

1. FINAL PUBLISHABLE SUMMARY REPORT

This section must be of suitable quality to enable direct publication by the Commission and should preferably not exceed 40 pages. This report should address a wide audience, including the general public.

The publishable summary has to include **5 distinct parts** described below:

1.1 EXECUTIVE SUMMARY (NOT EXCEEDING 1 PAGE).

This document presents the final summary report for the CompanionAble Project which was part-funded under the FP7 Programme as an integrated research project with the collaboration of 18 Partners from seven European countries over a period of 4.5 years from January 2008 to June 2012. The report provides a brief outline of the project context and objectives together with a set of 21 tested functions of the CompanionAble System Prototype, named Hector. Next the table of foreground contributed by various Partners is set out. Thereafter an outline of the potential impact is presented followed by the concluding sections of the report which include the project website and contact details, the dissemination and societal implications as well as the table showing the distribution of the EU-funding to the Partners.

The CompanionAble project has delivered a working prototype with a portfolio of several capabilities validated as proof-of-concept comprising the integrated Robot, and, Smart Home control environments providing care support for independent living of elderly people with Mild Cognitive Impairment (MCI); this has advanced the state-of-the-art in robotics for Ambient Assisted Living.

CompanionAble has deployed a rigorous methodology (UI-REF) for requirements elicitation and prioritisation based on well-established psycho-cognitive principles underpinning human Memory Recall of pleasure and pain and impressions formed within a persona and use-context-specific dynamic usability relationship model. This facility for care-recipients and care-givers to have their most-deeply-valued needs elicited, and, prioritised, proved pivotal to the provision of acceptable care support that can improve the quality of experience of all the stakeholders involved.

Accordingly 21 user-prioritised functions were developed and tested as described in this report; including: videoconferencing, cognitive training, agenda management, daily events dashboard, daily activities manager, smart medicine reminder, music player, family picture album presenter, smart home appliances and objects status detector, coming/leaving home reminders, robot navigation and autonomous re-charging, voice commanded "come/go-to/"follow me", user's posture/position/fall detector, voice-command/touch interaction, dialogue manager, personalised companion personas, emergency control centre remotely controlling the robot, detection of objects/appliances status.

Selected functions of the prototype have been clustered by the Consortium to form a number of candidate value propositions as part of an exploitation strategy that can be further refined to integrate with other AAL solutions to support mainstreaming given an appropriate business model and value chain for the mass market. Although a number of promising exploitation scenarios exist, it is concluded that the impacts of the CompanionAble project will be heightened to the extent that:

- Existing robotic architectures are harmonised within the consolidated robotic and AAL reference architecture towards a plug-and-play integration of robots and robotic devices in an open AAL platform. This would be best facilitated by addressing the challenge of interoperability of diverse systems through setting semantic interoperability standards across the AAL value chain involving not just the robotics domain but also the e-Health, home entertainment, home automation, and, household appliances, and built environment domains.
- Clustering and mobilisation of suitable solution sets for the market are supported by Pre-Commercial Procurement and Innovation Partnerships.

The CompanionAble results, if appropriately exploited, do offer the potential to deliver a high level of benefit realisation and contribution to the establishment of a thriving European AAL sector.

1.2 SUMMARY DESCRIPTION OF PROJECT CONTEXT AND OBJECTIVES (NOT EXCEEDING 4 PAGES).

There are widely acknowledged imperatives for helping the elderly live at home (semi)-independently for as long as possible. Without cognitive stimulation support the elderly dementia and depression sufferers can deteriorate rapidly and their carers will face a more demanding task. Both groups are increasingly at risk of social exclusion.

CompanionAble has provided the synergy of Robotics and Ambient Intelligence technologies and their semantic integration to provide a care-giver with an assistive environment. This supports the cognitive stimulation and therapy management of the care-recipient mediated by a robotic companion (support on-the-move) working collaboratively with a smart home environment (support at-home).

The CompanionAble Framework Architecture was motivated by the objective of graceful, scalable and cost-effective integration. CompanionAble has addressed the issues of social inclusion and homecare of persons suffering from chronic cognitive disabilities prevalent among the increasing European older population. A participative and inclusive co-design and user-scenario validation methodology (UI-REF) has driven the RTD efforts in CompanionAble; involving care-recipients and their close carers as well as the wider stakeholders. This was to ensure that end-to-end systemic viability, flexibility, modularity and affordability as well as a focus on overall care support governance and integration was fully accommodated; including quality of experience issues such as dignity-privacy-security preserving responsibilities.

As the number of persons suffering from cognitive disabilities in Europe has increased because of the increasing number of elderly people and pathologies associated with ageing such as Alzheimer's disease (AD) or depression, there are societal imperatives for the elderly to stay in their own homes for as long as possible. However, both AD and depressive persons suffer from memory and executive disorders as well as lack of motivation and self-esteem which reduce learning skills and induce decreased contact with the environment, impairment of daily activities and loss of autonomy. Such people and their family carer need support to help deal them overcome the risk of social exclusion - a challenge not yet well addressed by ICT technology.

Care-recipients at home have an increasing need for help from their family and professional care-givers. Familial carers feel burdened with a heavy responsibility in attempting to support their care-recipients. Both the cared for person and carer have to cope with a diminished quality of life; they need increasing professional support. However, the number of both professional and non-professional carers at home will not increase in proportion with the number of patients. Familial carers suffer from a heavy psychological, social and financial burden. Both professionals and family care-givers might lack support as well as knowledge, education, adequate advice and training skills in caring for people with disabilities. For both families and professionals, training sessions are difficult to implement because of the high cost.

Moreover, the personal feelings and likes/dislikes of elderly people must be considered. With this aim, the Spanish Centre for Sociological Research (CIS, Centro de Investigaciones Sociológicas)-IMSERO has conducted a survey in order to find the preferences of elderly people regarding staying in their own home or being cared for in a "residential home care centre". This survey has concluded that more than 70% of the people surveyed prefer to stay in their own homes, avoiding nursing homes for as long as possible. If they

need help, they still prefer to stay in their own homes, adapting them to their needs. The same study has shown that according to the age of the person surveyed, for more than 80% of the people aged over 65, the preferred option is their own home rather than nursing homes or assisted living centres.

CompanionAble has addressed the issues of social inclusion and homecare of the aforementioned persons suffering from chronic cognitive disabilities prevalent among the elderly. The RTD work in CompanionAble focused on care-recipients with slight and moderate dementia, with the aim of reducing the risk of onset or rapid progression of dementia. The care support as envisaged in CompanionAble project would be unsuitable for people with far advanced dementia who retain only marginal level of cognitive capability and thus would need special residential care. This is because people with advanced dementia typically do not live in their own home environment for several reasons including the risk of self-induced accidents (e.g. forgetting to turn-off the oven) and ending with the rising need for being under direct human observation around-the-clock.

One unique selling point of the CompanionAble project lies in the synergetic combination of the strengths of an embodied mobile robotic companion with the advantages of a smart home environment. In typical care scenarios the exclusive use of a mobile robot on the one hand or a smart home solution on the other hand would be inadequate for provide all the care support capabilities as provided by CompanionAble.

Moreover, the combination of robot mobility and user-adaptive interaction modes (e.g. via emotion recognition) provide continuous monitoring and detection of unsafe situations as well as interaction and cognitive stimulation available anywhere at home; this mitigates loneliness and enhances cognitive engagement. The CompanionAble system has been evaluated in various trials in France, Spain, The Netherlands and Belgium. The overall objectives of the CompanionAble projects are set out in table 1 below:

Nr	Objective
1	A new AAL solution through the synergetic combination of the strengths of an embodied mobile robotic companion with the advantages of a stationary smart home environment.
2	Semantic-Cooperative integration at sensors level
3	Semantic-Cooperative integration between the home environment (including smart house sensor network plus the robot) and the care system (District nurse/social services/healthcare system) as mediated by the CompanionAble; including alerts as required
4	Semantic-Cooperative integration of personal therapy management (possibly involving home information spaces such as the home TV screen, healthcare staff, medical profession, gerontologists)
6	A system for health education for the patient and family, enhancing self-confidence and quality-of-life
7	A system capable of supporting contacts between the care-recipient and his/her carers and the wider social setting
8	A system to support more efficient homecare monitoring and managing contacts with professional helpers
9	Social inclusion and homecare of persons suffering from chronic cognitive disabilities
10	Continuous availability of sense-ful close support and cognitive engagement of the elderly

Table 1: The Overall Objectives of the CompanionAble Project

1.3 MAIN S&T RESULTS/FOREGROUNDS (NOT EXCEEDING 25 PAGES),

The CompanionAble Project has resulted in a number of foreground innovations, both on a technological as well as on a methodological level. In the following section, these are described in more detail. An overview of the technical components is given in Figure 1; exiting state-of-the-art technologies have been applied in some cases if such solutions were deemed appropriate from the viewpoint of safety, robustness and user-centred acceptability.

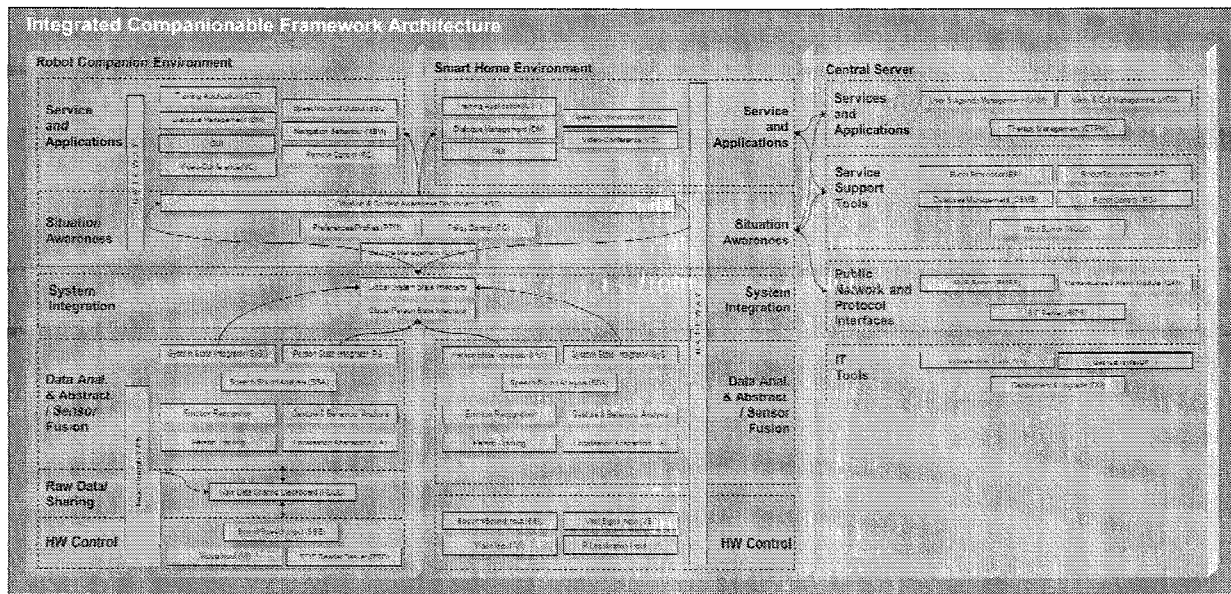


Figure 1: CompanionAble Architecture showing technical components

Capabilities realised through the integration of Hector the companionable robot in a smart home environment

In the following section, the main technical results and capabilities are outlined.

1. Video Conferencing Support

CompanionAble provides video telephony functionalities; these functionalities can be used both in order to stay connected to loved ones and friends as well as to facilitate regular contact with care-givers and specialist facilities such as call centres. Video calls can be initiated by the care-recipient and their friends and family. In addition, in emergency situations, the CompanionAble system can automatically initiate connections to specialist centres or on-site care-giver personnel. Designated (professional) care-givers can remotely control the robot to allow them to interact with the care-recipient directly for real-time support and assessment of any required emergency actions. The camera on the robot provides valuable information about the condition of the care-recipient and the safety status in the home -subject to user-specified privacy protective exceptions. In everyday use sessions are set-up automatically as required from wherever the care-recipient happens to be around the house; the robot finds and approaches the person and starts a video-conferencing session using its touch screen.

2. Cognitive Training

CompanionAble provides a variety of cognitive training games for elderly care-recipients; these cognitive activities are intended to stimulate the cognitive abilities of elderly persons as “serious games”; care-recipients will receive feedback on their performance and professional care-givers can monitor the performance as well and if needed adjust or personalise the therapy they can offer. The system automatically adjusts the difficulty level according to the performance achieved in these cognitive activities. This service is available through the robot screen, or tablet.

3. Agenda Manager

The agenda management system allows care-recipients to keep track of activities, appointments and events. The system can be updated by the end-user, by the care-recipient and by external care providers such as care centre organisations or, for instance, medical practitioners.

4. “Today Screen” Daily Events Dashboard

This provides an overview of relevant information for today; at-a-glance; one can see what is important to be dealt with on the particular day (to do items, appointments, weather information). The today screen offers a “one-touch” overview of tasks, notes and reminders for the current day.

5. “To-Do List”: Daily Task Prioritizer

The to-do list acts as the personal notebook of the care-recipient. It can be used in a similar way to the agenda management system. This particular function has been implemented as suggested by the users participating in the first series of CompanionAble usability evaluation trials.

6. Daytime Activities Manager

This component is integrated with the agenda management system. The robot delivers stimulating and positive reminders to engage in social interaction, cognitive stimulation and physical exercises, based on a personal profile. It facilitates reminder functionalities that alert the user about upcoming or overdue activities. The robot approaches the person and shares the information. These reminders can be shown once or repeatedly depending on the importance or urgency of the event.

7. Smart Medicine Reminder

Smart medicine reminders are reminders that alert the user that s/he needs to take medication. When medicine is not taken at the right time, the robot will approach the user and remind them to take their medication. In CompanionAble, this reminder function is demonstrated together with a smart pill box system that automatically dispenses the correct medication in the necessary time slot and can be remotely configured for instance by a medical practitioner. This prevents people from i) forgetting their medicine, and, ii) taking extra tablets needlessly if the prescribed item has already been taken.

8. Music Player

A simple music player interface has been implemented to integrate a smart home music system in order to demonstrate the potential that can be realised with integration of smart home facilities through the common robotic interface systems. The basic system as presented in demonstrations also shows how smart home services can be integrated into the CompanionAble system with little technical effort.

9. Family Picture Album Presenter

The family picture album is an example of a simple application that spans several screens in the smart home environment and/or on the Hector robotic system. The user can view pictures and a simple slide show controlling it through Hector, their television or any other (touch-enabled) display in the smart home.

10. Status Checker & Controller of Smart Home Appliances

Similar to the music player interface, this function demonstrates the seamless integration of smart home functionalities in the CompanionAble system. The home control functionalities allow users to control lighting and open/close curtains. This can be integrated into dialogue sequences so that the home control application can be triggered through dialogue; for instance reminding the user to have the lights turned off before leaving the house. The user can be notified of potentially dangerous situations when leaving the home; for example, a check will be made as to whether the oven is off, or, the doors are closed when people are going out.

11. Coming Home Welcome-Updates-Reminders

This is a function that demonstrates the integration of dialogue interaction with smart home and robot functionalities such as object detection via RFID and control of devices in the smart home. In the Coming Home user-scenario, the robot welcomes the user each time the user arrives back home, then notifies him of any events such as missed calls that may have occurred while they were away, and suggests that the user stores important items such as wallets and glasses with the robot so that they would be readily available for them with the robot pointing out where they can be picked up from (tray) on demand.

12. Leaving Home Reminders

The Leaving-Home user-scenario demonstrates the integration of specific functionalities as part of a robot-user dialogue. In this user-scenario, the smart home detects that the person is about to leave and the robot approaches the user and reminds them of any scheduled events at home that they may miss if they were to leave, and, asks them whether they want to take along items such as a wallet. The robot notifies the user of weather condition; suggests that they may wish to take along an umbrella if necessary; allows the user to control home appliances and settings such as light settings, curtains, conveniently before leaving. Moreover, a safety check is carried out to make sure no dangerous situations are likely to occur whilst the user will be out of the house; for example, that the system checks if the oven is off.

13. Robot Navigation & Autonomous Docking / Re-Charging

The CompanionAble robot knows the smart home environment and can navigate autonomously throughout the home when needed; it can follow and approach the user autonomously throughout the home and navigate to specific destinations on request or when a situation demands it. It is battery-powered but does not need to be connected to a power cord by the user as it comes with a charging station to which it can dock autonomously. The Robot will also try to identify situations in which he is not needed and use those to charge himself up; it can sense when it needs to charge its batteries and knows where the docking station is and will drive there and charge up its batteries automatically as needed.

14. Voice Commanded "Come-To"/GO-To" and/or "Follow-Me"

The user can send the robot to different locations in the home using voice commands, the touch screen or the "follow me" option.

15. Object/Person (Posture/Position) Tracker

The robot carries two RFID-enabled baskets in which small objects can be stored and carried. The robot knows which objects are being carried by it and therefore also which objects are not in the basket. The robot can detect persons as well and can track them to follow, to approach, or to adjust the orientation of its display screen when interacting with them.

16. Voice-Commanded and/or Touch Interaction – Dialogue Management

Users can interact with the CompanionAble Robot using speech input and/or a large touch screen mounted on the front of the robot. The touch screen can be automatically tilted to provide a comfortable viewing angle for the user during interactive scenarios. CompanionAble functionalities are furthermore accessible via smart home screens and displays that offer the same set of functionalities as available on Hector using the same user interface. Hector uses the touch screen display and speech output to communicate with the user. Some interactive scenarios between the user and Hector may be initiated by the user who can go to Hector or call him. However, one of the key added values of this CompanionAble care environment is the fact that a lot of system initiated interaction supports the user as well. This is especially important for people with memory impairment who tend to lack initiative. The system reminds people automatically of upcoming appointments, important events or tasks.

17. Remote Control of the Robot

In an emergency, for example if the care-recipient has had a fall, the remote control centre can take direct control of the robot, within a few seconds, to engage with the care-recipient and assist whilst the nearest key holder is alerted and/or emergency services are mobilised as required. Hector can be fully remote-controlled via an Internet-connected remote control interface. This allows the care centre operators to take control of Hector to gain understanding of an emergency situation. Remote control is available to support remote activation and control of smart home functionalities (e.g. open a door, turn on lights, etc.).

18. Personalised Companion Personas

One very important characteristic and pre-requisite of the CompanionAble care environment is the robust situation assessment and the highly personalise-able care support that it can provide depending on the user's preferences in given use-context. Participants in user trials actually reported that they expected the robot to become a buddy for them, a helping hand that delivers fun, care and valuable support in daily activities. Obviously, for the robot to be dependable as a helpful companion, it is important that its control system is capable of context-sensitive adaptation and personalisation responsive to user's current activity context, and the relevant situation assessment; this could include user's mood etc. Different people may value different behaviour from the robot, therefore it is necessary for the robot to be configured for different interaction styles and characters of the companion robot; this requires a repertoire of robot companion personas to be available which may involve embodiment adaptation as well as deemed essential although as far as the embodiment is concerned this is fixed for the current prototype but can be easily achieved in a mass-market environment.

19. Fall Detection and Connection to Emergency Care Centre

The CompanionAble framework includes a multi-camera video fall detection system that can be used optionally in user-specified living spaces subject to user-specified privacy preserving operational rules for video transmission. The fall detection system uses multiple cameras to detect user's posture and any falls and can trigger alert dialogues with the user that may lead to an escalation of the situation to an emergency

response being launched via an Emergency Call Centre. The fall detection function that can be deployed with the present prototype, subject to privacy-preserving operation, is the video-based fall detection system in a user-scenario where a detected fall triggers the robot to approach the user, ask whether help is needed, and to alert an Emergency Call Centre when no response is given or if the ^{user} initiates an alert. It is possible to integrate other fall detection systems similarly e.g. those based on accelerometers. The accelerometer-based solutions typically depend on the human subject's level of cooperativeness in wearing and keeping the wearable sensors and transmitters of data charged-up and connected to the network.

20. Detection of Doors/Curtains Open-Closed Status

The integration of smart home sensors within the CompanionAble system can be exploited to provide simple but useful services such as reminders when windows/curtains are open that may need to be closed in a particular situation, for instance when leaving the house or when it is starting to rain.

21. Detection of Appliance On/Off Status

Similarly to the open window/curtain sensors, the status of "smart devices" can be integrated within the CompanionAble system to allow the users to be warned of a possibly unsafe situation such as the kitchen appliances being on/off abnormally e.g. if the oven in the kitchen is still on after a certain time period has elapsed.

The Prioritised Requirements for the Integrated CompanionAble System were established by using UI-REF Mandatory (M), Optional (O) and Desirable (D) classification to reflect the user-specified ranking of the functions according to user's ordering of their most deeply valued needs; as set out in tables 2 and 3 below.

Functionality Requirement	SYSTEM Priority (M/D/O)	Functionality Requirement	SYSTEM Priority (M/D/O)
Safety		Services & assistive functions	
F1 The user can switch off the system anytime or in case of troubles	M	F29 Drug intake reminder	M
F2 To detect when the CR doesn't leave the bed	M	F30 Appointments & planned activities reminder (shared and remotely accessible) Agenda/Calendar/Notes board/Daytime Structure	M
F3 Detection of falls	M	F31 To remind of what a day of the week it is	D
F4 Detection of too slow movements	D	F32 Diet advices & recipe suggestions	O
F5 To detect that the CR cannot stand up after falling down	M	F33 Transportation and (safe) keeping of personal things (keys, wallet, mobile phone, glasses etc.)	M
F6 Detection of panic attacks	M	F34 Charge cell phone	O
F7 Checking health status / measurement of vital signs	M	F35 Show leisure and cultural events	O
F8 (secure) medical data transfer to professionals	M	F36 Wake-up call	D
F9 To detect when the patient remains immobile in an abnormal position	M	F37 To inform the care-givers about the activities of the CR (getting up, drugs intake)	D
F10 Remote control of the system by a professional carer in case of detection a critical situation	M	F38 Turn on lights automatically when CR is entering home	D
F11 Detection of gas emergencies	M	F39 Controlling heating, air conditioning	D
F12 Detection of fire emergencies	M	F40 TV assistant incl. distract the CR from watching TV	D
F13 Automatic call for help in case of critical situations	M	F41 Switching off electrical devices automatically when CR is going to bed	M
F14 Automatic call to relatives in case of critical situations	M	F42 Locating items of use (involves tracking of items and user)	D
F15 To ask the CR to turn off faucets, stove, microwave	M	F43 Tracking of items throughout the flat	D
Smart situation awareness		Therapy & Cognitive Exercise	
F16 Detection of CR is lying in the bed	D	F44 Cognitive stimulation (or initiation) programmes	M
F17 Detection of CR is sleeping	D	F45 Cognitive stimulation reminder	M
F18 Detection of a person is in a room	M	F46 To measure the response time on touch screen	M
F19 Detection of the CR is in a room	M	F47 To observe facial expressions - moods during cognitive stimulation programmes	D
F20 Detection of CR is moving in or to a room (bedroom, toilette, kitchen, living room, corridor, bathroom)	M	F48 To observe body and head movements during cognitive stimulation programmes	M
F21 Detection of no drugs intake	D	F49 To observe speech & prosodies during cognitive stimulation programmes	D
F22 Detection of CR is sitting	M	F50 Measurement of success of cognitive stimulation programmes	M
F23 Detection of CR is turning on/off faucets in the kitchen and in the bathroom	M	Usability	
F24 Detection of CR is turning on/off stove	M	F51 To try touch screen	M
F25 Detection of opening/closing/locking of the entrance door	M	F52 Recognition of oral orders	M
F26 Detection of key in lock inside when CR is going out or key has left outside when entering home	O	F53 Personalisation to user's preferences and profile	M
F27 Detection of CR is turning on the light		Communication	
F28 Detection of actual Compliance in medicine taking	J	F54 Video-conference Connection to relatives/friends/family doctor or health professionals	M
		F55 Virtual advice in daily activities (e.g. CR cannot use the stove)	O
		F56 Offer explanations about actions	M
		F57 Offer explanations about the system and its limits	M

Tables 2 & 3 User-Specified Prioritisation of the Safety and Functionality Requirements for the CompanionAble Systems Ranked as Mandatory (M), Desirable (D) and Optional (O) as defined in UI-REF

Limits and constraints of the achievements of CompanionAble

As the CompanionAble system was intended as a research proof-of-concept, it is at the prototype stage, therefore the next steps would be to make enhancements to enable it to function without some of its current limitations; as follows:

First and foremost is the inability of the current system to distinguish between different persons.

The system as it stands currently cannot distinguish between persons, thus in approaching anyone the system interacts with them as "the care-recipient". This can be overcome by speaker identification or users wearing identifiers such as RFID tags; and provision for switching between various user profiles for a specific group of persons that the robot should be able to communicate with as part of the care eco-system supporting the care recipient.

The second constraint is the use of wearable microphones for speech recognition. In the current configuration, environmental noise (e.g. from the robot itself, but also TV etc.) has a negative impact on the performance of the speech recogniser. Thus the microphone installed on the robot can only be used for video conferencing and it is necessary for the user to wear a wireless microphone close to the mouth. Of course, the user is able to interact with the robot based purely on touch screen interaction via the robot's touch screen or any touch screen in the house.

A third constraint is the somewhat fixed layout of the home environment required by the robot. This means that movements of larger items of furniture (e.g. sofa, recliner, etc) would impact negatively on the localisation and navigation of the robot to some extent essentially this can be resolved by enhancement that will allow the robot to initiate a re-mapping of the environment whereas currently such re-mapping has to be initiated by someone as a setup task. Minor movements of furniture and other items do not require such reconfiguration as these are taken care of by designating no-go zones for the robot.

Deviations from original planned outcomes

CompanionAble set out to provide an AAL solution as a proof-of-concept demonstrated through the synergetic combination of the capabilities of an embodied mobile robotic companion with the advantages of a stationary smart home environment. This has been largely achieved; however some deviations have been noted which are due to the complex nature of the domain and technical developments.

A major deviation is the number of test participants. Initially a participation of around 30 in Spain, 10 in Belgium, and around 40 in Netherlands had been foreseen. Whilst a large part of this population of users took part in the requirements engineering phase, it was possible for only a subset to take part in the evaluation of the system. This limit arose from having a single prototype and the multiple constraints arising from the availability of users and the timelines that would be required for each evaluation scenario to be properly conducted.

Only one prototype of each version was developed due to budget and time constraints. This, together with the time constraints for evaluation, meant that only a limited number of trials could be performed. The methodology used in the evaluations (UI-REF) necessarily required deep and extended user engagement and this needed an extended time for each trial so that it proved impossible to conduct a larger number of trials although each trial was provided much insight both in case-specific and generic terms about user expectations, likes and dislikes and the refinements indicated.

In addition, due to safety and operational constraints, it was found that the envisioned deployment of the robot in users' homes could not be realised. This meant that users visited the demo houses in Netherlands and Belgium to have longer interactions with and evaluations of the CompanionAble system; users were at liberty to stay overnight at the demo house but in any event they were encouraged to live an everyday life, alone with their carer, in the house through all day trials.

Despite the lower number of trials and the difficulty in making statistical inferences from the results, the consortium has endeavoured to maintain a diverse user base with a deep analysis of the respective backgrounds, knowledge, and affiliation to technology. This means that results obtained by the Consortium are valid and useful and notwithstanding the small sample of trials have provided much generic insight through deep UI-REF based analysis of effects, side-effects and affects of each usability feature of the system (pre/post)–experience as well as at-the-point of experience by users.

In terms of technical deviations, the main changes have occurred in emotion recognition where it was recognised that with the current state of the art in video monitoring a detailed facial analysis of the emotions in all situations was not achievable. However, in certain situations where the user is close to the camera of the robot, certain emotional-state estimation can be made. Due to this limitation, visual emotion recognition was omitted from the integrated version. The impact is limited as the recognition of the user's emotional state is performed on the basis of the analysis of the spoken input to which the robot responds based on the input received verbally and through touch input. Another deviation has been in regard of integration of developed technologies in relation to video monitoring. These were developed to provide to robustness of the person tracking, and in lab tests have proven successful. However, the installed tracking based on IR sensors and robot person tracking proved sufficient for the evaluations with end-users so that video-based tracking was omitted due to time constraints with respect to installation, calibration and also ethical issues.

To summarise, the deviations experienced are typical of those that can be encountered in implementation of most innovative projects and have not detracted from the CompanionAble project achieving its overall mission of establishing its proof-of-concept as already demonstrated in various arenas around Europe.

1.4 THE POTENTIAL IMPACT (INCLUDING THE SOCIO-ECONOMIC IMPACT AND THE WIDER SOCIETAL IMPLICATIONS OF THE PROJECT SO FAR) AND THE MAIN DISSEMINATION ACTIVITIES AND EXPLOITATION OF RESULTS (NOT EXCEEDING 10 PAGES).

The CompanionAble project has delivered a working prototype with a portfolio of several evaluated functions that support various aspects of independent living for elderly people, particularly for the care of persons with early stage Alzheimer's or Mild Cognitive Impairment (MCI); this has advanced the state-of-the-art in robotics for Ambient Assisted Living.

In the recent history of ICT Research and Technology Development many researchers, including some from the Human Computer Interaction (HCI) community, have proclaimed their total commitment to the "participative" and "user-centred" ideals of inclusive design. Nevertheless it has been difficult to see how any such claims were substantiated with a methodology based on well-established psycho-cognitive principles that systematically took account of the fundamental drivers of usability and user-acceptance in the process of helping users to articulate, and, prioritise needs in each situated context. This requires a methodology that can forensically identify and make sense of the root cause(s) of each user's (dis)satisfactions related to each of their activated personas in each priority use-context. This includes factoring in the user's preferences arising from personal pre-dispositions towards technology, memory bias, patterns-of-relating and impressions formed from new experiences as well as user's self-assured cooperativity in man-machine companion/team-worker relationships.

CompanionAble has deployed a rigorous methodology (UI-REF) for requirements elicitation and prioritisation based on well-established psycho-cognitive principles underpinning human memory recall of pleasure and pain and impressions formed within a persona and use-context-specific dynamic usability relationship model. This promoted deeper user engagement and new patterns of relating to man-machine mixed initiative working. This facility for care-recipients and care-givers to have their most-deeply-valued needs elicited, and, prioritised dynamically proved pivotal to the provision of acceptable care support that can improve the quality of experience of all the stakeholders involved.

The deep awareness of the needs of the elderly people, provided by those project Partners who acted as end-users' representatives, enabled the development of a solution system which has found user acceptance as a proof-of-concept and integrated prototype. Selected functions have been coherently clustered by the Consortium to form a number of candidate value propositions as part of an exploitation strategy that can be further refined to contribute to the AAL solutions to be integrated within an AAL platform to support mainstreaming given an appropriate business model and value chain for the mass market.

Accordingly the CompanionAble project has delivered an advanced robotic system integrated with an intelligent environment, a Smart Home, to provide solutions to users' needs of relevance to the improved independent living and quality-of-life of elderly people and efficiency of care in a context-aware manner; as such the results have advanced the state-of-the-art in Ambient Assisted Living (AAL) Technology.

In particular:

The comprehensive monitoring of the state of the environment and the care-recipient's condition including vital signs as well as speech-emotions-aware dialogue management informs a robust situation assessment as a fundamental basis of adaptive-responsive behaviour.

This has opened up opportunities for exploitation routes through:

- Integrated robotics and Smart Home solutions for AAL
- Standalone rent a Companion/Butler Robot
- Re-purposing or extending the applications for use in hotels and/or hospitals as a “Bell Boy” or (night) Nursing and/or medicine dispensing assistant respectively
- Integrated energy efficiency solutions.
- Fall Detector and postural tracking

Already the Robotics Partner, MetraLab has seen an increasing interest for service robots operating in new application domains whereby they interact with humans in shopping precincts, or warehouses etc. The sound source localisation and direction sensing capability developed by Harman has led to a real potential for exploitation in a number of industrial applications.

However to move towards establishing substantial demand and a significant share of the available market, concerted efforts are needed to promote interoperability, this will in turn facilitate shorter time-to-market, plug-and-play incremental deployment of AAL systems and services as required, lower entry level costs and thus affordability engineering and consequently a more thriving market for all the players in the AAL sector and for the European economy as a whole.

Accordingly the CompanionAble results if exploited appropriately can contribute to improved competitiveness of the AAL sector through proven feasibility; with economic benefits for the value chain as a whole. This includes, in particular, industries manufacturing basic robotics sub-systems such as electro-mechanical components to be integrated in the AAL platform and IT industries with competencies in product customisation or HW/SW technical support.

Given the demographic trends showing that an increasing proportion of the elderly population in most developed countries, USA, Europe and Japan have identified service robotics for care of the elderly as a clear market niche for economic growth. Thus the market of solutions for independent living represents a major opportunity for the European economy. With leading multinational companies in the field of telecommunication and entertainment, innovative SMEs in the area of well-being products for elderly people and a large and growing market of users, Europe can become the leader in the formation of a competitive market for ICT-based assistive services for the elderly.

However the field of social robotics is very unstructured and fragmented due to the different social systems and varying needs of users across Europe; additionally, manufacturing has demonstrated an increasing trend towards delocalisation away from Europe.

In Europe, compared to countries such as Japan, the integration of robots and robotic devices in AAL and care applications has not progressed much beyond research. This may be based on cultural differences but whatever the explanation for this, it is clear that, overall, the inclusion of robots and robotic devices into AAL applications and services is yet to be realised.

Affordability engineering is a major issue for such AAL RTD results as have been delivered by the Companionable project to find a route to commercialisation. This is an obstacle to be overcome through:

- Reducing the cost-and-time-to-market for AAL solution integration

- Focused support for innovation-to-mainstreaming management, win-win business model and support to establish thriving eco-system architecture for all stakeholders in the supply and demand side.

Thus the impacts of the CompanionAble project will be heightened to the extent that:

- Existing robotic architectures are harmonised within the consolidated robotic and AAL reference architecture towards a plug-and-play integration of robots and robotic devices in an open AAL platform. This would be best facilitated by addressing the challenge of interoperability of diverse systems through setting semantic interoperability standards across the AAL value chain involving not just the robotics domain but also the e-Health, home entertainment, home automation, and, household appliances domains.
- Clustering and mobilisation of suitable solution sets for the market are supported by Pre-Commercial Procurement and Innovation Partnerships.

Thus strategic and tactical effort is needed; both at the innovation investment management level as well as at the innovation integration level to provide a focus for mobilisation to overcome the fragmentation of research resources currently scattered across Europe and to strengthen the manufacturing of high-level robotics solutions in the EU.

The CompanionAble Consortium by integrating and testing its innovation of a number of user-specified high priority AAL functions has opened up the possibility for a set of value propositions to be exploited in convergence with the results from various such projects across Europe as can be facilitated through open standards, the AAL Framework and Innovation Partnerships.

This will:

- Help strengthen the potential for Europe to become a global leader in the field of AAL Robotics including the development of global interoperability standards in the field.
- Reduce the Digital Divide between people with impairments and the rest of the population concerning the usage of ICT products; as such it will promote the socio-ethical and societally inclusive objectives of the information society.

Thus the CompanionAble results, if appropriately exploited, do offer the potential to deliver a high level of benefit realization and contribution to the establishment of a thriving European AAL sector.

1.5 PROJECT PUBLIC WEBSITE, IF APPLICABLE AS WELL AS RELEVANT CONTACT DETAILS.

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