/60-80mmHg, grade I hypertension 140-159/80-89mmHg, grade II HT 160-179/90-99mmHg, grade III HT >180/100mmHg), less than 140/80mmHg during rest and less than 210/100mmHg during physical activity
  - weight evolution: weight gain/loose speed, body composition
  - diet: salt intake, food intake, water intake
  - cardiovascular signs: leg swelling, oedemas, body position (not breathing properly when in supine position)
  - cardiovascular symptoms: dyspnoea, palpitations, chest pain
  - flue signs: cough, fever, chills
  - comorbidities: ischemic heart disease, atrial fibrillation, pulmonary hypertension, diabetes, stroke, renal disease, anaemia
  - urinary infection signs: frequent urination, dysuria,
  - medication intake, additional medication intake
  - family support
- **Need description**: The main need for Gheorghe is to have an assistant at home that could support him in improving his cardiovascular fitness (Use case #9) and counsel him towards smoking cessation (Use case #10).

After this information, we identified the following next steps:

- **Personalized home rehabilitation pathway**: In addition to the medication and weight control actions, the rehabilitation team prescribes a 3 to 5 session per week of remotely supervised physical activity using serious games, stationary bike cycling, treadmill fast walking or Nordic walking. On top of this, Gheorghe will also receive a recommended number of daily steps to be performed. For the smoking cessation action, he will receive a plan of progressive reduction of cigarettes smoked per week/day.
- **Matching of use case and *vCare* model:** Figure 9 presents the type of approach aimed to improve cardiovascular fitness and to promote smoke cessation. The accent will be placed more on the rehabilitation component for the cardiovascular fitness through the virtual coach's ability of high level interaction followed by a high level interaction in terms of behavioural and well-being improvement. For smoking cessation use case there will be a high level of lifestyle-behavioural approach.
  Figure 10 depicts briefly the type of interactions that will take place:

- Low level interaction: the VC will notify dynamically depending the patient's previous status (previous values in conjunction with signs and symptoms) the need to perform a physical activity session, or the daily plan/status related to the daily steps, or related to the weekly smoking plan
- Medium level interaction will be provided by the VC by verbal interaction for physical activity coaching (using progressive loading) and for guiding the patient to maintain safe heart rate thresholds during the physical activity sessions. Also, he will coach the patient into reducing the smoking rates by applying progressive reduction strategy adjusted depending on the patients relapse symptoms and the alternatives used.
- High level interaction will be provided by the VC using free speech in order to motivate the patient to perform the daily recommended physical activity and the planned training sessions and also motivation to hold on the pathway towards smoking cessation.

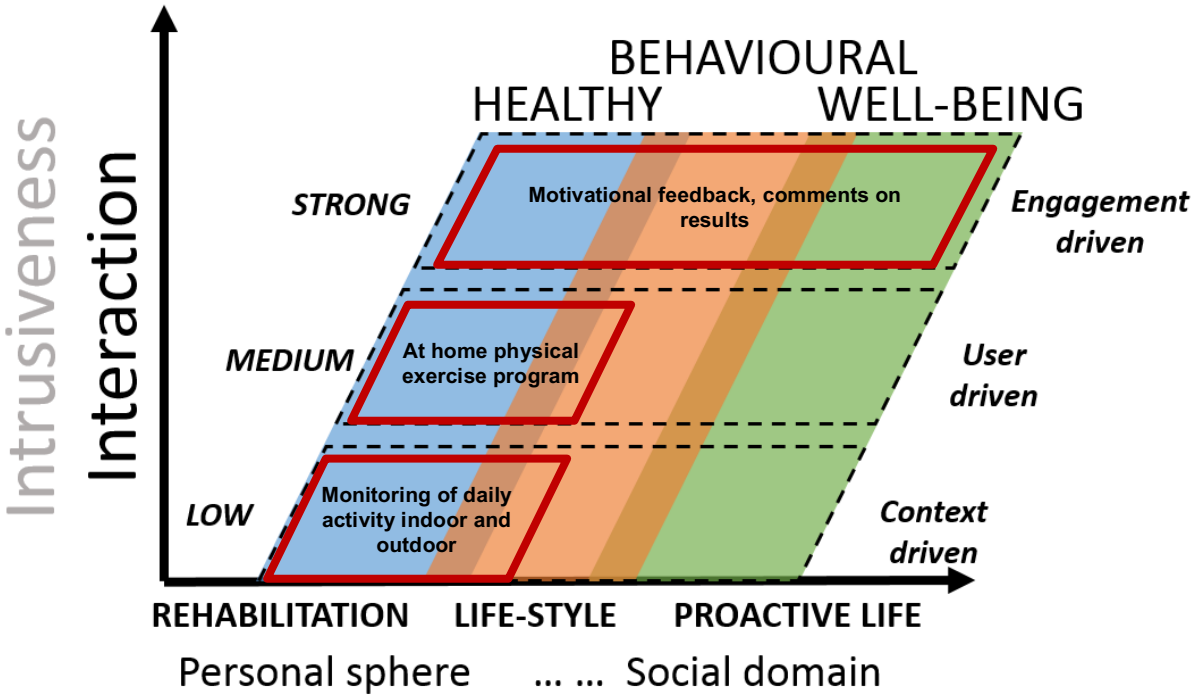

Figure 9 Graphic representation of use case #9 matched on the vCare model. Fields for a possible intervention by the *vCare* system are emphasised in the red boxes.

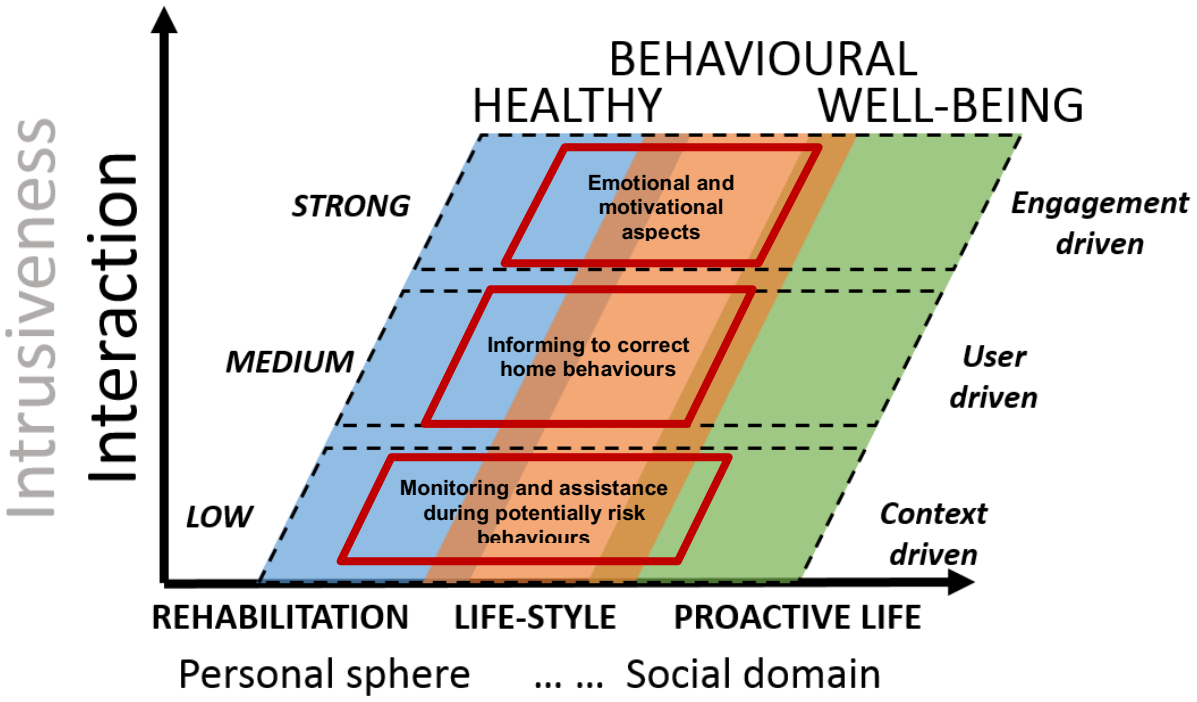

Figure 10 Graphic representation of use case #10 matched on the vCare model. Fields for a possible intervention by the *vCare* system are emphasised in the red boxes.

UC9-1	
Need	Improving cardiovascular fitness
Interaction level	**Low**: Monitoring of daily activity indoor and outdoor

Services: Activities monitor, steps tracking
Processes: Gheorghe is sitting at the laptop reading the news. He has a number of steps planned to be performed regularly every day. It is 12:00 and he has performed 15% of the required activity. The VC notifies him that he must move more so he is heading at the nearby shop to by some apples. At the end of each day he receives a short report related to his planned physical activity and his accomplishments.
Except his recommended daily activity, he has 3 sessions per week of personalised training planned. Today it's 10:00 am and it's one of the days in which he should perform a rehabilitation session.
At 10:00 am the VC notifies Gheorghe the need to perform physical activity through an acoustic feedback. Gheorghe ignores the feedback and continues his activity. 30 minutes later, the VC sends further acoustic feedback and Gheorghe agrees to perform the training session.
The notifications are recorded and made available for consultation at any time.

UC9-2	
Need	Improving cardiovascular fitness
Interaction level	**Medium**: At home physical exercise programme

Services: exergames, heart rate monitoring
Processes: Gheorghe receives a verbal message asking for what kind of training session he would like to perform: exergames, stationary bike cycling, treadmill walking or outdoor Nordic walking

He chooses, verbally, exergames:

Gheorghe moves himself in front of his TV screen.

The sensors recognize that the user is ready to start and then automatically turns on the screen, start the suite of exergames and shows the exercises available to the user, in accordance with his mobility resistance training programme. The heart rate monitoring sensor constantly tracks Gheorghe`s Heart Rate and transmits messages to lower the pace, in order to keep the HR within the designated thresholds.

He chooses verbally cycling, treadmill walking, or Nordic walking:

The second step will be to verbally reply to the question whether he wants *dynamic training* or *plateau style*.

Depending on the type of training he will chose, by using the heart rate monitoring sensor constantly for tracking the HR, the VC will recommend the increase or decrease of intensity making sure to keep the HR within the designated thresholds.

If during the physical activity, he has symptoms of chest pain or palpitations he stops the activity

At the completion of each exercise, the VC provides a graphic video-report on the activity performed by Gheorghe, on the screen.

At different standardised moments during training, the VC will ask the patient for the perceived exertion and will associate it with the intensity of the effort estimated by the current heart rate.

VC evaluates Gheorghe's results and compares this performance with the rehabilitation goal designated by the physician. According to the levels of compliance reached, the VC will propose evolving levels of performance to be reached (e.g., if Gheorghe's performance has a trend over a defined threshold, the VC increases the challenge of the next level, otherwise proposes the same level).

At the end of the session, when Gheorghe ends the rehabilitation session the VC:

1. updates Gheorghe's physical activity report;
2. saves the data of the motor rehabilitation session;
3. synchronizes the daily goals achieved with Gheorghe's profile at the reference healthcare facility;
4. records data on *vCare* platform and makes available for consultation at any time.

UC9-3	
Need	Improving cardiovascular fitness
Interaction level	**High**: Motivational feedback, comments on results

Services: exergames, heart rate monitoring,

Processes: During the physical activity sessions, by real-time analysis of the heart rate of the patient and through collection of perceived exertion scale rate, the VC formulates, at random moments in time, different messages related to the evolution of the patient:

- it's very good, you're doing better than the last time
- great progress
- what a good workout
- I'm feeling that you haven`t rested well last night
- how would you grade the exercise?

Gheorghe can ask the VC about his efficiency in performing the rehabilitation exercises during the last week.

The VC proposes strategies to improve Gheorghe performance for achieving better results.

As a feedback, the VC shows and tells motivating and/or correcting messages.

UC10-1	
Need	Smoking reduction
Interaction level	**Low**: Monitoring and assistance during potentially risk behaviours

Services: Notifications released
Processes: Gheorghe is known as a great smoker. He is trying very hard to quit smoking. Now the VC enters into play for helping him in reducing the smoking rates.
The VC will promote a strategy of progressive reduction of smoking with the weekly reduction of 2 cigarettes per day.
Whenever Gheorghe goes over the established threshold and he feels like smoking he announces the VC that he has the need. Following this, the virtual coach pops a message with one reason why he should refrain from lighting the cigarettes.
VC collects Gheorghe's smoking behaviour, updates which kind of potential risks the user has had and records the event to make it available for consultation at any time from *vCare* platform.

UC10-2	
Need	Smoking reduction
Interaction level	**Medium**: Informing to correct home behaviours

Services: informative multimedia elements.
Processes: Gheorghe is craving for cigarettes. Following three announcements that he feels the need to smoke the VC provides some suggestions:

- Is something disturbing you mentally?

And then it records the message and sends it to the psychologist

- Have you tried the nicotine gum or patch?
- VC suggests to Mr Gheorghe to view some multimedia materials about how to cope with the urge to smoke

At the end of the day the VC asks Gheorghe how many cigarettes has he smoked
VC updates Gheorghe`s "Risk management profile". Also, these activities are recorded on *vCare* platform to make it available to the close family and for consultation at any time.

UC10-3	
Need	Smoking reduction
Interaction level	**High**: Emotional and motivational support

Services: educational dialogue
Processes: Gheorghe has smoked a day before as planned. The VC congratulates Gheorghe for his accomplishment and sends notifications also to the close relatives of Gheorghe so they can support the process. In case Gheorghe has difficulties in maintaining the proposed level of cigarettes per day the VC will adapt automatically the number of cigarettes, (increase by 1 per day, or cut the cigarettes in two) to reduce the cravings but also to keep on an overall descending path.
The VC weekly provides verbal feedback on the evolution of Gheorghe`s smoking status.

3.4 ISCHAEMIC HEART DISEASE NARRATIVES

3.4.1 Introduction of exemplary patient profiles

This table provide an overall introduction to the ischaemic heart diseases narratives, depicting main characteristics of the patient profile, primary impairment and rehabilitation needs and the related use cases. Four ischaemic heart diseases narratives are introduced, referred to as use cases 11-14 (UC11-14).

Table 4 Narrative items for the ischemic heart diseases case

Narrative	Kirsten	Jens
Characteristics	Non-ST [2] elevation myocardial infarction	ST-elevation myocardial infarction
Primary impairments and rehabilitation needs	• Obesity • Hypertension • Hypercholesterolemia • Diabetes II Needs: • Achievement and maintenance of weight loss • Adherence to prescribed medication	• Anxiety of recurrence of a myocardial infarction or cardiac arrest Needs: • Reduce level of anxiety • Alcohol intake reduction
Related UC	UC 11 + 12	UC 13 + 14

3.4.2 First Narrative: Mrs. Kirsten – Use cases #11 and #12

- **Patients profile overview:** Mrs. Kirsten aged 71 years suffered from a non-ST elevation myocardial infarction. She was treated with a coronary artery bypass grafting operation since all three coronary arteries had significant stenoses. As normal procedure, her sternum was split during the operation. She was discharged after two weeks of hospitalisation. She started the mandatory phase II cardiac rehabilitation six weeks after the operation. The reason for waiting six weeks before starting phase II cardiac rehabilitation was to make sure of re-growths of the sternum and not exposing the sternum of twists or pressure during exercises. Furthermore, Mrs. Kirsten suffers from obesity, hypertension, hypercholesterolemia, and diabetes II, which she has suffered from since the age of 45. She is a widow and has no formal education and has been working part time as a cleaning assistant from the age of 45 to 65 years. She has never conducted regular exercises in her adult life. She managed to complete the 12-week phase II cardiac rehabilitation but does not have the strength or desire to follow a transition into a formal community-based rehabilitation programme mainly due to excessive tiredness. Therefore, she is left with rehabilitation tasks such as daily exercises and following a heart-healthy dietary regime in her home.
- **Variability of patients**: Kirsten's most preliminary symptom is tiredness. However, there is a variability in her tiredness in the sense that she is less tired in the mornings. To face

[2] An acute myocardial infarction is defined by elevated cardiac biomarkers with a rising or falling trend. One of the most used criteria are changes on an electrocardiogram (ECG), such as ST segment changes https://en.wikipedia.org/wiki/ST_segment

this variability, the *vCare* system might be set up and personalised by prompting exercises in the mornings instead of the afternoons. Furthermore, prescriptions of meals with slow-acting carbohydrates can be suggested for lunch after exercises by the *vCare* system in order to prolong the level of energy in Kirsten throughout the whole day. This is also in order to prevent Kirsten from eating fasting-acting carbohydrates and high-fatty meals or snacks in the afternoon and evening.
Due to Kirsten's relative low level of education and low level of network (being a widow), she cannot always see the purpose of taking the prescribed medication, and she does not always remember to take her tablets and insulin. To face this complication, the *vCare* system needs to make personalised reminders to Kirsten when she is due for medication several times per day. Furthermore, educational videos with easy understandable explanations of the reason for taking medication and performing exercises when you are suffering from obesity, hypertension, hypercholesterolemia, and type II diabetes can preferably be played automatically within the *vCare* system for example once every month to prevent recurrence of myocardial infarction or worsening of the ischaemic heart disease.

- **Needs description**: The *vCare* system must provide services to Kirsten in order to her treatments, needs, and support on a daily basis in her home. These services should encompass and address the following needs: Achievement and maintenance of weight loss (Use case #11)**,** Adherence to prescribed medication (e.g., Antihypertensive medication, statins, and insulin) (Use case #12)

After this information, we identified the following next steps:

- **Personalised home rehabilitation pathway**: *Exercises to achieve and maintain weight loss:* After having completed the mandatory 12-week phase II hospital-based cardiac rehabilitation programme, internal guidelines recommended to maintain exercise sessions of 30-60 minutes two times a week and walk 30 minutes every day life-long. The *vCare* system must personalise the intensity to Mrs. Kirsten’s needs according to the result from the symptom-limited bicycle test performed at the end of her phase II cardiac rehabilitation programme. Exercise training intensity must be 50-80% of maximal exercise capacity. Furthermore, the training must be aerobic with interval training combined with muscle strengthening exercises. The length and intensity of the cardio stress exercises must depend on the clinical condition and capacity of the individual patient. The intervals can last from few minutes up to 15 minutes in a total of 30 minutes. The muscle strengthening exercises must include training of the large muscle groups two times per week either with low load (3x15 repetitions) of 40-50% of maximal strengths or a moderate load (3x15 repetitions) of 60% of maximal strengths. *Dietary instructions to achieve and maintain weight loss:* The dietary instructions in the *vCare* system must be based on Mrs. Kirsten's individual dietary habits, her risks profile with obesity, diabetes, dyslipidaemia, and hypertension. She must be educated and motivated to make changes in her diet while taking her resources and barriers into account. Recommended diet for Mrs. Kirsten is: increased intake of vegetables and fruit, nuts, full grain, oils based on vegetables, high fatty fish, and a decreased intake of salt and saturated fat. *Adherence to prescribed medication:* The medication reminders in the *vCare* system must follow Mrs. Kirsten's prescription regimen recommended by her hospital specialist or her general practitioner. The proposed educational videos must be individualised to her level of education and health literacy.
- **Matching of patient’s needs on *vCare* model**: The needs of Mrs. Kirsten transposed into the *vCare* model is described in Figure 11 and Figure 12.

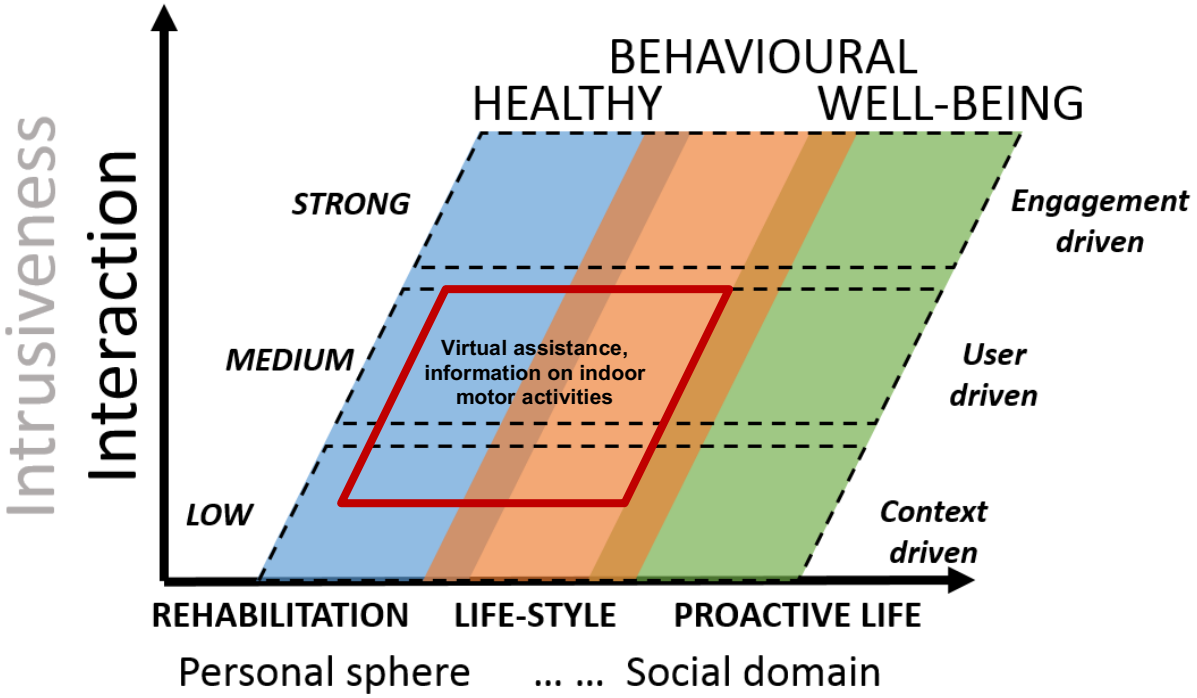

Figure 11 Graphic representation of use case #11 matched on the vCare model. Fields for a possible intervention by *vCare* system are emphasised in the red box.

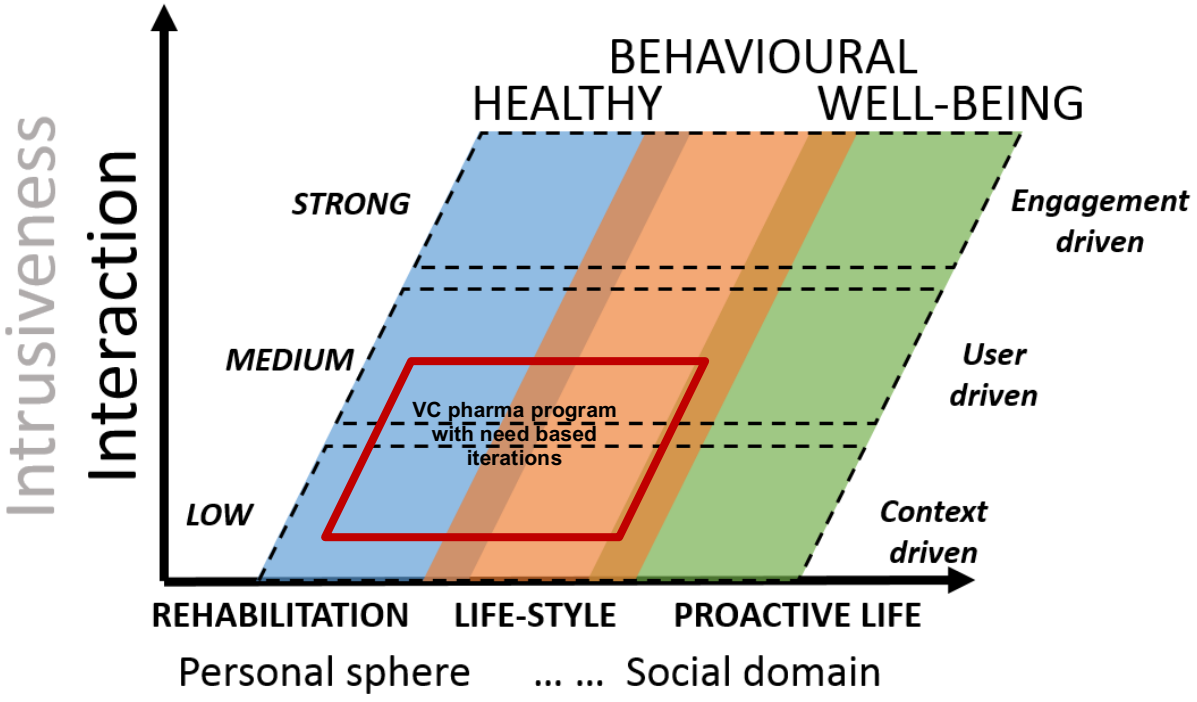

Figure 12 Graphic representation of use case #12 matched on the vCare model. Fields for a possible intervention by the *vCare* system are emphasised in the red box.

UC11	
Need	Achievement and maintenance of weight loss
Interaction level	**Medium**: Virtual assistance, information on indoor motor activities

Services: Activities monitor, serious games, in-house sensors for ambience monitoring and monitoring of pathway deviations

vCare platform takes the input values from various sensors and generates "TASK CHART". The task chart is iteratively updated based on irregularities in the pathway, and patient's response. Through response path, *vCare* system can inform the patient and/or the caregiver the upcoming schedules and/or any updates in the current pathway.

In the present narrative, the pathway process involves parallel monitoring and responses for at least four dimensions:

- Obesity
- Hypertension
- Hypercholesterolemia
- Diabetes

Processes:

- Mrs. Kirsten wakes up in the morning, the activity sensor detects it and fetches for the first task, which is to measure fasting glucose (diabetes) and weight.
    1) The measurements are taken and uploaded wirelessly into *vCare* system
    2) The weighing mat may be just at the convenience place near bed.
    3) The current measurement of fasting glucose updates the whole day plan.
    4) If the measurement is below threshold, the alternative breakfast with proper calorie balance is suggested by VC.
    5) The whole day activities are placed, followed and monitored by VC.
- Someone visits Mrs. Kirsten and schedules are skipped
    1) *vCare* system finds that scheduled walking is skipped.
    2) System intimates Mrs. Kirsten, after every time lapse (say 30 minutes) to complete the exercise.
    3) If the exercise is skipped, the VC suggests low calorie diet for dinner or low intake of insulin (whatever is planned)
- Its Mrs. Kirsten's 71st birthday and she could not resist the nice cake.
    1) The blood glucose shoots up
    2) System alarms for increase in the insulin intake and other prescribed medicines.
    3) The exercise plan, diet chart, gaming sessions are more aggressive for next few days.
- Hypertension
    1) The system reads high BP (Blood Pressure) and/or heart rate.
    2) Prescribed medicine is suggested.
    3) The monitoring schedule is now very frequent, if situation is not improved for a defined time interval, emergency services may be called.
    4) Complementary therapies such as yoga and breathing exercises, and living in absolute natural environment can also be integrated in the system.
- Hypercholesterolemia
    1) Mrs. Kirsten is scheduled for the cholesterol measurements, either from a Pathology Lab or home installed system.
    2) Next visit is scheduled after three weeks.
    3) Based on the current values, the next three-week exercises, diet plans, serious games and natural wellness are planned.

4) The plan may be altered on day-to-day activities.

- *vCare* system generates and follows the weight measuring schedules, daily, weekly, monthly, etc., basis.
- Age bounded quantum workouts can be planned, scheduled and followed.
- Hearth Rate Monitor (HRM) can be a great help to indicate hypertensions. Other sensors, depending upon the need, can be installed for more corrective approach.
- Mounted on the wristbands, a HRM sensor can send the status on regular intervals, and during abnormal situations.

UC12	
Need	Adherence to prescribed medication
Interaction level	**Medium**: VC pharma programme with need-based iterations

Services: Virtual support manager

Processes: (some portion is already discussed above)

- System holds the record of schedules for Mrs. Kirsten
- Mrs. Kirsten needs to visit Pathology Lab for health indicators such as liver and kidney functions, lipid profile, etc.
- The prescribed medical practitioner can generate the new pharma values, such as Antihypertensive medication, statins, and insulin, and uploads on the system.
- The daily dosage plan is sequentially reminded though ambience lighting, nice music or just plain texts.

3.4.3 Second Narrative: Mr. Jens – Use cases #13 and #14

- **Patients profile overview**: Mr. Jens aged 65 suffered from a ST-elevation myocardial infarction. During transportation from home to hospital he suddenly went into cardiac arrest. He received several electric cardio versions during the transport to the hospital and was brought back to consciousness. At hospital, he was treated immediately with a percutaneous coronary intervention with insertion of a drug-eluting stent in the left anterior descending artery. He was discharged after three days. Mr. Jens had never been hospitalised before and has no inherited dispositions for ischaemic heart disease. He is CEO in a company producing items to the windmill industry. He is smoking 30 cigarettes per day. He has a normal weight and is playing badminton one evening every week. He has completed the mandatory 12-week hospital based cardiac rehabilitation programme but has no time to follow a community-based phase III cardiac rehabilitation offer. After discharge from hospital he has felt very anxious about everything and is very afraid of recurrence of a new ischaemic heart disease event. He has managed to reduce his alcohol intake to three glasses of wine a day and has the intention to make a full cessation within the next six months
- **Variability of patients**: Mr. Jens' most preliminary symptom and the one that can have more variability is anxiety of recurrence of a myocardial infarction or cardiac arrest due to the severities of his past experiences. Therefore, the *vCare* system must screen Jens every four-weeks via the HADS questionnaire with an action to contact to general practitioner according to the threshold of the score to avoid the anxiety to develop into a depression. Mr. Jens has performed Fagerström's test of nicotine dependency and has a high level of dependency. Therefore, the *vCare* system must advice alcohol intake reduction.

- **Needs description**: The *vCare* system must provide services to Jens in order to his treatments, needs, and support on a daily basis in his home. These services should encompass and address the following needs: Reduce level of anxiety (Use case #13) and alcohol intake reduction (Use case #14).

After this information, we identified the following next steps:

- **Personalized home rehabilitation pathway**: If the level of anxiety achieved from the HADS questionnaire every four week is above threshold the *vCare* system must advise Jens to contact the general practitioner. Additionally, in order to reduce Mr. Jens' level of anxiety educational videos could be provided through *vCare* system regarding coping strategies related to live with ischaemic heart disease. Furthermore, a down-phasing plan for cigarettes and a plan for the nicotine substitution use.
- **Matching of patient's needs on *vCare* model**: The needs of Mr. Jens transposed into the *vCare* model are described in Figures 13 and 14.

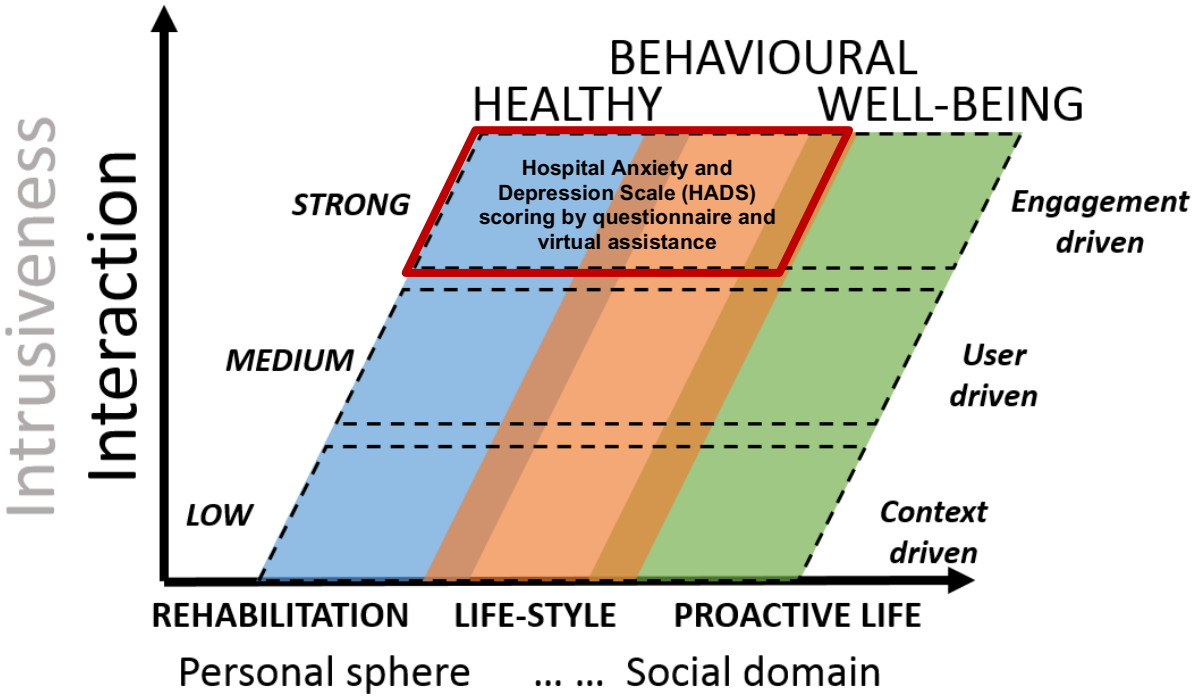

Figure 13 Graphic representation of use case #13 matched on the vCare model. Fields for a possible intervention by *vCare* system are emphasised in the red box.

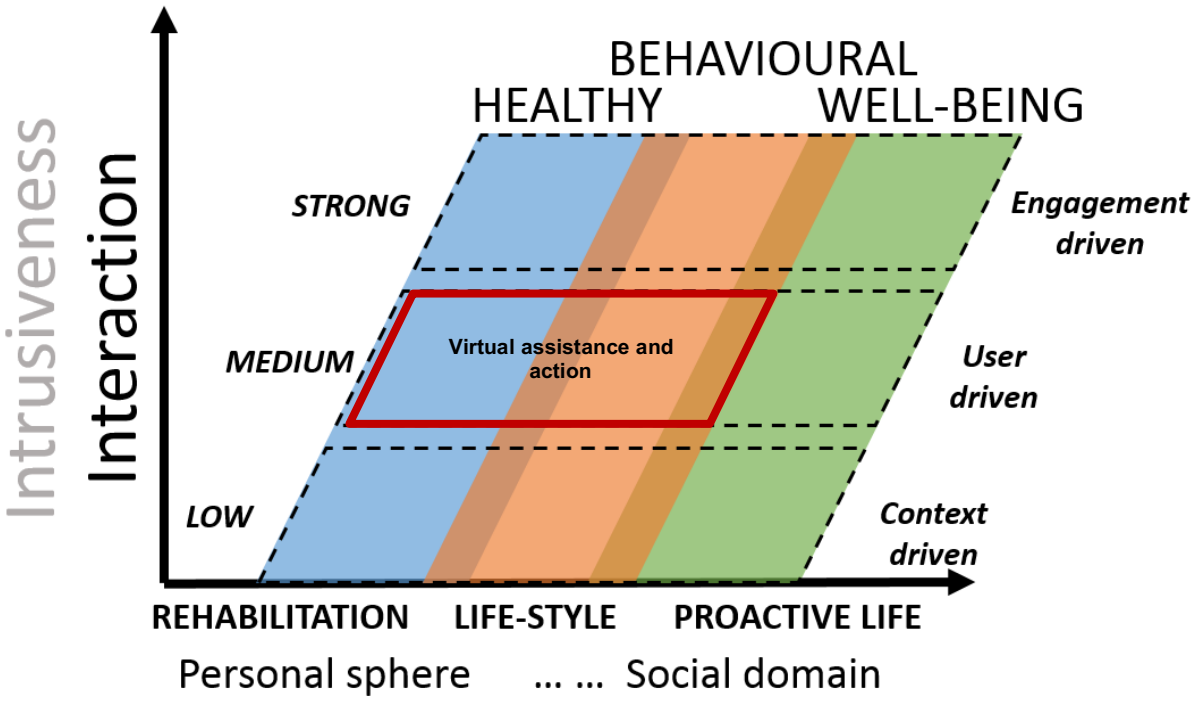

Figure 14 Graphic representation of use case #14 matched on the vCare model. Fields for a possible intervention by *vCare* system are emphasised in the red box.

UC13	
Need	Reduce level of anxiety
Interaction level	**High**: Hospital Anxiety and Depression Scale (HADS) scoring by questionnaire and virtual assistance

Services: The Hospital Anxiety and Depression Scale (HADS) questionnaire scoring, virtual assistance with personal coaching by health professionals

Processes: The best way to tackle anxiety is to keep the mind engaged in some good things.

1) Mr. Jens is sportive person and likes playing badminton, the VC allows Mr. Jens to get involved in other indoor and outdoor games and monitors the stress level and other sensor information for every game he plays.
2) Engagement with right games and right length of time helps Mr. Jens to have a nice sleep, which reduces anxiety.
3) HRM and activity monitor sensors map the anxiety level with the daily activities of Mr. Jens.
4) Alternative therapies such as yoga and meditation can also be introduced.
5) The activity scheduler can iterate the plan based on the kind of engagements Mr. Jens have with various activities. The objective of the VC is to keep Mr. Jens engaged in activities he likes than thinking of visiting hospitals.

UC14	
Need	Alcohol intake reduction
Interaction level	**Medium**: Virtual assistance and action

Services: virtual coach – implementing verbal support messages.

Processes: Alcohol intake consumption of Mr. Jens is monitored, the VC tracks and presents messages of well evolution to him.
In case Mr. Jens is increasing his intake consumption between measurements, different processes come into place. VC starts communicating with Mr. Jens based on the recommendations that were performed during the nutritional assessment.

3.5 PRIORITISATION PERSPECTIVE OF THE REHABILITATION SERVICES IN THE MEDICAL CASES

This part of the document outlines a series of tables that describe various aspects of the rehabilitation services relevant to the different diseases and reference sites. Each table is introduced textually prior to its display. The implications for the prioritisation process are explained after Table 1.
Table 1 summarises all the needs that can be derived from the use cases described in sub-sections 3.1-3.4. This mapping of the needs and the use cases does not represent a final selection of priorities. A number of the observations refer to therapies. In particular, the need for physical therapy applies widely to stroke, PD, heart failure and ischemic heart disease, while occupational therapy applies principally to the stroke use case (#1: fine motor skills in upper limb weakness). Cognitive training is especially useful in the context of neurological diseases, while emotional and social rehabilitation address the needs of different use cases for the four diseases. Moreover, speech and swallowing therapy are of special interest for PD. Risk factor modifications can be seen across most use cases in the study of the four diseases, such as pharmacological intervention and monitoring of vital signs. Sleep and pain appear to be specific for stroke (both phenomena) and PD (sleep only).

Table 5 Commonalities between use cases (#) concerning the diseases/ rehabilitation reference sites

Reference sites / Needs	**Stroke disease** CCP (Italy)	**Parkinson's disease** OSA (Spain)	**Heart failure disease** UMFCD (Romania)	**Ischaemic heart disease** AU (Denmark)
Physical therapy	**#1 #2**	**#5**	**#9**	**#11 #13**
Occupational therapy	**#1**	**#5**		
Cognitive training	**#3 #4**	**#6**		
Emotional and social rehabilitation (e.g. depression and anxiety)	**#3 #4**	**#6**	**#7 #8 #10**	**#13**
Speech and swallowing therapy		**#5**		
Risk factor modification (e.g. falls, smoking, diet, weight)	**#1 #2**	**#5**	**#7 #8 #9 #10**	**#11 #14**
Sleep	**#1**	**#6**		
Pain	**#1**	**#5**		
Pharmacological intervention	**#1 #2 #3 #4**	**#5**	**#7 #8**	**#12**
Monitoring vital signs	**#1 #2 #3 #4**	**#5**	**#7 #9**	**#11**

To better explain prioritisation, the eight narratives presented reflect very clearly the **"typical" patients' profiles** treated in the four rehabilitation centres. This is especially in terms of the characterisation of the impacted disease, which provides additional inputs to the expected relationship with the Virtual Coach.
The list of needs associated to the overall *vCare* patients' profiles have been subsequently analysed for each one of the four diseases in terms of **frequency** of the different symptoms: the clinical **know-how** (based on the opinions of the Panel of Experts already reported in D1.1) has determined the motivation for a **specific intervention**, where the priority level expresses just the clinical perspective of implementation (technical priorities have been set on functionalities. in deliverable 7.2). In this sense the priority level "**Needed**" expresses a need by which the *vCare* system must provide a technical answer at a certain pilot site. The priority level "**Applicable**" expresses a need by which, a specific pilot centre can implement a functionality, if provided to another pilot centre (and addressing the need in the same way). The priority level "Not Applicable", states that none technical answer is expected.

Stroke: The types and degrees of disability that follow a stroke depend on which area of the brain is damaged and how much of it is damaged. It is difficult to compare one individual's disability to another, since each stroke can damage slightly different parts and amounts of the brain. Generally, stroke can cause five types of disabilities: paralysis or problems controlling movements; sensory disturbances including pain; problems using or understanding language, problems with thinking and memory; and emotional disturbances. To be precise, more than 70% of individuals experience upper limb weakness post stroke (Nakayama et al 1994) and 30% of these patients have a permanent paresis (Nichols-Larsen et al 2005). Moreover, it has been reported that at six months after a stroke has taken place, 35% of survivors had depressive symptoms, 30% were unable to move around without assistance, and 26% were dependent in terms of their activities of daily living (Ovbiagele & Nguyen-Huynh 2011). Patients with cognitive deficits experience more difficulties in accessing rehabilitation services, thus impeding their recovery. Dysphagia and dysarthria can both be present in up to 28% of the population (Flowers et al 2013). Risk factor modification is fundamental for stroke prevention. Prevention begins with awareness and education of the patients (Romero et al 2008). Among risk factors for stroke, Obstructive Sleep Apnea (OSA) is one, especially in CVD patients (Valham et al 2008). According to the American Stroke Association, pain is one of the four common medical complications in stroke survivors, including musculoskeletal pain and shoulder pain (Gittler et al 2018, Jönsson et al 2006).
While current estimations are that, in general population, only one in six patients have perfect adherence to medication schedules (Urquhart 2002), there are findings that adherence to secondary stroke prevention medication can be high (between 87% and 100% up to six months after discharge) (Johnson et al 2012). Consequently, monitoring of vital signs is desirable along with the monitoring of medications adherence. Based on these outcomes, CCP described the behaviour of Mrs. Maria, who had experienced a left-sided cerebral stroke that caused a right hemiparesis; Mr Giuseppe, who has a sensitive and motor deficit following anright-sided ischemic stroke; and Mrs Rosa, an old woman who had a right-hemisphere stroke with a slight residual left hemiparesis, and mild attentional and amnesic deficits.
To further clarify the choice of a certain service, a stroke survivor will certainly need motor rehabilitation because of paresis (when physical therapy is needed). In some cases and with less frequency, he or she will benefit from pharmacological intervention and monitoring of vital signs, and according to his or own risk factors (as applicable).

For stroke disease, Table 2 therefore summarises the discussion by outlining the prioritisation (priority level) of the various therapies that are either needed or are applicable to particular types of patients, and describes the relevant motivations.

Table 6 Prioritisation (second column) of the most important needs (first column) and related motivation (third column), concerning stroke.

NEEDS	PRIORITY LEVEL	MOTIVATION
Physical therapy	**Needed**	30% unable to move around without assistance, and 26% were dependent in terms of their activities of daily living
Occupational therapy	Applicable	Stroke patients may experience impairment of their fine motor skills
Cognitive training	**Needed**	Patients with cognitive deficits experience more difficulties in accessing rehabilitation services, thus impeding their recovery
Emotional and social rehabilitation (e.g. depression and anxiety)	Applicable	Stroke survivors may show depressive symptoms and anxiety
Speech and swallowing therapy	Applicable	Dysphagia and dysarthria can both be present in up to the 28% of the population
Risk factor modification (e.g. fall, smoking, diet, weight)	**Needed**	Risk factor modification is fundamental for stroke prevention
Sleep	Applicable	Risk factor modification is fundamental for stroke prevention: Obstructive Sleep Apnea is a one of them
Pain	**Needed**	Pain is one of the four common medical complications in stroke survivors
Pharmacological intervention	Applicable	Adherence to secondary stroke prevention medication can be higher than in the other cases
Monitoring vital signs	Applicable	These depend on risk factors

For further details see paragraph 3.1.1 in D1.1.

Priority levels: First Level – “Needed”, Second Level – “Applicable”. NA: “Not Applicable”.

PD: The patient described here, Mr Alvarez, is at an advanced stage of the disease (phase IV of Hoehn and Yahr). Approximately 50% of patients are at an advanced stage of the disease, which corresponds to stages III, IV and V of Hoehn and Yahr, as reported by a recent meta-analysis (Enders et al 2017). According to several studies carried out by the OSA team, cognitive and mood disorders, motor fluctuations and gait disorders are the symptoms that most affect quality of life and should be prioritised in the rehabilitation processes (Gomez-Esteban et al 2007). The Mr. Alvarez prototype patient experiences motor fluctuations (levodopa-related fluctuations, including wearing off and on-off fluctuations) and dyskinesias, mild cognitive impairment and depression. Rehabilitation programmes guided by *vCare* (motor

and cognitive), modification of risk behaviours, and support to increase adherence to the treatment, will improve the situation for patients and their quality of life.

Table 7 Prioritisation (second column) of the most important needs (first column) and related motivation (third column), concerning PD.

NEEDS	PRIORITY LEVEL	MOTIVATION
Physical therapy	**Needed**	The main symptoms of PD (tremor, rigidity, bradykinesia and gait disorders) affect physical movement and daily life activities.
Occupational therapy	Applicable	Promote health and well-being in daily life activities.
Cognitive training	**Needed**	Dementia affects about 40% of patients with PD; the incidence of dementia in these patients is up to six times that in healthy people. Cognitive impairment is a common non-motor symptom in PD.
Emotional and social rehabilitation (e.g. depression and anxiety)	Applicable	PD patients may have symptoms of depression. Depression may precede the first motor symptoms of the disease.
Speech and swallowing therapy	Applicable	Dysarthria and dysphagia are common in idiopathic PD. Approximately 90% of persons with PD will develop dysarthria during the course of the disease, and more than 40% of PD patients have dysphagia.
Risk factor modification (e.g. fall, smoking, diet, weight)	Applicable	Risk factors, such as falling, may be present in PD in its more advanced stages.
Sleep	**Needed**	Fragmentation of sleep is common in people with PD. PD patients slept over five hours per night, and woke up twice as many times as adults.
Pain	Applicable	Pain is common in people with PD but can be already improved with antiparkinsonian drugs.
Pharmacological intervention	**Needed**	The adherence to the treatment and the schedule is very important in order to prevent the presence of motor fluctuations (OFF / ON).
Monitoring vital signs	Applicable	It is important to monitor orthostatic hypotension because this can worsen stability and gait.

For further details see paragraph 3.1.2 in D1.1.
Priority levels: First Level – "Needed", Second Level – "Applicable". NA: Not Applicable.

Heart Failure: UMFCD described two behaviours. First was the behaviour of Mrs. Elena, 64 years old, who suffered an acute heart failure event due to poor diet and medication adherence. Second was the behaviour of Mr. Gheorghe, 61 years old, who incurred an acute heart failure that appeared after a previous myocardial infarction, alongside physical inactivity, smoking and ultimately the development of atrial fibrillation. Heart failure can be the final stage of multiple pathologies associated with continuous exposure to the risk factors. Once it has developed, however, the cornerstone for avoiding its accelerated progression and decompensation episodes universally applicable and it is related to the optimal management of the reversible existing heart disease risk factors. With the Virtual Coach, *vCare* is aiming at

building a system that could provide an efficient rehabilitation programme to all the patients who could benefit from an ambulatory type of rehabilitation (covering patients with both systolic and diastolic heart failure with NYHA Class I-III).

Table 8 Prioritisation (second column) of the most important needs (first column) and related motivation (third column), concerning Heart Failure.

NEEDS	PRIORITY LEVEL	MOTIVATION
Physical therapy	**Needed**	Core component of the classical institutionalised cardiac rehabilitation programme. Improves heart muscle compliance and contractile function; Improves vascular elasticity.
Occupational therapy	NA	
Cognitive training	NA	
Emotional and social rehabilitation (e.g. depression and anxiety)	Applicable	Depression affects at least one-fifth of patients with CHF,; depression affects these patients with from two- to three-times more than the general population (DeJongh et al 2015). Anxiety can affect the quality of breathing negatively, creating panic and chest pain, and exacerbating the symptoms of heart failure (Vongmany et al 2016).
Speech and swallowing therapy	NA	
Risk factor modification (e.g. fall, smoking, diet, weight)	**Needed (weight control) /** Applicable (food/smoke monitoring)	Core component of the classical institutionalised cardiac rehabilitation programme: • Weight control • Food intake monitoring • Smoking monitoring
Sleep	Applicable	Monitoring sleep quality would be an advantage. Screening would be useful to identify patients with these problems for further treatment.
Pain	NA	
Pharmacological intervention	Applicable	Medication adherence monitoring would be an advantage.
Monitoring vital signs	**Needed**	Core component of the classical institutionalised cardiac rehabilitation programme: Blood pressure and heart rate monitoring are needed to ensure safe remote rehabilitation.

For further details see paragraph 3.1.3 in D1.1.
Priority levels: First Level – "Needed", Second Level – "Applicable". NA: Not Applicable.

Ischemic Heart Disease: Around 50% of patients suffering from either a non-ST or ST elevation myocardial infarction are challenged to maintain in the long-term the improvements they have made during hospital-based phase II cardiac rehabilitation (Hansen et al 2010, Kotseva et al 2016, Piepoli et al 2016). In the EUROASPIRE IV study, a high prevalence of

around 50% of patients involved persistent smoking, unhealthy diets, physical inactivity, diabetes, and obesity at six months or later after the onset of ischaemic heart disease (Kotseva et al 2016). Furthermore, approximately 30% of short-term readmissions in patients who had suffered from a myocardial infarction are unrelated to the incident disease, and the cause of readmission is unclear (Dunlay et al 2012). Some readmissions might be explained by psychosocial factors, such as stress or anxiety, or insufficient coping strategies (Richards et al 2017, Tully et al 2008, Tully et al 2014). In general, the predictors reported to prevent readmissions are enhanced communication, medication safety, advanced care planning, and enhanced training to manage medical conditions (Kripalani et al 2014).

Table 9 Prioritisation (second column) of the most important needs (first column) and related motivation (third column), concerning the Ischemic Heart Disease.

NEEDS	PRIORITY LEVEL	MOTIVATION
Physical therapy	**Needed**	Core component of the classical institutionalised cardiac rehabilitation programme - Improves heart muscle compliance and contractile function; Improves vascular elasticity.
Occupational therapy	NA	
Cognitive training	NA	
Emotional and social rehabilitation (e.g. depression and anxiety)	Applicable	Depression affects at least one-fifth of patients with CHF; depression affects these patients with from two- to three-times more than the general population (DeJongh et al 2015). Anxiety can negatively affect the quality of the breath, creating panic and chest pain, and exacerbating the symptoms of heart failure (Vongmany et al 2016).
Speech and swallowing therapy	NA	
Risk factor modification (e.g. fall, smoking, diet, weight)	**Needed (weight control) /** Applicable (food/smoke monitoring)	Core component of the classical institutionalised cardiac rehabilitation programme: • Weight control • Food intake monitoring • Smoking monitoring
Sleep	Applicable	Monitoring sleep quality would be a plus. Screening would be useful for identifying patients with these problems for further treatment.
Pain	NA	
Pharmacological intervention	Applicable	Medication adherence monitoring would be a plus.
Monitoring Vital signs	**Needed**	Core component of the classical institutionalised cardiac: blood pressure and heart rate monitoring needed for ensuring safe remote rehabilitation

Details in paragraph 3.1.4 in D1.1.
Priority levels: First Level – "Needed", Second Level – "Applicable". NA: Not Applicable.

In light of these previous reflections 10 summarises the matching of the needs with the four reference sites.

Table 10 Prioritisation of the most important features (first column) concerning the four rehabilitation reference sites (first row).
Priority levels: First Level – "Needed", Second Level – "Applicable". NA: Not Applicable.

Reference sites / Needs	**Stroke disease** CCP (Italy)	**Parkinson's disease** OSA (Spain)	**Heart failure disease** UMFCD (Romania)	**Ischemic heart disease** AU (Denmark)
Physical therapy	**Needed**	**Needed**	**Needed**	**Needed**
Occupational therapy	Applicable	Applicable	NA	NA
Cognitive training	**Needed**	**Needed**	NA	NA
Emotional and social rehabilitation (e.g. depression and anxiety)	Applicable	Applicable	Applicable	Applicable
Speech and swallowing therapy	Applicable	**Needed**	NA	NA
Risk factor modification (e.g. falls, smoking, diet, weight)	**Needed**	Applicable	**Needed**	**Needed**
Sleep	Applicable	**Needed**	Applicable	Applicable
Pain	**Needed**	Applicable	NA	NA
Pharmacological intervention	Applicable	**Needed**	Applicable	Applicable
Monitoring vital signs	Applicable	Applicable	**Needed**	**Needed**

In Table 11, the aims to be addressed for each reference site, and the related therapy needs, are compared to a Virtual Coaching platform/environment's approach that can be considered reasonable to support these in a home rehabilitation pathway. The reasoning displayed in the table comes from clinical experience, as already described in D1.1 in the Rehabilitation Pathways Analysis Section (par. 3.1). The specific technical implementation is out of scope of this report: rather, it is dealt with in WP5 and 7 where the clinical needs are transformed into specific technical service descriptions.

Table 11 Identification of aims to be addressed by Virtual Coaching-supported rehabilitation and outline of a respective Virtual Coaching-based approach

Reference Sites / Needs	Stroke disease CCP (Italy)	Parkinson's disease OSA (Spain)	Heart failure disease UMFCD (Romania)	Ischemic heart disease AU (Denmark)
Physical therapy	**Aim:** Regain motor activities, motor rehabilitation, foster motor rehabilitation adherence, active life-style **VC-based approach:** • Monitoring of activity • Serious games addressing physical activity	**Aim:** Improve gait/balance, posture/flexibility, Motor activities and rehabilitation **VC-based approach:** • Assistance and monitoring by VC • Serious games addressing physical activity	**Aim:** Aerobic training based on clinical condition, muscle strengthening exercises, active life-style **VC-based approach:** • Monitoring of activity • Serious games addressing physical activity	**Aim:** Aerobic training based on clinical condition, muscle strengthening exercises, active life-style **VC-based approach:** • Monitoring of activity • Serious games addressing physical activity
Occupational therapy	**Aim:** Ease daily & job-specific activities **VC-based approach:** • VC supervised training/therapy	**Aim:** Ease daily & job-specific activities **VC-based approach:** • VC supervised training/therapy	--	--
Cognitive training	**Aim:** Improve processing speed, visual and verbal memory, visuospatial abilities, and executive function, dual-motor tasks **VC-based approach:** • Serious games addressing cognitive activity	**Aim:** Improve processing speed, visual and verbal memory, visuospatial abilities, and executive function **VC-based approach:** • Serious games addressing cognitive activity	--	--
Emotional and social rehabilitation	**Aim:** Treatment of depression, anxiety, apathy, difficult social situation or lack of social support **VC-based approach:** • In-house sensors for ambience monitoring • Support by the VC for treatment	**Aim:** Treatment of depression, anxiety, apathy, impulse control disorder, difficult social situation or lack of social support **VC-based approach:** • In house sensors for ambience monitoring • Support by the VC for treatment	**Aim:** Reduce psychological or social problems (depression and/or anxiety, sleeping problems, hostility and anger, or lack of social support) **VC-based approach:** • Sensors to identify the emotional status of the patient • In house sensors for ambience monitoring • Support by the VC for treatment	**Aim:** Reduce psychological or social problems (depression and/or anxiety, sleeping problems, hostility and anger, or lack of social support) **VC-based approach:** • Sensors to identify the emotional status of the patient • In house sensors for ambience monitoring • Support by the VC for treatment
Speech and swallowing therapy	**Aim:** Reduce dysphonia, dysarthria, oropharyngeal dysphagia **VC-based approach:** • Serious games for therapy • Auditory and visual feedback by the VC	**Aim:** Reduce dysphonia, dysarthria, oropharyngeal dysphagia **VC-based approach:** • Serious games for therapy • Auditory and visual feedback by the VC	--	--

Risk factor modification	**Aim:** Falls risk reduction **VC-based approach:** • Daily activities diary • Smart home sensors • e-learning (ADL, IADL) to teach about safe behaviour	**Aim:** Falls risk reduction, improve aspiration **VC-based approach:** • Daily activities diary • Smart home sensors • e-learning (ADL, IADL) to teach about safe behaviour	**Aim:** Dietary instructions, smoking cessation **VC-based approach:** • Daily activities diary • Smart home sensors • e-learning (ADL, IADL) to teach about safe behaviour	**Aim:** Dietary instructions, smoking cessation **VC-based approach:** • Daily activities diary • Smart home sensors • e-learning (ADL, IADL) to teach about safe behaviour
Sleep	**Aim:** Sleep state monitoring **VC-based approach:** • Sleep monitoring sensors	**Aim:** Sleep state monitoring, improve sleep quality and quantify the times patient gets up from bed during night **VC-based approach:** • Sleep monitoring sensors	**Aim:** Sleep state monitoring **VC-based approach:** • Smart home sensors	**Aim:** Sleep state monitoring **VC-based approach:** • Smart home sensors
Pain	**Aim:** Reduce **m**usculoskeletal pain, motor rehabilitation related pain **VC-based approach:** • Monitoring pain in relation to activities and posture	**Aim:** Reduce musculoskeletal pain, PD-related chronic pain, fluctuation-related pain **VC-based approach:** • VC to monitor pain	--	--
Pharmacological intervention	**Aim:** Improve adherence to medication, prompt reminders **VC-based approach:** • VC to check and coach medication adherence	**Aim:** Improve drug adherence, subjective effectivity & side effects monitoring **VC-based approach:** • VC to check and coach medication adherence	**Aim:** Improve adherence to medication, prompt reminders **VC-based approach:** • VC to check and coach medication adherence	**Aim:** Improve adherence to medication, prompt reminders **VC-based approach:** • VC to check and coach medical adherence
Monitoring Vital signs	**Aim:** Avoid orthostatic hypotension **VC-based approach:** • Blood pressure variability monitoring • Heart rate variability monitoring	**Aim:** Avoid orthostatic hypotension **VC-based approach:** • Blood pressure variability monitoring • Heart rate variability monitoring	**Aim:** Blood pressure control, perform physical activity in safety, weight monitoring, body composition monitoring **VC-based approach:** • Heart Rate monitoring • Blood pressure monitoring • weight, glucose monitoring • Cholesterol monitoring	**Aim:** Monitoring of blood pressure, exercise capacity monitoring **VC-based approach:** • Heart rate monitoring • Blood pressure monitoring • Weight, glucose monitoring • Cholesterol monitoring

4 CONCLUSIONS AND NEXT STEPS

In the framework of the *vCare* project, this document provides a concrete step in the definition of the expected behaviour of the VC, declined according to the patient characterization. Starting from analysis of the innovation gap addressed by *vCare* in the current rehabilitation pathways (expressed in D1.1), D1.2 identifies the needs to be addressed (and the related treatments), starting from the different patient's characterizations. Driven by a bottom-up approach, the method used to express the needs to be addressed was that of the "narrative", declined afterwards in use-cases in order to identify rehabilitation treatments at home, to be enhanced by the VC system.

The narratives connect patient's characteristics with the manifestation of impairments, unexpected needs, and bad feelings. In *vCare*, the starting point for the description of these narratives' was a selection of the most common needs and aspects encountered by the *vCare* clinicians during their daily clinical practice or reported directly by a patient during a visit. The narratives reproduce the needs of the target group: this is defined as elderly citizens with existing or emerging chronic diseases, impairments and showing frailty in the rehabilitation setting.

With this regard, medical experts identified eight narratives:

- CCP described the behavior of **Maria**, a left-sided cerebral stroke that caused a right hemiparesis, **Giuseppe**, with sensitive and motor deficit following right-sided ischemic stroke and **Rosa**, an old woman which incurred in a right-hemisphere stroke with a slight residual left hemiparesis, mild attentional and amnesic deficits;
- OSA described the behavior of **Alvarez** is 75 years old with an advanced Parkinson's disease (PD);
- UMFCD described the behavior of **Elena,** 64 years old, which suffered an acute heart failure event due to poor diet and medication adherence, and of **Gheorghe**, 61 years old, which incurred in an acute heart failure that appeared on the foundation high blood pressure, physical inactivity, smoking and ultimately the development of atrial fibrillation;
- AU described the behavior of **Kirsten,** aged 71 years, which suffered from a non-ST elevation myocardial infarction and **Jens**, aged 65, which suffered from a ST-elevation myocardial infarction.

From the narratives, a list of 14 uses cases was declined, in order to identify the needs and the related treatments enhanced by *vCare*. In the neurological domain, the list includes mostly treatments related to physical/motor activity, emotional recognition, risk factor modification (fall) and cognitive enhancement. In the cardiological domain, the list includes mostly treatments related to physical/motor activity, emotional recognition (anxiety, depression), risk factor modification (smoke, weight) and adherence to therapy (pharmaceutical).

Finally, D1.2 includes the prioritisation of the needs for each one of the four rehabilitation reference sites, to be further defined from a technical perspective (see. 7.2).

Table 12 shows each use case and need, correlated by the activities proposed for the three interaction levels.

Table 12 Summary of proposed use cases concerning the four reference sites

Use case	Need	Response		
		Low Interaction level	**Medium Interaction level**	**High Interaction Level**
#1 CCP	**Recovery from paresis and reduction of functional disability**	Monitoring of motor activities indoor	Physical exercise programme	Physical exercise programme, motivational feedback, comments on results, assessment of pain, correction of wrong posture
#2 CCP	**Fall risk reduction**	Monitoring and assistance during potentially risk behaviours in indoor environment	Informing to correct home behaviours	Engaging user to correct behaviours, predicting dangerous situations and promoting virtuous behaviours in a proactive form
#3 CCP	**Improving memory ability attentional-executive functioning**	--	--	Home-based cognitive stimulation and generalisation techniques
#4 CCP	**Managing new concerns (anxiety) and negative thoughts (depression)**	Monitor user's emotional levels	Acquisition of awareness of one's own emotional states	Acquisition of awareness of the possibilities to change one's own emotional/cognitive state
#5 OSA	**Motor functioning**	Monitoring of motor status, motor complications, treatment compliance and effectiveness	Supervised individualised sensor-motor rehabilitation programme	Engagement in prevention of falls, in medication regimen adherence and in a proactive life towards indoor and outdoor rehabilitation activities
#6 OSA	**Cognitive & behavioural rehabilitation**	Automated monitoring of cognitive, behavioural and emotional status, automated adaptation of cognitive training and alarms for behavioural and emotional risks	Supervised individualised adaptive cognitive, behavioural and emotional rehabilitation programme	Home-based cognitive and emotional stimulation, specific focus preventing emotional and behavioural problems

Use case	Need	Response		
		Low Interaction level	Medium Interaction level	High Interaction level
#7 UMFCD	**Improving medication control**	Monitoring medication intake	Implementing verbal support messages	Implementing verbal support messages involving motivational aspects
#8 UMFCD	**Weight control**	Monitoring body weight	Informing so as to correct home behaviours	Informing so as to correct home behaviours involving emotional and motivational aspects
#9 UMFCD	**Improving cardiovascular fitness**	Monitoring of daily activity indoor and outdoor	At home physical exercise programme	Motivational feedback, comments on results
#10 UMFCD	**Smoking reduction**	Monitoring and assistance during potentially risk behaviours	Informing so as to correct home behaviours	Informing so as to correct home behaviours involving emotional and motivational support

Use case	Need	Response		
		Low Interaction level	Medium Interaction level	High Interaction level
#11 AU	**Achievement and maintenance of weight loss**	--	Virtual assistance, information on indoor or outdoor exercise activities, and dietary regimes	--
#12 AU	**Adherence to prescribed medication**	--	VC pharma programme with need-based iterations such as medication reminders through calendar schedules	--
#13 AU	**Reduce level of anxiety**	--	--	Hospital Anxiety and Depression Scale (HADS) scoring by questionnaire and virtual assistance and actions
#14 AU	**Alcohol intake reduction**	--	Virtual assistance and action	--

The transition of the clinical needs to functional and non-functional technical requirements are presented in D7.1 and D7.2 as well as the respective derivation of coaching services in D5.1 as a major component of the envisaged vCare solution

As expressed in the figure below, other WPs will benefit from the outcomes of this deliverable.

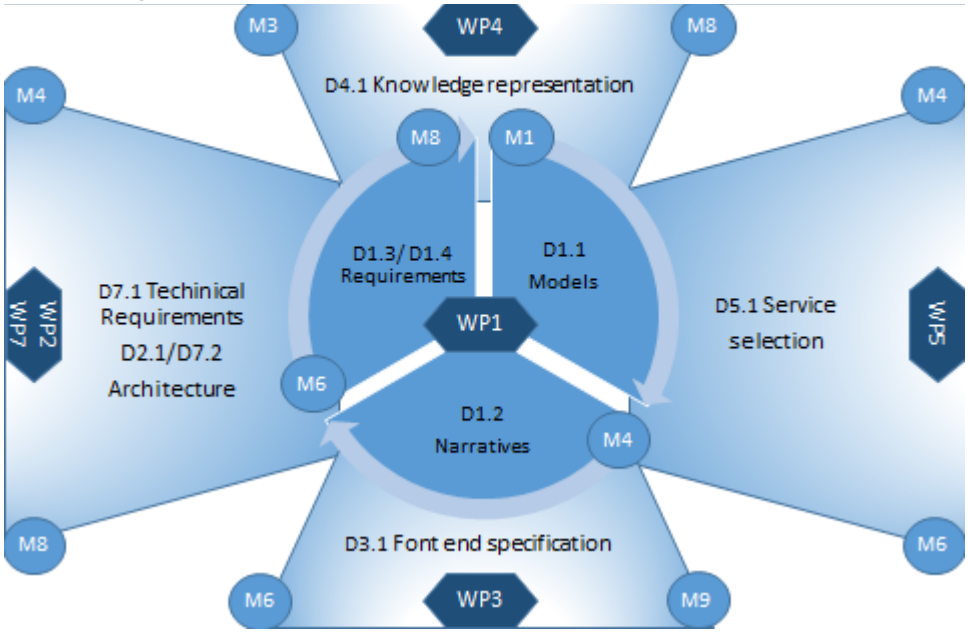

Figure 15 WPs interconnecting with WP1, M1-M8.

WP3: In Task 3.1, this deliverable provides practical examples of expected interaction between the patient and the Virtual Coach to be investigated according to the *vCare* model that was defined in Task 1.1.
WP4: In Task 4.1, this deliverable provides the needed information for the specification of use cases against which the models will be validated. The deliverable also supports the creation of the clinical pathway ontology.
WP5: In Task 5.1, this deliverable provides the framework by which to investigate the enabling services.
WP7: This WP is highly dependent on D1.2. As a matter of fact, Task 7.1 will work in parallel with WP1 in order to translate the user specifications (i.e. use cases) into appropriate technical requirements.

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