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Abstract:

The present deliverable, titled “Preliminary User and System Requirements” provides an overview on the user requirements – as they stem from the previous work performed in the domain of health monitoring and assisted living projects – and of system requirements, which are derived from the initial concept of eWALL as described in the DoW and developed through consortium discussions.

Keyword list: user requirements analysis, eHealth, assisted living, home automation, health monitoring, physical training, cognitive training, COPD, MCI.

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Table of Contents

1 Executive Summary

The present deliverable, titled “Preliminary User and System Requirements” attempts to offer an overview on the user requirements – as they stem from the previous work performed in the domain of health monitoring and assisted living projects – and of system requirements, which are derived from the initial concept of eWALL as described in the DoW and developed through consortium discussions.

The first step of user requirements analysis, the definition of the primary eWALL users, is analysed in detail in deliverable D2.2 (Initial scenarios and use cases), which is processed in parallel with the present. In a nutshell, eWALL’s target group includes older adults with: (1) MCI; (2) COPD and (3) people who suffer from non-severe age-related impairments. When experiencing symptoms of their impairment – whether it is physical or cognitive – the target users often lose trust in their abilities as well as motivation to perform activities and they often succumb in isolation, which further deteriorates their health.

In this deliverable, the user requirements analysis is completed with an exploration of the State of the Art in the domain of physical health, with a special focus on COPD (Chronic Obstructive Pulmonary Disease) and the domain of cognitive health, particularly for the case of MCI. At the time of writing, there was a need to gather insights regarding services that would be provided to the users; therefore we focused our research on research projects and commercial products with similar goals and target groups in order to shed light on best practices and drawbacks of current project concepts.

The preliminary user requirements reflect the insights gathered from the State of the Art analysis, the user profiling and the definition of use cases in deliverable D2.2 (Initial scenarios and use cases) and the feedback received during the iterations of the present. Three draft concepts on the interaction with eWALL and on gaming are additionally presented, thus initiating the eWALL iterative design process.

Moreover, the preliminary eWall system requirements are presented, consisting of generic requirements and specific requirements. The generic requirements provide a general viewpoint on envisioned eWall system functionalities and should serve as general guidelines on the eWall platform capabilities. The specific requirements refer to specific technical aspects of the eWall system that make it viable and reliable under different possible circumstances.

D2.1 (Preliminary user and system requirements, the present document) offers a first glimpse into eWALL’s system architecture and a detailed overview of the landscape of assisted living, identifying drawbacks of existing projects and pinpointing plausible areas of innovation. In combination with D2.2 (Initial scenarios and use cases), the two documents provide the necessary foundation to support the design and development efforts of eWALL.

2 Introduction

The following pages provide a brief overview on the overall goals of the eWALL project and a description on the scope of this deliverable together with an outlook on the further steps for the overall analysis of the user and system requirements for the eWALL solution.

2.1 A brief description of eWALL project

The main objective of the eWALL project is to create a beyond the State of the Art assistive platform that will support independent living of older adults with mild cognitive and physical impairments. In particular, the project will target three specific user profiles: COPD patients, older adults with MCI and older adults with age-related impairments. The primary users will be supported through in their autonomy, functional capacity and participation in society. Informal and formal caregivers are defined as secondary end-users and eWALL is planned to provide a framework for information exchange and communication between them and the primary users.

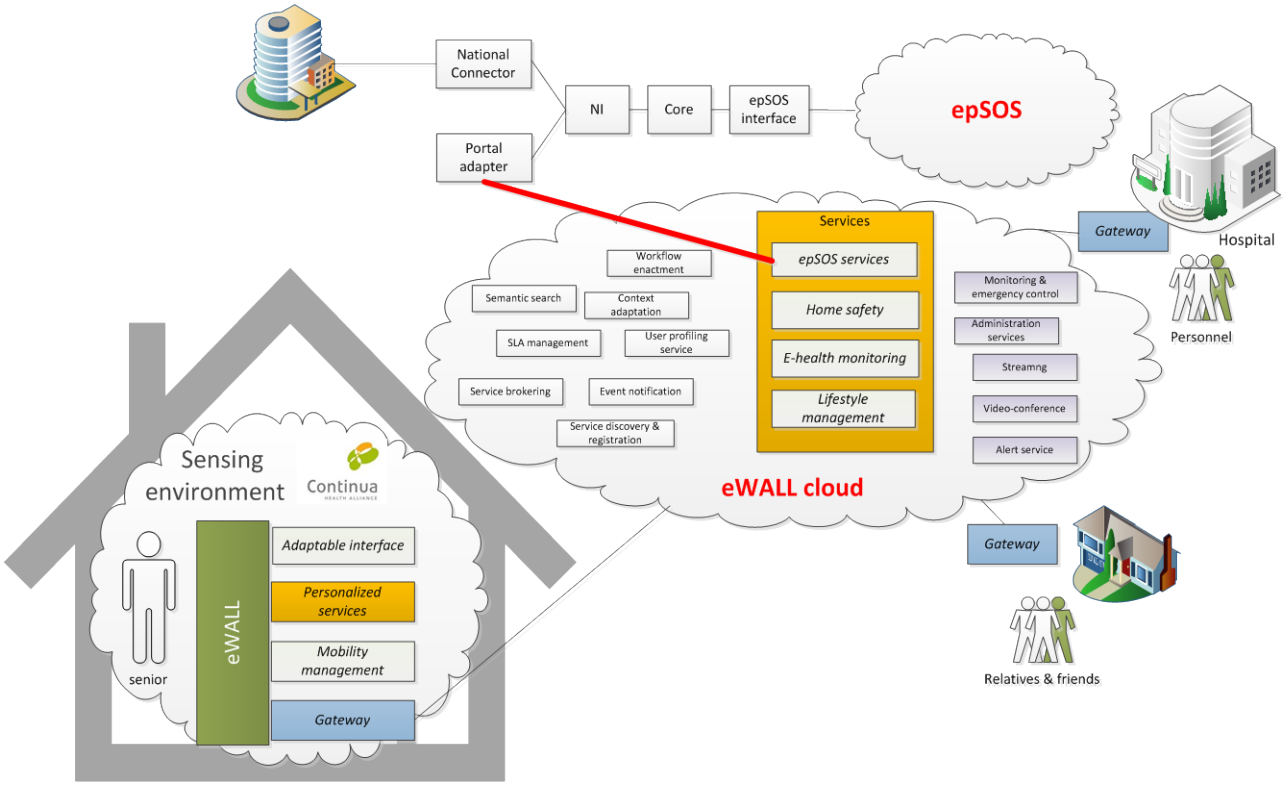

Figure 1 The holistic Service Oriented Architecture of eWALL

According to the DoW, eWALL will provide applications in the following areas: (a) risk management and home safety, (b) eHealth and (c) lifestyle management. The project will carry out multidisciplinary research and a large-scale demonstration activity for validating the concept with solid clinical evidence. This will include technical, user and legal evaluations, the criteria of which will be defined along with the progress and development of eWALL. The project will also perform so-

cio-economic studies to deliver recommendations for the health sector that will result in mid- and long-term benefits for the sustainability of national health systems.

WP2, Requirements Analysis & Use Case Scenarios starts with shedding light to the landscape of technology, projects and products supporting ADL (Activities of Daily Living) for older adults. Through this investigation of the State of the Art, we will acquire the necessary background in order to create a concise eWALL concept that is valuable to the life of its end-users. The concept development will be initiated in the present deliverable D2.1 (Preliminary user and system requirements). Within WP2, a functional eWALL architecture model will be proposed. Interoperability, privacy and the integration with existing platforms such as epSOS [13] are among the aspects that will be addressed in the design of the eWALL architecture. Last but not least, WP2 also focuses on defining the evaluation and validation methodology through which eWALL's impact on the life of its end users will be assessed. The whole consortium contributes to this work package, led by CURE.

2.2 The scope of this deliverable

The deliverable D2.1 (Preliminary user and system requirements) describes the preliminary user and system requirements and it is expected to serve as a compass in all the forthcoming design and development efforts. Therefore it is important to define all the dependencies, parameters and user roles in as much detail as possible right from the start.

It is often the case that especially user requirements are taken lightly and are subject to various interpretations due to the fact that technical developers often face challenges that force them to drive the project out of its initial objectives. The main goal of this deliverable is to contribute to the project not only with a set of user and system requirements but also to derive preliminary tangible concepts that describe potential services of eWALL. The concepts included in D2.1present ideas for some of the services proposed and agreed by the consortium. Preliminary use case scenarios are developed in D2.2 (Initial scenarios and use cases).

D2.1 provides the first rough sketch of eWALL, and thus, it sets the framework on which the eWALL devices and sensors will be precisely defined (WP3), the intelligence of the system will be modelled (WP4) and the services will be developed (WP5). Table 1 gives detailed insights into the dependencies of D2.1.

Table 1: Dependencies of D2.1 (Preliminary user and system requirements)

WP	Deliverable	Dependency from D2.1
WP2: Requirements Analysis & Use Case Scenarios	D2.2 Initial scenarios and use cases	D2.1 will provide **State of the Art** analysis and **first eWALL concepts** that together with user profiling are going to define the use cases (D2.2). Out of the use cases, **functional requirements** will be drawn and included in D2.1. Since the 2 deliverables are so closely related, they will be developed in parallel.
	D2.3 Preliminary system architecture	D2.1 will provide the **preliminary system requirements**, thus setting the basis for the system architecture
	D2.6 Evaluation and validation	D2.1 provides insights regarding users' needs, there-

	methodology	fore it shapes to an extent the evaluation criteria and goals. Moreover the projects described in the State of the Art analysis can serve as benchmarks in order to evaluate the performance of eWALL.
	D2.7 Final user and system requirements and architecture	See section 2.3 for the roadmap between final and preliminary.
WP3: eWALL devices and processing algorithms	D3.1 eWALL Networked devices	D2.1 examines State of the Art projects from the perspective of the networked devices they use, thus it can contribute to informed decisions for this deliverable.
	D3.2 Perception from sensors	D2.1 provides examples from the State of the Art on the use of sensors in in-home monitoring networks.
WP4: eWALL platform	D4.1 Semantic model of eWALL middleware services	The semantic ontology will be based on the eWALL concept and information architecture, which will be initialized in deliverable D2.1 D2.1 will contribute here with analysis of the State of the Art and first draft concepts, as well as define the framework for the applications through the functional requirements.
	D4.2 Intelligent support system for eWALL	
WP5 Personalized Services & applications	D5.3 Intelligent context-aware services & applications	

2.3 Roadmap between preliminary and final user and system requirements

In this section, we would like to clarify the roadmap between D2.1 (Preliminary user and system requirements, month 4) and D2.7 (Final user and system requirements and architecture, month 15). The present deliverable D2.1 aims to offer an overview of State of the Art projects with similar focus in cognitive and/or physical health of older adults. The examination of relevant projects leads to a better understanding of the challenges we are going to face in the design and development of eWALL. The result of this examination is a number of open questions regarding different elements of eWALL (mainly functionality) that have to be addressed in the beginning of the design and development process as well as a set of preliminary user requirements.

In the meantime between deliverable D2.1 and deliverable D2.7 different concepts will be visualized with storyboards or videos and proposed for eWALL (this task starts in this deliverable in section 2.7) and the consortium with the involvement of end-users will attempt to select the best parts of each of them and synthesize a robust, feasible concept for eWALL, closer to the final concept.

Therefore, it is expected that in D2.7, the concept and the primary and secondary user groups will be defined in higher fidelity and feedback from other deliverables (e.g. D2.3, Preliminary system architecture) will be incorporated. Moreover, the State of the Art will be completed with projects and literature that target specific challenges that we need to address.

Regarding the system requirements, the present deliverable D2.1 aims to systematically extracting the most important generic and specific eWALL system characteristics that the consortium will

work on in the following period. It analyses the necessary requirements for the architectural blocks and the associated interfaces along with their importance level towards the final eWALL system. The current version of the system requirements should serve as a bridge between the scenarios and use cases, on one side, and the actual architecture design on the other. They will be modified and refined in the following period and their final version will be included in the deliverable D2.7 (month 15).

3 Preliminary user requirements

In this chapter we will attempt to extract preliminary user requirements for eWALL taking into account the target user profiles (described in deliverable D2.2), research projects and commercial services which serve similar goals and/or target groups plus our own first draft ideas regarding how primary users could interact with eWALL.

Section 3.1 describes the methodology we employed to extract the requirements. Section 3.2 presents the personas developed in deliverable D2.2. Section 3.3 includes a summarized table of the State of the Art projects we analysed and various aspects that stem from them. Section 3.4 attempts to offer an initial collection of interaction design concepts that describe how the primary user could interact with eWALL. Section 3.5 contains the preliminary user requirements as distilled from our research.

3.1 User requirements' objectives and methodology

eWALL is an ambitious project that aims to utilize State of the Art technologies, interaction techniques and lifestyle management methodologies to improve the lives of users with specific physical and/or cognitive limitations. Therefore, in order to design the eWALL system we need to collectively acquire up-to-date knowledge regarding all these domains from medical symptoms of certain diseases to in-home monitoring technology. In this section, we will sketch a methodology that will allow us to gather and distil the relevant information for the design of eWALL.

First of all, we need to acquire knowledge on **the profiles of our end users**. Primary end users for eWALL are people with age related physical and cognitive impairments who wish to live independently. The consortium decided to focus on three specific categories of users:

- Older adults with COPD
- Older adults with MCI
- Older adults with age-related impairments

For the time being, the focus on the two main target groups, older users with COPD or MCI, facilitates better focus of the design process. The reason is that these target users have an urgent need to adapt their lifestyle in order to manage their disease –cognitive and physical exercises, frequent consultations with doctors, etc. To support users in this process is a major challenge for eWALL. Despite not being threatened by a specific disease, the third target group (older adults with age-related impairments) will certainly benefit from a healthier lifestyle promoted by eWALL; hence we will explore the possibilities to extend eWALL's applications to address them.

A detailed presentation of user profiling is included in deliverable D2.2. In section 3.2 of D2.1, the personas from D2.2 are included along with our observations on certain behavioural patterns observed in these personas.

An important objective in the user requirements analysis is to study the **State of the Art** systems currently addressing the needs of the selected target group and the functionality they offer. A curat-

ed list of relevant projects is provided in section 3.3.1. The DoW defines the following functionality domains for eWALL:

- Risk management and home safety
- eHealth
- Lifestyle management

All these functionality categories imply a well-thought framework for **in-home monitoring**, namely the process of gathering sensor and audio-visual input with the aim to facilitate the life of a person with/without impairment(s) and her caregivers. In section 3.3.2, the curated assisted living projects will be analysed to their components and examples of innovative approaches will be showcased.

All the above-mentioned sections serve the purpose of laying down a number of aspects that are going to be part of eWALL and providing examples of State of the Art projects in respective fields. However, they leave open issues and questions regarding the eWALL concept that have to be resolved by the consortium before starting the development process. Section 3.3.3, **design directions**, attempts to address some of the issues by visualizing a number of different first eWALL concept drafts.

Finally, drawing from the design directions and the State of the Art analysis, we will attempt to provide a number of first eWALL concepts in order to kick-start the design process in section 3.4. These first draft concepts will provide the opportunity to the consortium to discuss the open issues outlined in section 3.3.3, consortium views on different aspects of eWALL and recommendation for updating the concepts. The concepts will be further refined and improved and will serve as a basis for the design process and the updated user requirements that will be completed in D2.7.

3.2 Profile of eWALL end-users

This section aims to offer insights on the everyday life of the primary target users of eWALL. The following personas representing potential primary users of eWALL were developed in D2.2, where a more detailed description of the profiles of primary and secondary users, as well as information on their medical condition is presented.

3.2.1 Overview on eWALL end-user personas

In a nutshell, what the primary target users of eWALL have in common, whether they belong to the cognitive or to the physical impairment group, is that they **lose trust** in their cognitive or physical abilities and they gradually **abandon their former activities**. As a result, their **confidence and mood** is affected and they often **succumb in isolation**. This has an impact on their overall health and social life. Moreover, rehabilitation therapies are expensive and have certain duration; even if they are proven to be effective, patients often lack the **motivation** to continue the training on their own. This is a vicious cycle, which has to be addressed by eWALL concept design.

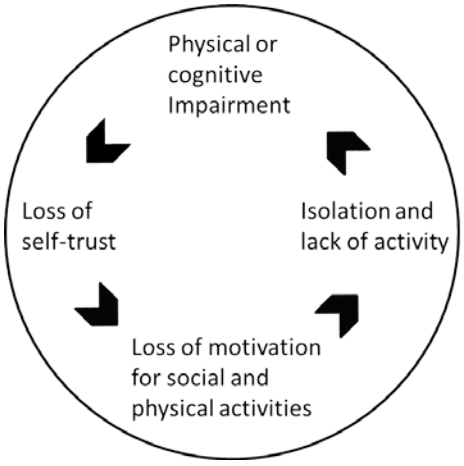

Figure 2 The vicious cycle of behavior showcased by the personas.

In Figure 2 the critical points of the vicious cycle described in the personas can be identified; almost all personas experience **loss of self-trust** and subsequently, **loss of motivation.** The result is isolation, lack of activity and low or no adherence to therapy which can potentially deteriorate the physical and/or cognitive state of the patient even further. Therefore, we should strive that these two emotional parameters, self-trust and motivation are placed at the core of eWALL's final concept.

3.2.2 Personas with age-related impairments

Michael, due to MCI, gradually loses trust in his memory and he experiences low motivation to go out and be active, which affects his overall health. Simone prefers to stay at home and watch TV because of her balance issues. Visits to the physiotherapist have become physically challenging for her and her social life suffers because she feels embarrassed for her condition.

3.2.2.1 Persona with age-related cognitive impairment "Michael"

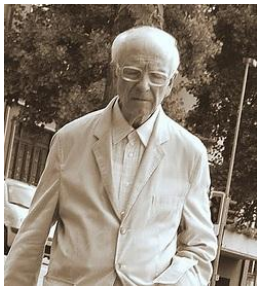

Figure 3 Persona 'Michael'

Michael is a 67-year-old former business consultant who lives with his wife, Maria, in an urban center. Michael retired two years ago and Maria, who is expecting to retire in a year from now, has a job as a social assistant in the community centre of their neighborhood.

As a business consultant, Michael had a very active life. He often travelled between the several departments of the company and met new people almost every day. During his last year as an employee, Michael started noticing difficulties in memorizing the names of the people he met. Keeping in mind the importance that social interaction has in his job, these lapses of memory often led to frustration. Michael thought this was only the result of a life of hard working and everything would come back to normal after retirement, by adopting a more relaxed lifestyle.

Actually, the situation only got worse. Michael started forgetting the birthdays of his friends, and he often failed to remember to take the medication for hypertension, a condition he was diagnosed of decades ago. Michael knows the importance of this medication and feels frustrated that Maria has to remind him all the time.

Maria encourages her husband to go for a walk in the central park of the city while she is at work but Michael does not want to do that. He used to enjoy the busy characteristics of the big city and feel excited about the crowded metro during the early mornings or the chaos in the main cross-roads. Now Michael is afraid of leaving the house alone. He feels disturbed in overcrowded places and, to find a calmer place, Michael has to go to the outskirts of the city. But in general he prefers to stay at home. Maria suspects that Michael spends most of the time on the couch, contrarily to what is recommended by the cardiologist, and she would like to be able to see how active her husband was during the day. She feels he needs a push to continue an active life.

To stimulate Michael's memory, Maria proposes playing games very often but Michael is not enthusiastic about the idea. She tried everything from Sudoku to Tic-tac-toe or word-games in the newspaper. In fact Michael shows a lack of enthusiasm in almost everything his wife proposes. Michael knows that Maria is trying to help him in all possible ways but he does not feel capable to cooperate. He feels frustrated and closes himself in his own world.

3.2.2.2 Persona with age-related physical impairment "Simone"

Figure 4 Persona 'Simone'

Simone is a 72 year old woman with reduced mobility due to balance problems. Simone is afraid of falling and prefers to support herself while walking by holding the wall, the furniture or handles placed specifically for this purpose by her son John. Her fear of falling also made her prefer to walk using her walking stick whenever possible. She doesn't go outside without it. Simone was never a very active person and the mobility impairment works as an excuse to spend her days sitting on the couch watching TV, ending up isolated in her home environment. As a result of her lack of self-initiative for almost any activity, Simone ends up eating much more than necessary. John is worried about the continuous weight gain of his mother, especially because she should follow a healthy diet due to her diagnosed hypertension and high level cholesterol, two common conditions at her age. Every time they talk on the phone, John asks if Simone cooked and what she ate during the day. Sometimes Simone avoids answering and John gets worried about her health. John believes his mother is totally capable of living independently at the cognitive level, but if her physical condition does not improve he will suggest a home care facility.

Due to her mobility issues, Simone was advised to do physiotherapy twice a week. However, to reach the clinic, Simone has to take two buses and she does not feel confident to do that by herself anymore. It is not possible for John to join his mother every week and Simone withdrew after the first month. Simone would benefit from a system that would allow her to do the exercises at home.

Simone's social life was encumbered by the mobility limitations. Simone used to go to the market every Saturday morning with her old friend Joanna, enjoying the time spent with the two of them. But now she feels ashamed of her walking pace and she tends to find excuses to skip the meetings week after week.

3.2.3 Personas with Mild Dementia

Jane gradually lost trust in her memory and consequently also her motivation to walk. She avoids social interaction as she has difficulties following discussions and she feels depressed.

Philip had a stroke, which impacted his cognitive abilities. Since then, he became fearful and unwilling to socialize. He gave up on his demanding task of being a cashier and takes walks alone, with the risk that he will be lost.

3.2.3.1 Persona with Mild Dementia "Jane"

Figure 5 Persona 'Jane'

Jane is a 74 year-old-woman who has been living alone since her husband passed away ten years ago. Her only child Sarah lives 200 km away and tries to visit her mother once a month. In recent years, Jane has noticed some deficits in her memory capacity. In the beginning she would forget small routine appointments such as the weekly visit to the butcher. More recently she began losing track of things around the house. The pots appeared in the wrong place, and she couldn't find her favorite earrings.

Jane experiences some sleeping problems related to the work shifts she used to do during her nursery job in the local hospital. Jane was accustomed to uncommon sleep-wake patterns but after a point she would wake up during the night to go to the toilet and suddenly forgot what she was doing.

Jane used to be a very active outdoor person. Now she does not feel able to do much physical activity but she would never give up on her daily walks through the neighborhood. These walks made her feel calm. It was when she found herself lost in her own neighborhood that she felt the urge to visit her General Practitioner. After several tests Jane was diagnosed with Mild Dementia. Jane's GP set a plan including both physical and cognitive stimulation. Jane was advised to keep active by doing her daily walks and keep leisure activities as reading or playing games with friends. The GP also wants to arrange more frequent meetings with Jane but he is very restricted in his available time. Jane is advised to keep a journal to write what she does during the day, what she cooked, etc. Jane finds it funny because it reminds her of her diaries during childhood.

Recently Jane tried to go for a walk a few times but was too afraid of getting lost. She ended up walking around her house and going back home after a couple of minutes. She knows this is not enough to elevate her heart rate but cannot fight the fear. Jane also thought of doing some exercises at home but she does not know what to do. And she cannot find the motivation to do it.

One of Jane's weekly routines used to be the reading club. These meetings encouraged Jane to read and also supported the contact with old time friends. However, lately Jane has found it more difficult to follow the flow of the discussions. She was afraid that other people would notice her difficulties and progressively withdrew from the meetings. Actually, Jane started to avoid every kind of social contact. And the more social interaction Jane avoids the lonelier and depressed she feels.

After the diagnosis, Sarah calls more often. She is worried about the fact of her mother living alone without regular assistance. She wishes she could have an insight on Jane's daily routine and be more present in her life, but she can't visit more often due to the distance separating the cities.

3.2.3.2 Persona with Mild Dementia "Phillip"

Figure 6 Persona 'Phillip'

Phillip is a grocery store owner who lives with his younger sister Theresa in a rural area. Two years ago, at age 64, during a normal working day, Phillip suffered a stroke. A few months after the incident, Phillip was feeling physically recovered. Theresa suspected however that his cognitive capacity had been affected. Phillip frequently seemed disoriented and his mental calculations as cashier were not as fast as they used to be. Theresa also noticed occasional changes in the mood of her brother. Phillip was always a relaxed person but suddenly started showing irritability at minor things and even some aggressiveness. As he advanced in age, Philip's eye site got worse. After the stroke, he noticed that it is very difficult for him to recognize objects further than 5 meters away.

The serious concerns started one day when Theresa arrived home from work and found the stove on and Phillip relaxed in the living room watching TV. When asked about the incident, Phillip answered that he did not have any memory of turning the gas on. At this moment, Theresa started fearing for her brother's safety. After this episode Theresa registered all events of forgetfulness on her notebook. When she thought she had collected a substantial number of events, Theresa confronted Phillip and, although reluctant, he was convinced to visit the General Practitioner. Phillip answered a couple of standardized questionnaires and talked to the physician about the events of the last months. Theresa's notebook played a crucial role. Finally Phillip and Theresa got the diagnosis that Phillip suffers from Mild Dementia.

After the diagnosis Theresa started searching for information on how to help her brother. Books, Internet, special issues of magazines. It was in the community group for caregivers of persons diagnosed with Mild Dementia that she found the biggest support. She found out that Phillip should keep performing activities that challenge him both physically and mentally. This could be difficult, considering that Phillip feels fearful and suspicious about almost everything and everyone.

Phillip's cognitive decline is clear to everyone. He used to deal with a lot of people during the day in this grocery store but lately he often asks Theresa to replace him at the cashier, preferring other back-up tasks such as stock checking or replacement. It became hard for Phillip to follow a conversation. He often has troubles finding the words he wants to say and keeping track of the conversations. For that reason, Phillip also withdrew from the weekly hiking meetings with some of his oldest friends. Instead of meeting his friends, Phillip started going outside alone. This is a big concern for Theresa considering that for three times Phillip got disoriented and could not find his way home, even when doing well-known paths. He was only able to get back home because an acquaintance was passing by. Against Theresa's advice, Phillip does not give up on his walks in the surroundings.

3.2.4 Personas with COPD

Petra has dyspnoea due to COPD and she is also often fatigued and overweight. Stress deteriorates her condition and physiotherapy works only as long as she is committed to a program, as she is not engaged to continue the exercises on her own. Her social life suffers.

Bob has severe dyspnoea due to COPD and can no longer work as his working environment makes his symptoms worse. He is gradually deprived by his social-life and his confidence. The rehabilitation program worked well for him, but he is not motivated to continue the training on his own.

3.2.4.1 COPD persona “Petra”

Figure 7 Persona 'Petra'

Petra is a 43 year old woman, diagnosed with COPD GOLD Stage II. She has a part-time office job, preventing her from being physically active during the day. This has caused her obesity as well as her bad physical condition. She has a husband and 2 daughters. Her oldest daughter Michelle is a student at a university in the city, 150 kilometers from her house, and her youngest daughter Alice studies in the local high school. Petra is suffering from moderate dyspnoea (short lasting and with medium recurring frequency), but she became more and more fatigued due to progressive gain in weight.

Alice, her youngest daughter, usually invites her friends to her house and sometimes Petra feels that her home environment suddenly becomes too crowded causing Petra’s stress. In these situations, Petra usually prefers to interact as little as possible with the teenagers, as she is afraid they will not understand her condition. As her stress level rises, Petra risks manifesting some forms of dyspnoea. She usually sneaks out on the balcony and smokes. She feels less stressed after a smoke break. Petra and her husband are long time smokers; they tried to stop on multiple occasions, but never managed to succeed.

Once per month, the oldest daughter, Michelle, comes to visit and it is a family tradition for all members to spend the evening together. It is important for Petra to be socially integrated and to maintain a healthy and active social life involving group activities. She justifies her lack of physical activity by not having enough time between her job and her taking care of the family. In reality, her social life revolves around her daughters and she makes little time for meeting friends and not-immediate family members.

One year has passed since Petra’s last medical visit targeting her COPD. She decides to see a lung physician. Her evaluation showed that her COPD has worsened. Petra is advised to increase her daily medicine intake and is reminded by the doctor that it is critical to undertake a physical activity program. Due to her obesity, she also suffers from heart and circulatory problems and high cholesterol. This also contributes to her fatigue in her daily life physical activity (like walking to work, standing up for long periods of time, climbing stairs). She accepts to attend the physical activity program and starts with 2 months of guided exercises by a physiotherapist at the physical rehabilitation center in her town. After the 2 months, Petra starts feeling better and she gets a higher confidence in herself. Her physiotherapist makes a daily exercise plan that Petra is supposed to follow at

home. She follows the plan for 2 months, but she slowly decreases the amount of exercises she performs, gradually loses her motivation and reverts to her old habits of physical inactivity.

3.2.4.2 COPD Persona "Bob"

Figure 8 Persona 'Bob'

Bob is a 65 year old male and lives in the rural area of Enschede, the Netherlands. He was diagnosed with COPD almost ten years ago, and despite the fact he quit smoking, his disease is getting worse. Bob is a furniture maker, but due to his disease he stopped working. His dyspnoea became severe, he became more and more fatigued, became progressively underweight, was coughing a lot and he felt increasingly limited in his physical capabilities – the intense scent and dusty work environment made him feel even worse. He has difficulties in hearing and this makes communication extra difficult for him. The consequence is that his self-confidence substantially decreased. Moreover, he felt uncomfortable around his colleagues, who did not really understand his problems. He decided to stop working; he is at home a lot. He lives alone and one year ago, he decided to get a dog. Bob really enjoys the fresh air and walking with the dog in the forest.

During a visit to his general practitioner he was referred to the lung physician at the local hospital, since he was now in GOLD stage III, and from now on the lung physician would monitor him. He visits the hospital twice a year: once for an appointment with the lung physician and once with the nurse practitioner. They tell him that it is very important to stay active and strong: a lack of movement causes his physical condition to decrease rapidly, increasing his symptoms, and a vicious cycle will ensue. When his body is in a better condition and shape, Bob is able to do more with the same lung function. Therefore, Bob has to participate in a COPD physiotherapy programme, but he rarely goes since he finds it too far from his house, and he finds it boring to do exercises there.

But Bob's situation is getting worse. This year Bob was even admitted to the hospital twice, due to exacerbations. Bob also lost 2 kilos of weight. The doctor again explains to Bob that exercise is really important to break the vicious circle and that nutrition provides his energy to breathe.

The dyspnoea remains very severe and Bob is afraid to experience extreme dyspnoea. He rarely walks the dog anymore. He likes to watch television, especially soccer and avoids physical activities and situations that might cause an attack of dyspnoea again. His grandchildren say they sent him lots of emails, but he never reads them, because he doesn't know how this modern technology works.

His lack of movement causes his physical condition to decreases rapidly and he has trouble sleeping, caused by the low oxygen levels in his blood and the coughing. He also feels depressed, since he is less socially active. Therefore, Bob participated in the rehabilitation program for 3 months. Within these 3 months Bob trained with other COPD patients which he enjoyed and he improved his physical condition. However, 2 months later, he reclined to his original low activity levels, since he was not motivated to be this active by himself.

3.3 State of the Art in industry and research

This section includes our effort to summarize relevant research projects and commercial services. We focused on projects targeting similar target groups, offering similar services and/or employing technologies we are interested in. Like the future eWALL system, most of the projects we analysed offer a rich collection of services for their target users focused in their overall well-being but also in their specific disease symptoms. For this reason and since this deliverable is the first after the DoW to describe the eWALL system, we made the choice to focus our research on application and service concepts. This exploration will allow us to identify successful practices and ideas applied in other projects as well as drawbacks and space for innovation. In later stages, when eWALL concept will be defined in greater detail and some crucial design decisions will be taken, we also plan to examine the academic research to draw best practices in specific interaction design issues that arise.

The results are summarized in Table 2. Each row represents a project that is described according to the following attributes:

- **Project**: the project name and the company or the funding framework behind it
- **Media/links**: links to website, videos, articles that demonstrate the concept
- **End-users**: description of the target primary and secondary users
- **Services/Use cases**: the most important use cases addressed
- **Technology**: devices, sensors, algorithms utilized
- **Interoperability**: compliance with standards
- **Status**: project status/roadmap, exploitation and its current use

The projects are further classified in three categories:

- **Cognitive health projects**
- **Physical health projects (with emphasis on COPD)**
- **Other health issues or general support**

This classification matches the broader definition of the three primary user groups we will focus on: projects on cognitive health, physical health and other health issues or general support. However, it should be noted that the classification borders between or inside the categories are not always clear. Moreover, specifically the cognitive health projects deal with a gradient of cognitive health phases from patients who are cognitively healthy but care for prevention; patients with diagnosed MCI or memory loss; up to patients with dementia. This explains the variety of functionalities we come across in these projects.

3.3.1 Overview of related projects and systems

Table 2: Overview of related projects and systems

Project Project name and company or funding framework	**Media/links** Links to website, videos, demonstrations, articles, …	**End-users** Description of the target primary and secondary users.	**Services/Use cases** The most important use cases addressed	**Technology** Devices, sensors, algorithms used	**Interoperability** Compliance with standards	**Status** Project status/roadmap Exploitation, current users
COGNITIVE HEALTH						
Mobiserv – EU FP7 Project	Website: http://www.mobiserv.info/ Video: http://www.youtube.com/watch?v=6DFJwnwzhPs	• Older adults with memory or mobility problems • Informal caregivers • Medical experts	• Robot monitors user's behaviour • Reminders for eating, medication and socializing. • Caregivers customize Robot's reminders. • Communication with caregivers and alerts for emergencies	• Robot • Smart textiles for vital signs monitoring • Optical recognition of eating, drinking and emotion • Sensors inside home	• Not known	• Ended 2013 • Running extensive evaluation sessions in the UK and in The Netherlands.
Long Lasting Memories (EU FP7)	http://www.longlastingmemories.eu	• Older adults, cognitively healthy or with mild cognitive decline.	• Cognitive exercises • Physical exercises • ADL monitoring	• Wii peripheral devices for physical training • BrainFitness, Gradior software • eHome monitoring system	• interoperable components used (Wii devices, BrainFitness software and eHome system)	• Evaluation took place in Austria, France, Greece, Spain, and the Cyprus for a period of 15 months
Dakim Brain-Fitness (Dakim)	Website: http://www.dakim.com/	• Older adults (60+) with memory problems	• Cognitive training software	• PC or touch-screen system for non-computer users	• Not known.	• Clinically tested with 36 participants for 6 months • commercial product
Lumosity and the Human Cognition project -	Website: http://www.lumosity.com Article on trials: http://www.lumosity.com/press/releases/lumosity-training-improves-attention-in-older-adults	• Everyone who wants to train her cognitive abilities.	• Cognitive training software	• Pc, tablet or smartphone	• Lumosity offers free access to data for research purposes and for the validation of its platform.	• Commercial product • Lumosity has been shown to improve cognitive performance in older adults with MCI

ISISEMD EU CIP ICT-PSP project (HP,AAL)	Website: Demo Videos: http://www.youtube.com/user/ISISEMD#p/u http://isisemd.blogspot.it/2011/03/dissemination-activities-on-region-of.html Links page: http://www.isisemd.eu/redir.asp?p1=41654&p2=3145	• Older adults with MCI • Formal caregivers • Informal caregivers, such as relatives	• Reminders for ADL and medication • home environment monitoring (Doors, cookers, lights, bed) • Fall detection • Outdoors geo localization • Memory training • Video communication • Emergency button • web-portal for caregivers for reminders configuration and remote monitoring	• Web-based platform • *Server side:* J2ee-based web portal and a set of services • *Client side:* • large touchscreen PC • domotic sensors • wearable fall detection and GPS device	• Modular extensible platform based on web services • Vertical services communicate over http messages	• Ended 2011 • Has been deployed to real end users' homes (about 80 users) in four Countries (Denmark, Finland, Greece, Ireland) • The platform is still up and running for a small set of end users
Dem@Care	Website: http://www.demcare.eu/ Video (quite technical): http://www.youtube.com/watch?v=jbZP4IjGnEo	• Older adults with MCI • Informal caregivers • MCI clinicians	• ADL recognition • Automatic assessment of cognitive situation (early Alzheimer, MCI, healthy) from short vocal exercises • Personalized adaptive feedback • Lifestyle monitoring: sleep, exercise, sociability, mood, eating • intelligent decision support	Wearable sensors: • Physiological: WIMU, DTI – 2 • Life-logging: SenseCam • Audio-visual: wearable mic, GoPro camera Ambient sensors: • Gear 4 Sleep Clock • Static cameras: Sony Kinect, ASUS RGB-D • Benchmark ADL datasets	• Not known	• Running until 2015
CareBOX (Dutch, SBIR)	Website: http://inertia-technology.com/carebox-2 Video: http://www.youtube.com/watch?v=0pKDAoysB5U	• Older adults with MCI • Informal caregivers.	• In-home monitoring • Feedback to the Informal caregivers (family).	• ADL monitoring: Infrared, movement and pressure sensors • Smartphone application for informal caregivers for remote monitoring.	• ZigBee compliant sensors	• Project ended 2013, new phase started as follow up. • Commercial exploitation under research.
ROSETTA-Guidance and Awareness Services	Website: www.aal-rosetta.eu Video (Password: rosetta):	• Persons with MCI- and/or Parkinson's disease • Care providers (and	• Daynavigator: calendar for memory support and ADL reminders.	• Touch screen • Smartphone • Calls to the stable phone	• Not known	• Ended 2012

for Independent Living (AAL Joint Programme)	http://vimeo.com/44715367	mobile care team) • Informal caregivers	• Early Detection System (EDS): detecting lifestyle changes • Unattended Autonomous Surveillance (e.g. fall detection) • Carers have access to this data, even camera footage	• Movement detection sensors • Camera (living room) • Speaker		
SOCIABLE (EU FP7)	http://www.cognitivetraining.eu/	• Older adults with MCI or healthy • Mild Alzheimer patients	• cognitive training software	• portable surface or tablet PC providing multi-touch functionalities	• Not known.	• Finished • Evaluation with 117 older adults
HERMES EU FP7 project	Website: http://www.fp7-hermes.eu/ Demo videos: http://www.fp7-hermes.eu/video/	• Older adults with memory problems • Informal & formal caregivers	• In and out-of-home reminders • Cognitive games referring to user's life • Facilitation of episodic memory • Conversation support • Mobility support	• Small multi-touch screens • Cameras & microphones • A/V detection, Low-level Information Fusion, Context Modelling • Sensing infrastructure	• Open standards for video encoding	• Ended 2011
JDOME BikeAround	http://jdome.com/healthcare/	• Older adults with MCI	• Virtual bike tours in any place • Physical exercise	• Google Street View • Bike • the sensors in a Samsung Galaxy Tab to steer the bike	• Google Street View	• Commercial product • Initial testing as shown positive results
PHYSICAL HEALTH (WITH A FOCUS IN COPD)						
COPD app &project – SINTEF, NO financed by the Norwegian Research Council	SINTEF project: http://www.sintef.no/home/Technology-and-Society/Projects/Projects-SINTEF-TS-2011/Care-and-treatment-of-persons-with-COPD-the-impact-of-gender-socio-economic-status-and-geography/ SINTEF app: http://www.sciencedaily.	• Older adults with COPD • A hospital • Possibly municipalities	User can: • Report daily to a certain hospital • Call hospital • Learn about COPD • SINTEF is studying data from thousands of COPD patients in NO in order to understand the impact of socio-economic	• Tablet • Communication with care centre • Data from thousands of patients including age, gender, severity, diagnosis, type of hospital treatment, socio-economic background, use of prescribed medicine and hospital characteristics.	• Not known	• 5 patients are currently testing the app

	com/releases/2013/09/130913085704.htm		status, hospital treatment, geography to the progress of COPD.			
IS-ACTIVE (EU, AAL)	Website: http://www.is-active.eu/ Video: http://www.youtube.com/watch?v=K9ILgYXXEvw	• COPD Patients in GOLD stages II and III. • Caregivers	• Physical Activity monitoring and coaching in everyday life. • Virtual community	• Inertial activity sensors • Intelligent coaching system on smartphone. • Gaming environment with sensors	• ZigBee compliant sensors	• Ended 2013. • Evaluations ongoing. • Marketing and business plans being researched.
COMMONWELL	http://commonwell.eu	• COPD patients • caregivers	• Telecare integration • Social alarms & telecare system Telehealth monitoring and alerting system	• MyMedic • SHOKO call-centre system • Care2U • HIS	• SOAP 1.2 binding for WSDL 2.0 as is described by W3C	• finished
NEXES	http://www.nexeshealth.eu/	• Older adults with chronic conditions: mainly COPD, CHF and diabetes	• Home-based wellness and exercise-training • Home hospitalization and early discharge • Remote support to primary care for diagnosis and therapy	• ICT platform (ELIN) providing Health Information Exchange (HIE) in Norway • a Health Information Sharing (HI-Sharing) approach, Linkcare® platform	• ELIN, Linkcare®	• Evaluated with hundreds of participants • Finished in 2012
mCOPD lung function diagnosis and exercise app	Publication: http://www.cs.ucla.edu/~mingchuh/docs/Conferences/huang-petra2013a.pdf	• Older adults with COPD	• Daily lung function diagnosis • Exergames for breathing	• Computational modelling to estimate lung function through sound signal	• Smartphone sensors	• On research
SCRIPT EU FP7 project (IRCCS, RRD)	Website: http://scriptproject.eu/	• Chronic stroke patients • Therapists and caregivers	• Wrist and hand rehabilitation • Rehabilitative games of increasing difficulty • Remote monitoring of therapy sessions and recovery gain • Assessment of clinical outcomes and patients satisfaction	• Touch screen technologies for human-device interface • Position sensors • a sensorized robotic active and passive exoskeleton • Active and passive robotics • Web-based therapy control	• Not known	• Project ends in November 2014 • Finalizing large scale demonstration of passive device • Now running active device prototyping

Home Sweet Home (EU FP7)	http://www.homesweethome-project.be/	• Elderly people with declining autonomy	• Monitoring weight, blood pressure, etc. • Cognitive games	• Portal • HIS Mambo 2.5 • Smart Home • Vital monitors • Computer calendar	• Not known	• running
OTHER HEALTH ISSUES OR GENERAL SUPPORT						
VieDome – TKH Care Solutions, NL (developed by Mextal)	Website: http://www.tkhcaresolutions.com/viedome.html Presentation: http://de.slideshare.net/mwdgielen/viedome-presentation-eu-11778981	• Older adults with a variety of health conditions • Care organizations • Housing corporations	• Video communication with family or affiliated parties • Intruder alarm • Camera supervision • Video intercom • Door opening with remote control • In-home monitoring	• Own pc, touch pc, home unit or NetTV • Smoke detection • Wandering detection • Acoustic surveillance • Burglar alarm	• Modular, services depend on care org & user • Open standards such ESPA, IP, Mpeg4, H.264, RS232, RS485, …	• Approx. 500 clients • The largest project for long-distance care in the NL • Care centre in Veldhoven provides services via VieDome
AGNES EU AAL project & Peace of Mind (developed by Modern Families)	Website: http://agnes-aal.eu/site/ Demo videos: http://agnes-aal.eu/site/index.php?option=com_content&view=article&id=12&Itemid=20	• Older adults • Informal caregivers	• In-home monitoring • Recognition of user's state • Social network for older adults	• Laptops with their camera and microphones • Sensors • Smartphone sensors • Perceptual algorithms for mood and gesture recognition	• XML messaging between all components ensured interoperability	• Ended 2012, still in the news • Commercial: "Peace of Mind" offers an affordable service for older users and carers, using existing technology
Just Checking (Just Checking Ltd)	Website incl. Video: http://www.justchecking.co.uk/ Video II: http://www.justchecking.co.uk/families/testimonials/	• Older adults living at home • Relatives, friends who are physically absent	• In-home monitoring • Older adult does not interact with the system • family receives alerts ("visitor late", "door left open")	• 5 sensors in every room • Carers: PC/ Smartphone/ Tablet to access the web platform • Older adults: no input to the system.	• Not known	• Low-cost commercial service
I-DONT-FALL, funded by CIP, EU	http://www.idontfall.eu/	• Seniors - fall detection and prevention management • Cognitive training software	• fall detection • call/contact center integration • balance motor • alarming	• Doc@HOME (gateway of the Platform) • FALLWATCH • HEALTHWATCH • i-WALKER • Wearable IMU	• Not known	• running
Care@Home (EU, AAL)	Website: http://www.careathome-project.eu/	• Healthy older adults	• In-home monitoring Video communication	• Interactive multimedia SmartTV. • Wireless and fixed	• Develops its own standard for Smart Home integration.	• Running project (till November 2014).

	Video: http://www.youtube.com/watch?v=qCNP74QEcpY			sensors.		
DREAMING	www.dreaming-project.org	• Healthy older adults and safety monitoring and assistance in their homes	• Alarm & alerts • In-home monitoring	• Health and environmental sensors, TV based videoconferencing	• Not known	• Finished
CAALYX-MV	http://www.caalyx-mv.eu/	• Older adults over 65 years old • Their family • Caregivers	• Social and health in-home monitoring • ADL support	• Set top box or media center • TV and (at least) a camera • Wearable Light Device (WDL)	• Not known	• Running
inCASA	http://www.incasa-project.eu/	• Over 65 years old, living at home alone and with a sufficient level of autonomy and self-care ability	• In-home monitoring • Health conditions monitoring • Continuity of care • Integration of home automation	• Home Sensor Network (HSN) and Domotic Devices • Human Monitoring Sensors (HMS) • Base Station connected to HSN and HMS to collect and send data • Smart Personal Platform (SPP): behaviour application for data analysis	• Not known	• Finished
Wireless ECG monitoring system	http://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=5172426&queryText%3Dwireless+ecg+simunic	• People with ECG disorders who want to have unlimited motion	• Monitoring of ECG signals wirelessly in homes, hospitals, ambulances etc.	• ECG sensors, Bluetooth communication devices, personal computer	• Bluetooth	• Ended 2009
STANDARDIZATION						
universAAL EU FP7 IP project (consolidated the work of EU FP projects: PERSONA, MPOWER,	Website: http://universaal.org/ SW Release of platform and tools (free and publicly available): http://universaal.org/index.php/en/download universAAL Architecture Handbook and other technical docs: http://universaal.org/inde	• Primary: SW Architects and Developers (AAL application and platform developers) • Secondary: End users – Assisted Persons	• A platform for creating commercial grade AAL services (AAL showroom) • platform for creating a market place for AAL services (uStore) • Platform for supporting developers	• An open and scalable technological platform that facilitates the development of AAL services • OSGi and ontologies for semantic operability • Development tools integrated into Eclipse	• Supports Continua HA devices • Several aspects are currently under standardization (UI Framework in IEC TC100 and IHE Document Encryption (DEN) profile specification)	• Project ends in January 2014 • Platform and tools have been released as FREE OPEN SOURCE

SOPRANO, OASIS, AMIGO and GENESYS)	x.php/en/press-room/technical-papers		and users in AAL innovation (Devel-opers' depot)	(AAL Studio) • Support for protocols such: KNX, ZigBee, UPnP, r-OSGi		

3.3.2 State of the Art Analysis

Once we accumulated a substantial number of relevant projects, we attempted to understand their services and classify them in a meaningful way. We tried out a number of taxonomies which didn't work because the services were highly correlated and connected with each other. For example, in the DoW, applications are classified in the following areas: (a) risk management and home safety, (b) eHealth and (c) lifestyle management. Even if this categorization makes sense to the reader, it might not be sufficient when we examine the system from a technical perspective, because in many cases eHealth and lifestyle management use the same hardware (e.g. motion sensing) and software (e.g. reasoning algorithms) to induce conclusions about the health and the lifestyle of a user. Therefore, we came up with the following taxonomy which we think addresses better the needs of our analysis.

All the assistive projects included in Table 2 address a broad audience; from cognitively healthy adults to older people with diagnosed MCI. Thus, they provide a wide range of functionalities, most of which have a common core, the **monitoring of the user and her home environment**. **In-home monitoring** refers to the process of acquiring sensor and audio-visual data focused on the user and her home environment and applying machine learning, fuzzy logic and other artificial intelligence algorithms to make sense out of it. In-home monitoring primarily aims to give insights into user's life; particularly her behaviour and performance of ADL activities, her adherence to coaching instructions and the condition of her home, in terms of safety. Moreover, data collected over longer periods of time can result in identifying patterns and warning signs in the user's life.

The insights gathered by monitoring are often utilized to provide **feedback to the user herself and communication with her family and/or her caregivers.** The content of the communicated message can be ADL support reminders, home automation notifications, alerts for dangerous situations or progress reports.

In-home monitoring and in particular motion sensing is used for **physical training**, often in an exergaming context; the user moves the avatar on the screen with her own body in a way that reminds common fitness routines. Physical training is an essential component of systems which offer services for users with physical impairments, such as COPD patients.

Likewise, **cognitive training** is incorporated in systems targeting people with cognitive impairments, although it can be used also for prevention of cognitive decline. In our research, we found independent services offering cognitive training as well as complex systems which provide a set of functionalities to their users including cognitive exercises.

Among the most prominent services offered by assisted living systems are applications regarding h**ome automation** which include remote control of windows, doors, cameras and other devices or control with badges.

The following subsections provide best practices and examples on the above-mentioned components drawn by the analysed projects (see Table 2).

3.3.2.1 In-home monitoring approaches

In this section, examples of monitoring of the user's activity and home environment from the analysed projects (Table 2) will be presented with the goal to gather insights on different implementations of monitoring and to identify pioneering practices in other projects.

Long Lasting Memories project has the LLM Independent Living Component (ILC), based on the eHome system, which consists of distributed sensors wirelessly connected to an embedded system and a local UI unit. The system does not employ cameras or microphones and does not transfer data outside user's home without her consent. Over time, it learns user's patterns of behaviour and detects changes to it. Moreover, it operates an intelligent power outlet for TV and radio. When a dangerous situation has been detected (e.g. a fall), the eHome system automatically notifies via telephone a chain of secondary users, from family members to an emergency call centre. The eHome system was developed within an Austrian consortium (CEIT RALTEC, University of Technology Vienna, Treventus GmbH and Kapsch CarrierCom AG).

In **Mobiserv**, monitoring is taking place via a Smart Home Automation Unit, a Wearable Health Supporting Unit and an Optical Recognition Unit. The Smart Home Automation Unit offers secure communication mechanisms and an interface for interacting with third party Smart Home infrastructure. The Wearable Health Supporting includes smart shirts, bands and pyjamas for continuous health monitoring where vital signs (ECG and respiration), activity (3-axis acceleration) and physiological extracted parameters are acquired. The physiological extracted parameters extracted are heart rate (HR), breathing rate (BR) and activity classification (lying, standing, walking, running and others).The Optical Recognition Unit performs visual-based eating and drinking recognition as well as emotion recognition which assesses user's facial expressions as either positive or negative. In this Unit, the MOBISERV-AIIA Eating and Drinking Activity Recognition Database has been developed to facilitate research in nutrition support (activity and object recognition, person identification, etc.).

Dem@Care employs wearable sensors (the physiological WIMU and DTI-2, the life-logging sensor SenseCam, a GoPro camera and a wearable microphone) ambient sensors (Gear4Sleep Clock and static cameras Sony Kinect and Asus RGB-D). The captured low-level information is integrated in a semantic model that provides high-level information on the behaviour and state of the person with Dementia (the target user). Additionally, the monitoring aims to gather insights on the overall health of the user (sleep quality, anxiety, etc.), her day routine and to detect disorders associated with dementia and dangerous situations (e.g. fall). Moreover, speech processing is used for diagnosis of the cognitive state of the user in short tests for memory and vocal ability under cognitive load. Within the frames of the project, a dataset for ADL activity recognition was developed with participants over 65 years old in a realistic room setup.

In **Rosetta**, the system monitors in which room the user is located and if lack of motion or unusual motion (e.g. crawling) is detected, sends an alert to the care centre. The monitoring system is made up mainly of motion sensors, which detect movement and a camera placed in the living room. When the person is detected to be in the living room for long time without moving, a picture is taken and the system decides whether the user is in dangerous situation (e.g. is she lying on the floor or resting on the couch?). The system tracks the pattern of the user visiting the rooms for the first two weeks,

thus gathering insights on the routine of the user with the goal to detect early potential changes in it. An example of how the monitoring is used to determine the condition of the target users the distinction between the use cases ‘getting out of bed aimlessly’ versus ‘getting out of bed with a specific goal’. This distinction is useful for the caregivers, as it is known that getting out of bed aimlessly indicates an intermediate stage of dementia.

Just Checking employs wireless sensors which are triggered by the movement of the target user inside the home. The data is sent by the controller via the mobile phone network to the Just Checking server. No additional gear is required and the system remains invisible for the primary user. The family and the caregivers can log in the Just Checking website to view charts of the activities the target user performed.

AGNES employs near-field user monitoring within home, feedback devices, and a social network dedicated to elderly users to facilitate communication and combat isolation. The communication is aided by the automatic recognition of gestures and user mood. When the user is away from the computer, there are 2 feedback devices (Ambient Display and Tangible Object) used for two-way communication between him/her and the social network. The Ambient Display is composed of coloured LEDs and can inform the user of information coming from the social network. The Tangible Object is a hand-held device that can send messages to the social network or cancel alarms. Additionally, when the user is next to the computer, a webcam can be used to detect mood (to update the user’s status on the social network) and gestures (to provide simple control of the social network)

3.3.2.2 Feedback to the primary user & communication to secondary users

In **Just Checking**, a commercial application, the primary user does not interact with the system at all; practically, the system is invisible for him. The informal caregivers, which are the only actors interacting with the system, receive alerts on visitors, exit of the home, open doors and other dangerous situations (see Figure 9). Moreover, they receive reports that show the activity of the user inside her home. The basic premise is that the data from user’s movement from room to room, the time she spends in each room as well as the alerts, enable the caregiver to have greater insight into user’s health state and mood and thus, it facilitates a feeling of security and control to both.

CAALYX-MV enables the primary user to establish live audio-visual connections with family and formal caregivers. A report which consists of clinical history, treatments and medication, specific questionnaires and camera footage is available for the caregivers. The primary user receives feedback and various types of reminders.

Care@Home allows family members to set reminders and leave notes to the primary user and receive alerts in case of a dangerous situation or emergency. The formal caregivers are given access to key measurements of primary user’s health and thus, they can track his progress.

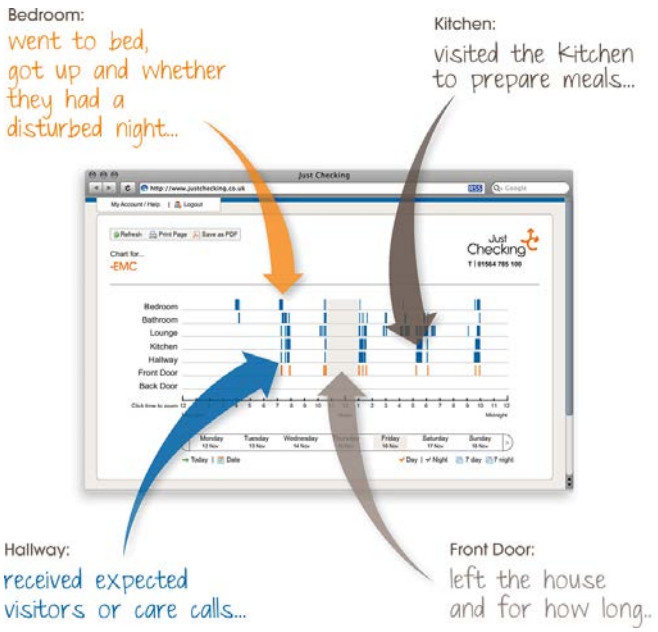

Figure 9 In the service 'Just Checking', family members can check the activity inside the home of their relative older adult which implies certain everyday chores.

3.3.2.3 Physical training approaches

A recent approach to physical training is called exergaming. It is a form of videogame in which the user's body is actively engaged to interact with the objects presented on the screen. Some popular exergaming platforms are Nintendo Wii Fit, DDRs (Dance Dance Revolution) like Dance Town (focuses on the elderly population), ConnectAndPlay and Positive Gaming. In particular, Nintendo Wii has been widely used in rehabilitation therapy, while the Wii Balance Board and the dance mat peripheral devices were proven valuable for the assessment and the training of balance [1] [2], thus reducing the risk of fall.

In **Long Lasting Memories,** the physical training of the primary users includes aspects of exergaming as well as fitness equipment (bikes, treadmills, etc.). For the **Long Lasting Memories,** a new exergaming platform, called FitForAll, was developed (see Figure 11). The platform utilizes Wii peripheral devices and allows the therapists to collect statistics on users' performance and physical condition. The FitForAll games have many different levels of difficulty and have been designed to meet capabilities and limitations of older adults.

In **mCOPD**, an android app for COPD patients, users use their smartphone not only to get a diagnosis for their lung function, but also to play a breathing exergame. In this game, user controls the movement of a ball by blowing air in a specific suggested way (pursed-lip breathing or diaphragmatic breathing) to the microphone.

An interesting example of the combination of physical exercise with cognitive stimuli is the project **jDome BikeAround. The project** aims to provide physical training for older adults with MCI. It comprises of a simple static bike with a curved projection display in front and it utilizes the graphics from Google Street View (see Figure 10). The user selects the location of her preference and can virtually bike to any place available on the map. The system can be also potentially used to

revive user's memory of a place of particular importance for the user. The system has been evaluated with older users in a dementia home with positive results.

In the **IS-ACTIVE** project, physical training is provided on two levels. First, patients are given a simple accelerometer-based activity sensing for tracking daily activity. A connected smartphone application provides feedback to stimulate a healthy amount of daily activity while staying within the limits imposed by the disease (COPD). The application provides personalized feedback by automatically learning the opportune moment for providing feedback. The second approach to physical training is through gaming. The patient can perform exercises (weight lifting is used as an example) using sensor enabled exercise equipment. The movements are registered and used to move a submarine through a 3D underwater environment with the objective of catching air bubbles. The sensor equipped dumbbell measures current levels of oxygen saturation to provide safety.

The **SCRIPT** project develops a system which is built for stroke patients with hand impairments, so they can exercise at home with help of a robot hand. This robot hand provides active support during exercise. The exercises are performed on a computer in the form of games, which should make exercising less boring. The robot hand serves as an input device for the games. The care provider can monitor the patients and prescribe exercise plans remotely.

Figure 10 jDome

Figure 11 Long Lasting Memories

3.3.2.4 Cognitive training approaches

Dakim Brain Fitness program focuses on six cognitive domains: long-term memory, short-term memory, critical thinking, visuospatial orientation, computation, and language (see Figure 13). For each domain, a number of games are developed which utilize music, humour, graphics and videos to engage the users and motivate them to return to the training. The program adjusts according to participant's performance and offers different gaming levels that cover the spectrum of healthy cognitive function to mild-to-moderate cognitive impairment.

Lumosity is a web-based application designed to stimulate five cognitive domains: memory, attention, speed, flexibility and problem solving (see Figure 12). The participant customizes the training program according to the preferred domains and starts the 15-minute training a day, which over time, becomes more difficult. Lumosity estimates the expected improvement in each domain and provides the user with detailed progress reports. One game targeting working memory and reaction time, called "Speed Match" shows the user subsequent symbols asking her to decide whether the current symbol is the same or different than the one which preceded it. In "Raindrops", users are required to complete easy mental calculations within a limited time frame and in "Word Bubbles" participants are asked to come up with words that fulfil certain limitations. Lumosity runs the Human Cognition Project which enables scientists and researchers to use Lumosity's toolbox in projects and studies. Moreover, Lumosity has developed the Brain Performance Test which measures performance on cognitive and neuropsychological tasks in the domains memory, attention, speed, flexibility and problem solving.

SOCIABLE offers a variety of cognitive exercises covering the areas of memory, executive functions, constructional praxis, attention, logical reasoning, language and orientation. In addition, it provides the "Book of Life" application which is a virtual personal diary, including life experiences,

visual material and thoughts created by the primary users and shared with a virtual community (see Figure 14). The application aims to foster the self-esteem of the older adults and encourage them to communicate about topics and past events they feel comfortable to discuss. Medical experts participate in the system by curating a cognitive training program for their patients and monitoring their progress. An evaluation of the system with 117 subjects has shown that systematic use of SOCIABLE platform had a positive impact on the MMSE (Mini Mental State Examination) and the CDR (Clinical Dementia Rating) scores. Moreover, healthy participants experienced positive effect on memory, attention and executive functions and MCI patients showed improvement in abstract reasoning.

Although **Dem@Care** does not offer cognitive training, it provides an cognition assessment tool based on the repetition of a sentence by the participant. The user is instructed to repeat a sentence she heard and her memory and vocal abilities are evaluated to produce a diagnosis regarding her cognitive state, which were proven 83.3% accurate in trials performed.

Hermes targets the facilitation of episodic memory by offering cognitive training applications and games. These use a multi-touch medium size display (19 to 24 inches) as the I/O device. The content of the application and games stems from the everyday life of the elderly users: their in-house activities are automatically recognised by an audio/visual sensing environment. These populate the users' timeline in an agenda. Interesting events populate the game content. HERMES also follows the users' agendas and issues personalised reminders, always respecting the users' privacy by taking into account their context in selecting the most suitable means for notification.

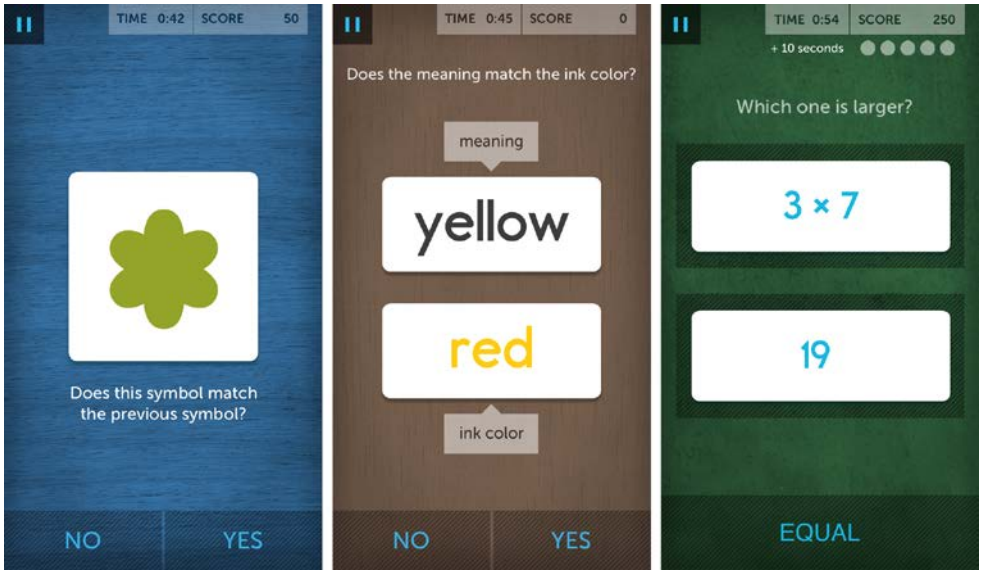

Figure 12 Lumosity

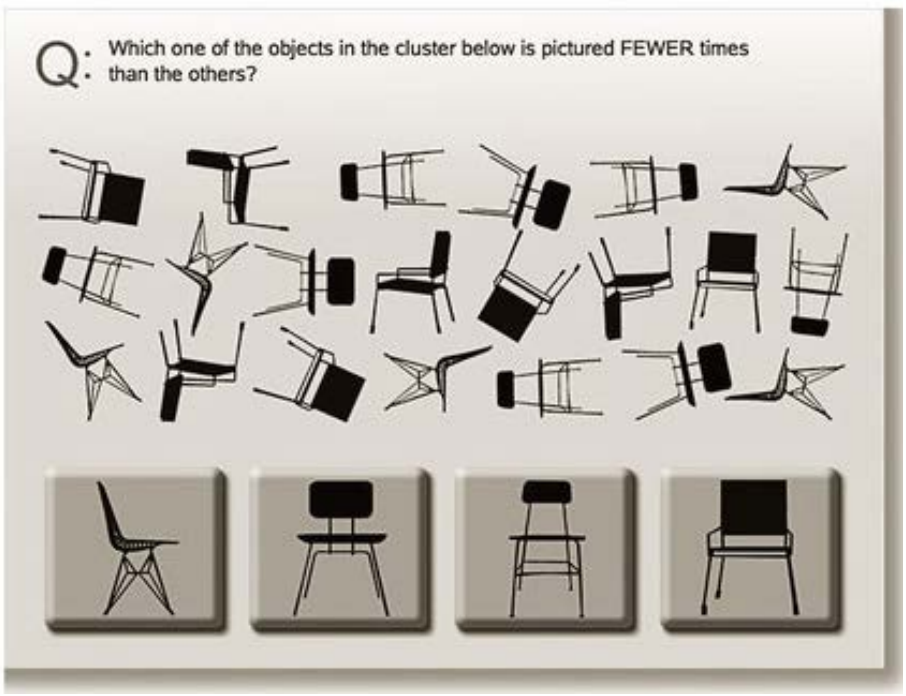

Figure 13 Dakim Brain Fitness

Figure 14 SOCIABLE project, Book of Life

3.3.2.5 Home automation approaches

Apart from sensors and cameras that belong to the necessary equipment for in-home monitoring, several of the analysed systems are connected with devices, objects and textiles in order to inform the user about potentially dangerous situations as well as for the purpose of measuring health indicators.

Mobiserv and CAALYX-MV showcase the use of smart textiles in combination with in-home monitoring. The Wearable Health Supporting Unit in **Mobiserv** consists of smart shirts, vests, bands and pyjamas which acquire throughout the day vital signs (ECG and respiration), activity (3-axis acceleration), heart rate (HR), breathing rate (BR), activity classification (lying, standing, walking, running and others) and moving average mechanical equivalent energy over 45 minutes. In **Home Sweet Home**, doors and windows open with badges and there is automatic climate and energy control.

In **CAALYX-MV**, a wearable light device (WDL) shirt was developed. The shirt has electrical conductivity and can replace wirings due to silver yarns and its GPS functionality allows localization of the user. Moreover, on WDL, there is a central unit logging and analysis box which includes medic sensors for temperature, breath, heart rate, oxygen saturation and physical activity for continuous health monitoring. The data from WDL and in-home sensors will be complemented with other relevant information, analysed and presented in the Care Service System to the caregivers.

Drawing examples from existing home automation networks, we observe that the following devices are programmed for automatic and/or remote control: light, TVs, HiFi equipment, and heating, ventilating, and air conditioning systems, doors and windows (not only opening and closing can be monitored, but also sensors for glass-breaking and for the operation of window shades are available) [3]. These connections operate under many different protocols, such as ZigBee, Z-Wave, Wavenis, INSTEON, KNX and IP-based solutions [3].

3.3.3 Design directions

Upon the exploration of industrial and research projects, we identified a number of open issues and questions regarding eWALL system that will be mostly resolved within the design process. Some of the issues require the participation and consent by the consortium. Therefore, this section opens a discussion to be completed in the course of eWALL's design and development with all the project partners. The open issues are summarized in Table 3.

The design directions described in the following subsections follow the classification derived from the State of the Art analysis: (1) in-home monitoring; (2) feedback to the primary user/communication to secondary users; (3) physical training; (4) cognitive training and (5) home automation.

Table 3 Open issues to be discussed by the consortium.

Open issues		
1	**Monitoring COPD and MCI patients**	In the cases of COPD and MCI: Which **instances of user's behaviour** should be monitored for better diagnosis and prevention?
2	**Feedback to the primary user & communication to the secondary users**	What kind of information should be communicated to • **the user herself**? • **her family?** • **the caregivers?**

3	**Physical coaching**	Is eWALL going to develop new physical training exercises or use existing ones?
4	**Cognitive coaching**	Is eWALL going to develop new physical training exercises or use existing ones?
5	**Home automation**	Which devices are going to be integrated to eWALL?

3.3.3.1 In-home monitoring directions

In-home monitoring is perhaps, the most crucial part of the eWALL system and assisted living systems in general. It puts at stake user's privacy (although it is in the best of our interest to apply practices to prevent that) for a good reason: to assist the users in living an independent life and to support their well-being. Therefore, the first step we are going to take in the eWALL design process is to define in-home monitoring: what do we need to know about our end-users? What can we know for sure and what we can assume? Are some specific behaviours indicative of the health status of the end user? For example, motion sensors can tell us whether a user has entered or exited the kitchen, but they cannot inform us whether user ate for lunch or not. In order to get this information, we have perhaps to combine data from the motion sensors and from kitchen appliances. Deciding which appliances and which sensors we are going to use, as well as whether we need this piece of information for a particular target user will take us a step forward in the eWALL design process.

Defining the monitoring output, namely what we want to achieve through monitoring is also important, because it opens space for innovation. For example, in the Rosetta project, the symptom of 'getting aimlessly out of bed' is a symptom of early dementia stages and at the same time, it could be detected with in-home monitoring, without any cognitive test to the user, without any extra cognitive load or cost. This is an example of how combining the expertise on symptoms and behaviours indicative of cognitive or physical impairments together with sensor data can be innovative, beneficial and unobtrusive. It is therefore, extremely useful to examine such symptoms and indicative behaviour and compile a list with them so that we can later examine, which of them we could apply artificial reasoning and sensor data to detect it.

3.3.3.2 Feedback to the primary user & communication with secondary users

An important aspect of eWALL will be the feedback shown to the primary user as well as the communication with the secondary users. The communication includes reminders, notifications, alerts and reports and it should be designed in such a way that both the primary and secondary user has sufficient and clear insights into primary user's life without being overwhelmed. The communicated content must also help in better medical decisions, better diagnosis, more customized therapies.

Table 4 classifies all possible types of communication between the system and the primary and secondary users according to the **communication goals**: first, the system communicates in order to ensure the **well-being** of the user (or even her **survival**); second, to enable the user to **control her home** and stay safe and third, to **sufficiently inform family and caregiver(s)** and enable them to provide their help to the primary user. The column "fed by" describes which user or which system

produces the content of the message. The column “sent to” enlists the users, which receive the message. In this table, three types of users are identified: primary user, family (or informal caregiver), (formal) caregiver. This implies that at least three different interfaces have to be developed during the development of eWALL:

- eWALL and/or mobile interface for the primary user
- Mobile/desktop interface for the informal caregiver/family member
- Mobile/desktop interface for the formal caregiver

The concept and/or the types of users involved in the system are open issues to be discussed by the consortium before starting the system development.

Table 4 The different aspects of eWALL will possibly generate messages targeting the primary or the secondary user(s). This table provides all the different message types that will be possibly propagated by eWALL.

Feedback and communication			
Goal	**Message type**	**Fed by**	**Sent to**
For user's **survival** up to **well-being** (with descending priority)	**Emergency alert**	• user • in-home monitoring	• family • caregiver(s)
	Therapy reminders and notifications: • medical instructions • medication	• caregiver(s) • devices,e.g. pillbox	• user • family
	ADL support reminders: • eating • drinking • socializing • sleeping.	• in-home monitoring • family (e.g. for customized ADL tasks)	• user
	ADL adherence notifications and alerts (when ADL are skipped)	• In-home monitoring	• user • family
	Other reminders: • reminders for physical and cognitive exercise • wellness advices and reminders • family/caregiver set reminders	• family • caregiver(s) • device(s) (e.g. reminder for cleaning)	• user
	Progress reports (motivational): • activities over time • changes over time • health and mood progress	• user • in-home monitoring long-term • devices, e.g. scale	• user
For **home control**	**Home automation notifications and alerts:** • to turn off devices • close/open windows/doors • to adjust home environment (e.g. climate, temperature, etc.)	Devices: • doors, windows • lights • kitchen appliances • smoke alarm • intruder alarm • other devices (?) User or family can calibrate home automation notifications.	• user
For **enablement of family & caregivers**	**Progress reports (informative):** • activities over time • changes over time • exacerbations and symptoms • adherence to therapy • health and mood progress • clinical history	• user (e.g. mood input) • in-home monitoring short-term (a day's activities) or long-term (change in lifestyle pattern) • device(s), e.g. scale	• family • caregiver(s)

3.3.3.3 Physical training directions

Exergaming with motion sensing platforms is a neat solution for physical training for eWALL, as it requires no additional equipment or space, it has elements of thrill and there are already a number of different games available made by various vendors, e.g. PlayMotion[8], Dance Dance revolution [7], Xbox [9], etc. We believe that the variety and the rich graphic environments of the games available can provide fuel to the motivation of the target users to exercise. An open issue regarding exergaming is whether eWALL will focus on designing new games, appropriate for the target users or it will integrate existing games.

So far, research has shown that exergaming with commercial platforms (e.g. Nintendo Wii, Microsoft Kinect) had positive results in the balance, the well-being and the physical condition of older adults suffering from various cognitive and physical impairments [1],[2],[5],[6].

3.3.3.4 Cognitive training directions

Cognitive training is a key element in the assistance of persons with cognitive impairments, thus it will be a crucial component of eWALL. The open issue that has to be discussed and resolved among the consortium members is whether we will focus in integrating existing cognitive exercises and games or if we will attempt to create new ones from scratch.

We believe that we should in any case, take into account the added value of the eWALL's form factor; eWALL is planned to offer an immersive display which covers a large part of a wall in user's living room. Therefore, in our integration and development efforts, we should focus on exploiting the potential of eWALL to be an engaging, immersive platform for gaming.

We have developed a concept that deals with the combination of cognitive and physical training in eWALL (see section 3.4.2). We believe that such a combination would be meaningful because in everyday life, cognitive and physical challenges are presented to us in random times and often follow one another. The "reflecting on the day" concept offers an alternative to how a memory exercise could look like; an overview of one's day seen as a last thing before sleep gives a possibility to the user not only to remember the day but to reflect on and hopefully optimize it (e.g. "*am I watching too much TV?"* Or "*I enjoyed doing my exercise today as the first thing in the morning; perhaps I should follow this schedule"*).

Another design direction for cognitive training is the combination of gamification and ADL support: for example, instead of reminders to primary user to perform her everyday tasks, eWALL could present easy brainteasers (e.g. "*your shopping list had 4 items. The first two: milk, bread. Try to guess the other two."*).

Overall, the design of the cognitive training should focus on creating a positive user experience for the user and challenge her to a level that it is still enjoyable, yet beneficial for her brain function. Finally, it is important to note that our proposed means of interaction in eWALL is special and offers a new, exciting interaction paradigm that affords innovative design and ideas.

3.3.3.5 Home automation directions

We mentioned above the different types of devices that can be connected in home automation networks. Before laying down our design directions for eWALL, it is useful to take into account the views of users who have already chosen to live in such interconnected home environments. According to study conducted for Microsoft Research by Brush et al. [4], users face a number of barriers with their in-home monitoring systems months or years after they install them:

- **High cost**: the systems are expensive both in time and money.
- **Inflexibility**: The users often have to choose between ease of integration (when they buy a system made by one vendor) versus flexibility (combining different vendors' systems).
- **Poor manageability**: The users have to rely on expensive consultants in case of damage, functionality adaptations (when they want to change their initial automation configuration), errors or unpredictable system behavior.
- **Security**: While remote access to home automation system was considered valuable by the participants, particularly for vacation scenarios, it often turns out to be a trade-off between convenience and security. Users are afraid that if access to their home (doors, windows) is software-controlled, it can be hacked.

During our design and development efforts, careful examination of these concerns could provide us with ideas and solutions to overcome them.

We believe that there is high potential in connecting eWALL with home appliances and even more with devices that are part of the life of patients already (see Table 5). In particular, COPD patients use a variety of different devices, the connection of which to in-home monitoring could reduce the cognitive load for the patients and could result in a more holistic and intelligent care system and Internet of Things. For example, a use case could be: eWALL measures low air quality and activates trickle vents in windows, as well as reminds the user to book an appointment with cleaning services.

Table 5 Devices used by COPD patients for the facilitation of their symptoms, for air quality control and for comfort.

COPD instruments and devices	
Aerosol Nebulizers	Devices that change the liquid medicine into a mist to be inhaled by the COPD patients. It can be used instead of portable medication inhalers and it is considered more effective as the patient breathes in deeply the medication over a longer period of time and because patients use potable inhalers often incorrectly.
Home Oxygen systems	Oxygen-rich flow of air provided to the patient through nasal cannula or mask
Mobility scooters	Smaller scooters, appropriate for indoor use, can support COPD patients with reduced mobility to cover longer distances and to go for shopping, as they have storage space.

Power wheelchairs	Wheelchairs that require minimum physical effort by the user and allow for independent mobility.
Dehumidifiers	Devices that maintain stable humidity (relatively dry environment) inside a house
Air-condition or heating units	Devices that maintain an appropriate temperature (relatively high but not too high) inside the house. Especially for COPD patients, air filters of these units have to be replaced every 3 months.
Ventilator/extractor-fans	Devices that remove airborne grease, combustion products, fumes, smoke, odours, heat, and steam by evacuation of the air and filtration.
Windows with trickle vents	New double glazing windows have small holes with manually adjustable covers that allow in a controlled flow of fresh air. COPD patients are advised to regularly open such vents.
Carbon-monoxide indicators	Device that controls for carbon-monoxide concentration and notifies the user when needed.
Sensors for flood, temperature, gas, smoke	Smoke, dampness, gas and changes in temperature might hinder COPD patients' breath and these devices are notifying the user for such incidents.

3.4 Exploring different eWALL concepts

While the process of extracting user requirements does not necessarily involve the creation of design concepts, we have until now gathered sufficient insights on the needs of our target users, as well as knowledge on which services and applications are or will be available in the market.

In this section, we present some initial interaction concepts which we aspire to serve as a basis for discussion among the consortium. The concepts are indicative of possible design directions for eWALL. Though they might influence eWALL design, they will not necessarily be followed in the following design iterations. In the creation of this concept, an effort was made to suggest interaction paradigms beyond what we found in the analyzed commercial and research projects (see section 3.3.2).

3.4.1 Shadow interaction concept

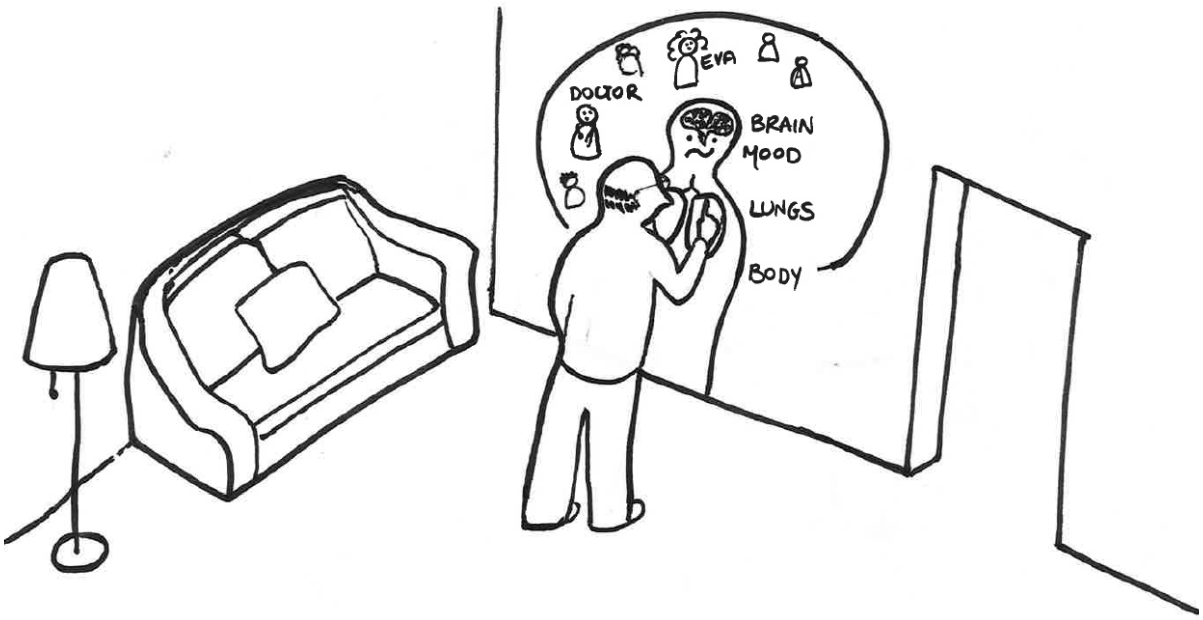

Figure 15 The user is standing in front of eWALL and interacts with his shadow: he taps on the lungs of the shadow to access breathing exercises.

In this concept we propose an intuitive way for the activation of eWALL and the selection among different application categories by the primary user (see Figure 15).

Bob stands up from his couch and approaches the wall. His shadow forms on the wall and when he gets in close proximity, his shadow on eWALL is separated into the brain part, the mood part, the lungs part and the body part. Around the contoured shadow, friends and family of the user are presented as small avatars. The user can select the brain for cognitive exercises; change mood by swapping emoticons in front of his shadow's face (from ☺ to ☹); make breathing exercises by selecting lungs; perform physical exercises by selecting the body and interact with his social cycle by pressing one of the avatars around him. The interface appears exactly on the segment of the wall that the user is standing in front of; its reach extends from the one side of the wall to the door. As the user moves away from eWALL, the shadow becomes smaller, until it disappears and this way, eWALL's display is deactivated until the user approaches it again.

3.4.2 Game combining physical and cognitive training

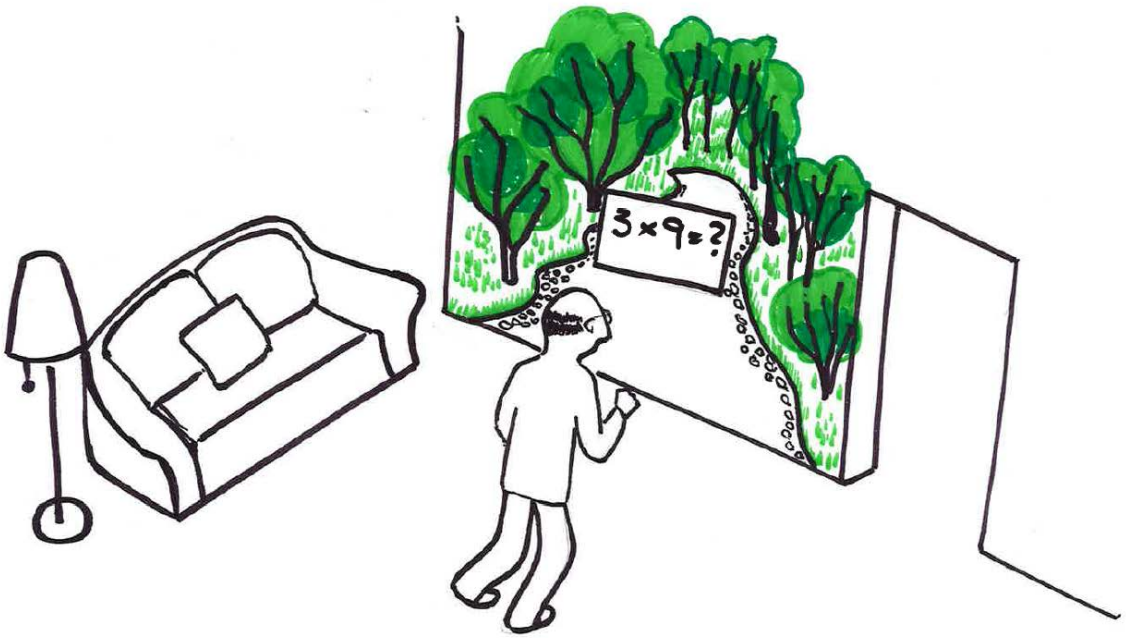

Figure 16 The user performs a combination of cognitive and physical training in front of eWALL which displays an immersive 3D environment.

This concept presents an exergaming paradigm, in which the user is faced with cognitive and physical challenges as he moves through an immersive 3D environment (see Figure 16).

Bob stands in front of eWALL and selects the forest game. eWALL displays a high-fidelity 3D forest environment. Bob takes his place on a little stepper hidden under the couch. While he exercises on it, he moves in the forest. On his way into the forest, challenges pop up and his task is to solve them. Moreover, as he takes a new path, it is likely to encounter passengers-avatars, played by other eWALL users and initiate a chat.

3.4.3 Reflecting on the day concept

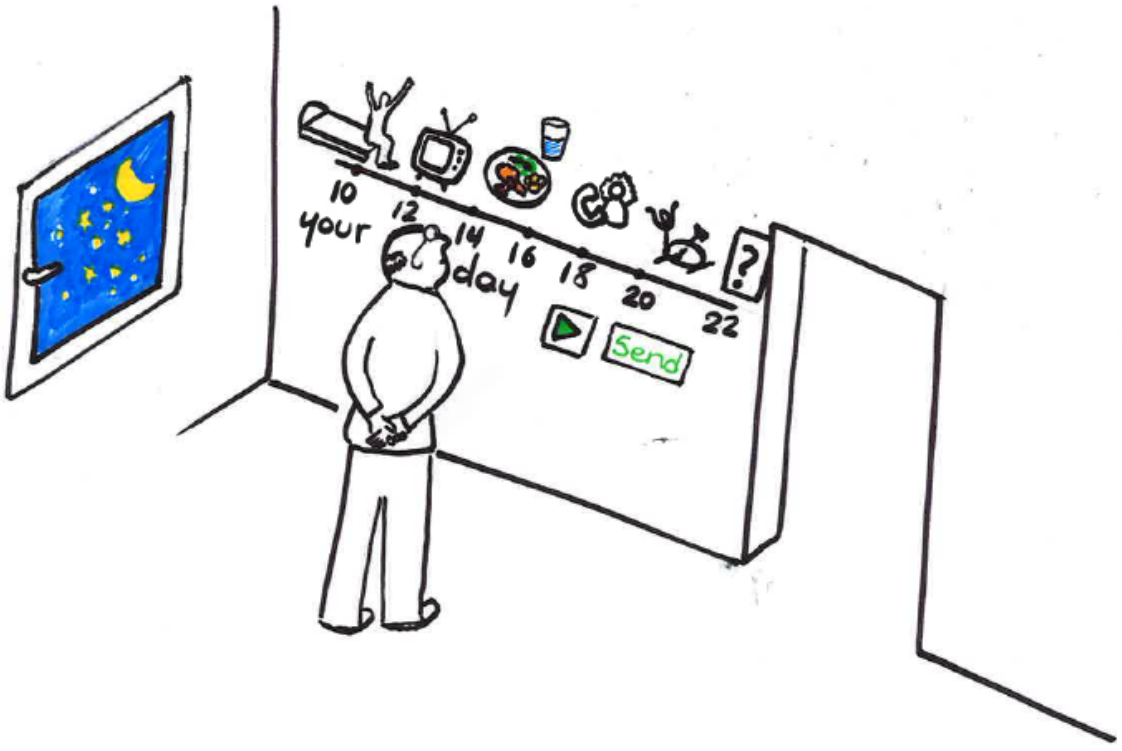

Figure 17 The user has the chance to have a look at the overview of his day, before he goes to bed.

In this concept the user has the opportunity to have a visual overview of his day and reflect on it (see Figure 17).

It is 23.00 and Bob feels it is time to sleep. Before going to bed, he approaches eWALL. The interface lights up and suggests Bob to watch the overview of his day. The data collected from the activities of Bob are beautifully assembled in a short dynamic presentation (e.g. video), containing pictures of his day, graphic elements that represent his activities and music. In case Bob spent the whole day watching TV or skipped important activities, the system can mildly suggest activities to perform in the next day.

When the system compiles the overview of Bob's day, some activities might be identified and labelled incorrectly: for example, if Bob was dancing at 22.00 in the living room, the system might has detected intense activity and correlated with cleaning or left the activity unlabelled. Similarly, if Bob leaves the house for some hours without his smartphone the system will have no information about a certain timeframe. Thus, when the overview of the day is presented, the system can ask Bob to label the unidentified activity and give feedback to the system in general and whether the overview matches his actual day. This feedback could then be used for machine learning purposes and to verify how in-home monitoring works.

Reflecting on one's day will be beneficial for MCI patients, because they have the need of keeping events, places and people in their life "in an order" in their memory. Moreover, it is a practice that allows people to self-reflect and get a deeper understanding in their habits, thus giving them stimuli

and motivation to change unhealthy behaviours (such as watching TV for hours). If the overview is done in an aesthetically pleasant manner, enhancing user's life with multimedia and graphics, users might feel proud of it and want to share it with friends and family.

3.5 Preliminary user requirements

In every home, there is a different ecosystem of devices (TVs, desktop computers, laptops, tablets, smartphones, Hi-Fis, devices specific to diseases etc.) that serve a variety of purposes and are placed in several positions. Older adults often follow an everyday routine consisting of habits closely linked to this device-ecosystem; for example, watching TV in the morning to listen to the news and logging in to Facebook in the evening to send messages to grandchildren. In the case of eWALL, the primary target users often have specific needs addressed by the use of specialized devices, such as oximeter for COPD patients. Thus, the introduction of a new system, which interferes with the setup already existing in user's home - for example an extra screen placed close to the TV in the living room - would be presumably not easily accepted.

This observation leads to the first requirement, which is that **eWALL should be modular**. In other words, eWALL should be designed and developed as a basic unit with extension components which can be added and/or removed easily, according to users' needs. Modularity refers both to software as well as hardware components (e.g. sensors). We could extent this requirement by saying that **eWALL is not a set of finite services but a framework which allows for customization and on which different services can be plugged in.** The service categories decided by the consortium so far, are:

1. Physical exercise
2. Daily activity monitoring
3. Daily functioning monitoring
4. Nutritional coach
5. Safety
6. Medication support
7. Social integration
8. Healthcare support
9. Calendar
10. Cognitive stimulation
11. Domotics
12. Outdoor guidance
13. Health monitoring

This is an indicative list and it is likely that only a subset of these service categories would be implemented in the eWALL prototype.

This leads to the second requirement that **eWALL should be adaptive and flexible**. Flexibility refers to the ability of the system to adjust its services according to users' cognitive and/or physical

abilities, needs (of the primary but also of the secondary users) and as mentioned above, the ecosystem and particular features of primary user's home.

The user's flow of actions should be highly respected. **eWALL should be unobtrusive**; the messages it delivers should be clear and prioritized, calling for a particular action and even facilitating it. They should only interrupt the personal flow of a user only when it is necessary and in this case they should be perceived with the severity/importance they deserve, not more or less (for example a repeating loud beep sound as a reminder is acceptable if the user forgot the oven on, but not for a cognitive exercise reminder).

As it was also noted in section 3.2.1, the persons who exhibit symptoms of MCI, COPD or mild physical impairments appear to gradually lose trust in themselves and motivation to perform activities that were part of their life before. For this reason, trust to one's abilities is a very important aspect that we will attempt to address in eWALL; the user should feel in control of her interaction with the system. Otherwise, the user will feel overwhelmed or confused and this feeling could possibly harm her already low self-esteem and self-trust and possibly invoke frustration. On the other hand, a satisfying interaction with a smart-home system will presumably give the user a feeling of achievement and pride and encourage her to remain active.

Thus, trust as a requirement means that (1) user trusts the system and (2) user develops trust for her own abilities. In order to achieve the first objective, we should ensure that by design, **eWALL is reliable**; it has a reliable interface as well as reliable services. For this reason, robust interaction modalities must be preferred over fuzzier ones (for example, touch is a robust input modality which produces less errors than speech recognition through living-room microphones).

Moreover, the user should not be overwhelmed by the amount of input the system expects from her. Therefore, **eWALL -** both in its basic version and the extension units - **should require the minimum possible input from the user**.

As mentioned above, users should not only feel in control but also enjoy their interaction with the system; this way, they will be more willing to adhere to medical instructions and training schedules. The amount of reminders they receive regarding their well-being, home and family (see Table 4) could easily be overwhelming and demotivating. Consequently, **eWALL should be designed with the goal to motivate the user.** In other words, the user should wish to interact with the system consistently. This requires intuitive and aesthetically sound interfaces and some motivation/persuasion strategy inbuilt in the interaction with the user as well as prioritization to the messages, reminders and alerts presented to the users.

Table 6 summarizes the above-mentioned requirements and provides design directions or ideas which could help in the realization of the requirements.

Table 6 Preliminary user requirements

RQ No.	Description	Implementation directions	
User_01	**eWALL is modular.**	DD1.1	The basic version of eWALL's can consist of the **motion tracking of the user inside her home**, the **feedback** messages (to the user) and the **communication** of this information on to the secondary users.
		DD1.2	The rest of devices and sensors that will be integrated should be easily plugged in/removed, like LEGO bricks.
User_02	**eWALL is adaptive.**	DD2.1	eWALL can observe the user's willingness to interact with the system and adjusts the **feedback** shown to the user and potentially also, the **input required from the user** by the UI.
		DD2.2	Users' cognitive and/or physical abilities and needs should be automatically estimated in order to adjust eWALL services accordingly (e.g. in case of cognitive training).
User_03	**eWALL is unobtrusive.**	DD3.1	The messages from the various eWALL services should be prioritized and follow a consistent aesthetic and communication style.
User_04	**eWALL is reliable.**	DD4.1	Reliable input modalities should be the default way to interact with the system (e.g. touch over gestures).
		DD4.2	A strategy should be developed in order to prevent/early fix errors caused by broken sensors, appliances, etc.
User_05	**eWALL requires the minimum possible input from the user.**	DD5.1	The eWALL services should be optimized to ask for minimum input from the user and display only the necessary output.
User_06	**eWALL is motivating.**	DD6.1	eWALL can easily be overwhelming due to the fact that it requires from users to change their lifestyles. Therefore, attention should be given in UI design, which should be beautiful and intuitive.

4 Preliminary system requirements

The eWALL project targets enhanced Activities of Daily Living (ADL) support through seamless integration of various ICT solutions into a unified, user-transparent and easy-to-use "eWall innovation", i.e. a prefabricated wall incorporating many functionalities and features for elder citizens. The added value of this approach is its capability to address several ADL areas such as a) risk management and home safety, b) eHealth and c) lifestyle management through fostering of different services and applications and interconnecting to various ongoing efforts and solutions in the domain (e.g. epSOS, Continua Alliance etc.). However, the associated complexity with the adopted approach yields a development of novel eWall system architecture addressing all previously mentioned aspects. Therefore, the definition of the system requirements (primarily from a technical point of view) is a crucial step towards mapping the previously discussed user requirements (stemming from usage scenarios and use-cases) into fully functional and operational system architecture.

The eWall system requirements should encompass all envisioned eWall system functionalities. They will differ according to the actual architectural part they target (e.g. the blocks or the interfaces), but, nevertheless, should provide a clear and unambiguous guideline at the early project stage. Therefore, this chapter focuses on provisional generic and specific eWall system requirements without dwelling into different architectural details. The system requirements presented here should provide sufficient basis for initiation of the architectural work and will be constantly monitored and updated in the first 15 months of the project. Deliverable D2.7 will discuss the final system requirements derived after several iterations with the user requirements from one side and the initial architecture design from the other.

4.1 Relevant activities in the field

Before analyzing the eWall system requirements, it is very important to pinpoint several activities in the field that tackle similar aspects and can be a potential anchor for the overall eWall scope and relevance. As a project that addresses ADL support, eWall aims to bridge the potential gap between the ADL related services, products and platforms and use the strengths of different solutions to provide its innovative approach in its areas of interest mentioned above.

The Continua Alliance [10] is an international group of technology, healthcare and fitness companies focusing on connected personal health and fitness products and services. This enables patients, caregivers and health care providers to proactively address ongoing health care needs. It relies on proven connectivity standards to foster an entire ecosystem of health related products designed and developed using a common framework, therefore addressing the interoperability issues. The eWall system should be capable of supporting the Continua Alliance certified products and integrate within its framework.

Apart from products and services, one of the quintessential aspects of efficient and proactive eHealth systems is the Electronic Health Record (EHR) aspect. In this direction, the European ProRec initiative [11] builds awareness on limitations and obstacles towards practical deployments of interconnected EHR systems. One of its most important initiatives was the formation of EuroRec

[12], a non-profit organization that promotes the importance of high quality EHR systems in the EU. The most recent effort in this direction is the epSOS [13] effort focused on design, creation and evaluation of a service infrastructure that demonstrates cross-border interoperability between EHR systems. The epSOS project uses existing technical solutions that transparently communicate and enable cross-border electronic prescriptions when needed. The eWall platform should be capable of interacting with the epSOS using it as a backbone for larger scale experimentation of its potentials.

The epSOS initiative also emphasizes the importance of the concept of Linked Data [14]. As personal patients' information (e.g. EHRs) become web accessible, it is beneficial to provide efficient means for interconnecting distributed data such as best medicine practice for a certain medical problem, various available medications and their implications for a certain medical problem etc. The Linked Data concept is increasingly gaining momentum enabling easy and efficient usage of online data based on the semantic web [14].

There are also other relevant activities in the area of eHealth focusing on telemedicine, m-health, health knowledge management etc. They all contribute to the design and development of novel integrated solutions for ADL support and will be used as cornerstones for defining the necessary eWall system requirements.

4.2 Prerequisites for system requirements definition

Necessary prerequisites for eWall system requirements analysis are the clear and unambiguous definition of system scenarios and appropriate use-cases as well as the minimal data model within the eWall platform.

The eWall project currently focuses on COPD and MCI - related patient scenarios, i.e. eHealth solutions. Some of the associated use-cases within the scenarios comprise physical exercise monitoring, daily activity monitoring, remote health monitoring, electronic health recording, remote diagnostics and possibly electronic prescribing of appropriate measures under different patients' conditions, indoor and outdoor guidances etc. At the same time, there is a clear need for interoperability among the eWall system and other eHealth or general solutions that deal with electronic ADL facilitation. This provides a general overview on the potential field of eWall applications, therefore defining the boundaries where the eWall system requirements will arise.

The minimal data model set of the eWall platform should include patient context (i.e. location, health record and plausible actions), patient devices status (e.g. home sensors capabilities), eWall gateway status and its connections and enabled patient services. The data model is needed for the system requirements and the architecture design and gives an insight into the eWall embedded system functionalities.

After analyzing the relevant activities in the field and the necessary prerequisites of the eWall system, the following sub-section will discuss the preliminary eWall system requirements derived from the analysis of section 3 in this deliverable and deliverable D2.2.

4.3 eWall system requirements

The eWall system requirements are divided (at the early project stage) into:

- Generic requirements and
- Specific requirements.

The generic requirements provide a general viewpoint on envisioned eWall system functionalities and should serve as general guidelines on the eWall platform capabilities. The specific requirements refer to specific technical aspects of the eWall system that make it viable and reliable under different possible circumstances (e.g. different components capabilities). Both carefully consider the relevant scenarios and use-cases within the eWall project. Tables 4.1 and 4.2 list the generic and specific eWall system requirements applicable for all envisioned eWall scenarios.

The tables show a small description of every system requirement that is currently proposed as well as its requirement level towards the architectural design. The tables are not exhaustive and it is expected that they will be extended/modified in the following months up to Deliverable D2.7.

Table 4.1: Generic eWall system requirements

Requirement ID	*Description*	*Status*	*Requirement level*
Gen_001	**Flexibility** – ability to support a variety of market available or eWall developed user and network devices	Proposed	Mandatory
Gen_002	**Scalability** – ability to easily scale the eWall platform to all envisioned use-cases	Proposed	Conditional Mandatory
Gen_003	**Traceability** – ability to log and track the taken actions throughout the platform operation	Proposed	Mandatory
Gen_004	**Extensibility** – ability to easily integrate novel devices in the platform (transparent protocol formats and protocol messages)	Proposed	Mandatory
Gen_005	**Reliability** – ability to provide reliable communication within the platform and always on-time reaction	Proposed	Mandatory
Gen_006	**Compatibility** – ability to integrate various information from various devices in a user transparent manner	Proposed	Conditional Mandatory
Gen_007	**Responsiveness** – ability to dynamically react and/or reconfigure eWall platform elements	Proposed	Optional
Gen_007	**Multiuser capability** – ability to support multiple eWall users with guaranteed profiling	Proposed	Conditional Mandatory
Gen_008	**User mobility detection** – ability to track the position and the movement of users in-house (important for various eWall services)	Proposed	Optional

Gen_009	**Emergency reaction capability** – ability to extract contextual information and respond accordingly	Proposed	Optional
Gen_010	**Interoperability** – ability to interconnect with other systems (e.g. epSOS)	Proposed	Mandatory
Gen_011	**Security** – ability to secure the eWall users' data from obtrusive and accidental eavesdropping	Proposed	Mandatory
Gen_012	**Social networking** – ability to interact with family and friends in order to ease the potential social isolation experienced	Proposed	Conditional Mandatory
Gen_013	**A/V interaction with the user** – ability to supply appropriate and user relevant information in audio and visual formats	Proposed	Conditional Mandatory
Gen_014	**Privacy** – ability to keep personal information from being disclosed and shared with unauthorized parties	Proposed	Mandatory
Gen_015	**Context information** - ability to provide context information that is useful for services to adapt themselves according to the needs, preferences and situation of the user	Proposed	Mandatory
Gen_016	**Service orientation** – ability of a system to ensure reusability and composability of services and service components	Proposed	Mandatory
Gen_017	**Semantic interoperability** – ability to enable semantic interoperability between applications and services for ensuring the highest degree of decupling (enables an open system and facilitates reuse of existing services and applications)	Proposed	Conditional Mandatory
Gen_018	**Maintainability and configurability** - ability to easily maintain and configure the system after deployment	Proposed	Mandatory
Gen_019	**Multi-modal user interaction** – ability to support multi-modal user interaction	Proposed	Conditional Mandatory
Gen_020	**User data separation** – ability to create pseudo identifiers for privacy protection supported by eWall user and network devices	Proposed	Mandatory
Gen_021	**Distributed decision making** – ability to make decisions in the patient's home system in addition to the eWALL cloud environment	Proposed	Mandatory
Gen_022	**Anonymity** – ability to switch off eWALL sensors and devices and manage the deletion of raw data from these sensors	Proposed	Mandatory

Table 4.2: Specific eWall system requirements

Requirement ID	*Description*	*Status*	*Requirement level*
Spec_001	**User pattern recognition and detection** – ability to extract repetitive user behaviors	Proposed	Conditional Mandatory
Spec_002	**Interference detection and localization** – ability to detect potential interference sources (important for the wireless communication part within the eWall platform)	Proposed	Optional
Spec_003	**Reconfiguration** – ability to reconfigure system and technical parameters according to the environmental context	Proposed	Conditional Mandatory
Spec_004	**Synchronization** – ability to provision synchronous operation of user devices and sensors	Proposed	Optional
Spec_005	**Spectrum sensing** – ability to support opportunistic spectrum access and interference minimization	Proposed	Optional
Spec_006	**Learning** – ability to learn and store user behaviors	Proposed	Conditional Mandatory
Spec_007	**Reasoning** – ability to reason upon stored user behaviors and choose appropriate actions (e.g. reminders for taking prescribed medicine)	Proposed	Conditional Mandatory
Spec_008	**Adaptive A/V formats** – ability to support audio and video bit rate adaptation to accommodate various possible display devices	Proposed	Mandatory
Spec_009	**Remote accessibility** – ability to provide remote access to the eWall platform	Proposed	Mandatory
Spec_010	**Priorities management** – ability to handle different simultaneous requests and messages with different priority levels	Proposed	Conditional Mandatory
Spec_011	**A/V based user tracking** – ability to process audio and visual data from in-house sensors in order to track humans, eye movements etc.	Proposed	Mandatory
Spec_012	**Monitoring of household appliances** – ability to handle potential hazardous situations when household appliances are turned on	Proposed	Mandatory
Spec_013	**Memory training games** – ability to interact with the users and aid their potential memory loss problems	Proposed	Optional
Spec_014	**Ambiental parameters monitoring** - ability to monitor critical ambiental parameters such as temperature, air quality, smoke etc.	Proposed	Mandatory
Spec_015	**Monitoring users' vital parameters** – ability to monitor (using wearable sensors)	Proposed	Mandatory

	body temperature, blood pressure etc.		
Spec_016	**Monitoring users' associated vital parameters** – ability to monitor vital parameters that affect the users' status such as sleep length, sleep quality, amount of conducted physical activity etc.	Proposed	Mandatory
Spec_017	**Identification, authentication and authorization** – ability of system components to identify, authenticate and authorize an entity (human users and other system components) that wants to use them before allowing them access to resources	Proposed	Mandatory
Spec_018	**Confidentiality** - ability to maintain confidentialy (the way in which the information disclosed or managed by the system is treated) of identifiable data, including controls on storage, handling, and sharing of data	Proposed	Mandatory
Spec_019	**Integrity** – ability to detect data modifications and prevent unauthorized modifications, especially related to service user data, sensor data and commands sent to actuators.	Proposed	Mandatory
Spec_020	**Non-repudiation** – ability to trace back every action on sensitive assets to the person or system component that performed it	Proposed	Mandatory
Spec_021	**Auditing** – ability of a system to log all actions on sensitive assets, including failed access attempts	Proposed	Mandatory
Spec_022	**Consent specification** – ability to provide a usable interface to capture the consent of the end-user about sharing data with services	Proposed	Mandatory
Spec_023	**Communication –** ability to enable inter-component message-based (or event-based) and call-based communication between distributed components	Proposed	Mandatory
Spec_024	**Context history** – ability to provide access to past/historic context information (the history length will depend on the actual context information)	Proposed	Conditional Mandatory
Spec_025	**Conflicting context information** – ability to provide means for resolving conflicting context information coming from different context sources	Proposed	Optional

4.4 eWall interfaces requirements

The eWall platform will inevitably be a complex platform integrating various user devices and enabling different personalized user services via a user transparent communication within and with other relevant entities. Therefore, the eWall system will encompass several types of interfaces:

- Interface among user devices;
- Interface between user devices and the eWall gateway and
- Interface between eWall and other systems.

Therefore, the project will specifically target the analysis of the interface requirements as a subset of system requirements, but defined separately because of their importance. The preliminary eWall interface requirements are summarized in table 4.3.

Table 4.3: Functional interface requirements of the eWall system

Requirement ID	*Description*	*Status*	*Requirement level*
Fun_001	**Device registration** – ability to register an eWall device in the eWall system (the registration may encompass the location, the type and the measurement capability of the device)	Proposed	Mandatory
Fun_002	**Device de-registration** – ability to temporarily or permanently de-register an eWall device in the eWall system	Proposed	Mandatory
Fun_003	**Continuous reporting** – ability to provision continuous communication of user data among all envisioned interfaces – continuous message communication (including communication to/from cloud environment)	Proposed	Mandatory
Fun_004	**Emergency triggered reporting** – ability to trigger specific reporting on a specific interface whenever needed – push/pull communication (including communication to/from cloud environment)	Proposed	Mandatory
Fun_005	**Remote configuration/reconfiguration** – ability to provide remote configuration or change of devices parameters according to the up-to-date context (including communication to/from cloud environment)	Proposed	Mandatory
Fun_006	**Remote service access** – ability to support communication to/from cloud services	Proposed	Mandatory

Table 4.3 showcased the functional interface requirements of the eWall platform. The functionality refers to the envisioned control and data plane functionalities that are being tackled by the defined

preliminary interface requirements. Additionally, there may be some non-functional interface requirements, which are similar to the generic eWall system requirements (i.e. flexibility to support various devices on a unified and transparent interface, traceability to support backlogging of measurements and activities, security to support only authenticated devices etc.).

The interface requirements are crucial towards defining custom eWall communication protocols along with specific eWall protocol formats and messages. Similarly as with the system requirements, the interface requirements will be extended/modified in the following months up to Deliverable D2.7. Their detailed analysis will be a subject of investigation once the preliminary system architecture is established.

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[8] PlayMotion platform. Information available at: http://www.playmotion.com/

[9] Xbox platform. Information available at: http://www.xbox.com

[10] Continua Alliance. Information available at: http://www.continuaalliance.org.

[11] ProRec Initiative. Information available at: http://nl.prorec.be.

[12] EuroRec Initiative. Information available at: http://www.eurorec.org.

[13] European Patients Smart Open Services (epSOS). Information available at: http://www.epsos.eu/home.html.

[14] Linked Data. Information available at: http://linkeddata.org/home

[15] Semantic Web. Information available at: http://semanticweb.org.

Abbreviations

MCI	Mild Cognitive Impairment
COPD	Chronic Obstructive Pulmonary Disease