User Interaction Concepts in Smart Caring Homes for Elderly with Chronic Conditions

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Abstract. This article addresses the design and implementation of user interaction concepts for smart caring homes. Elderly suffering from age related frailty or chronic diseases, such as chronic obstructive pulmonary disease and mild dementia are the targeted primary users. Their informal and formal caregivers are regarded as secondary users. The current smart home approach to user interaction is either too intrusive or too unobtrusive. This article proposes an alternative that implements both concepts in complementary interaction paradigms, using multiple types of feedback devices.

Keywords: Ambient assisted living · Smart caring home · Elderly · Chronic disease · Human-Computer Interaction

1 Introduction

Healthy aging entails the need to cope with physical and cognitive changes that lead to an age-related functional decline. Common age-related physical impairments are audio and visual problems, muscle and bone weakness and balance difficulties. At a cognitive level, decline of memory function, perceptual reasoning and processing speed constitute the most common impairments [1]. Together with age-related factors, multimorbidity can aggravate functional decline [2-3].

Functional decline leads to disabilities in activities of daily living, negatively affecting independent living of the elderly. Formal caregivers (e.g. medical practitioners and visiting nurses), or informal caregivers (e.g. family and friends) play an important role in facilitating independent living for as long as possible. However, their availability can be limited, affecting the support to the elderly. In interviews conducted in eight European countries regarding the reasons for institutionalization of people with dementia, 15% of informal caregivers reported their heavy burden as one of the reasons [4]. At an economic level, e.g. in the Netherlands, it is expected that 50% of

A. Geissbühler et al. (Eds.): ICOST 2015, LNCS 9102, pp. 38–49, 2015.
DOI: 10.1007/978-3-319-19312-0_4

the increase in healthcare expenditure will be due to the increased number of people aged over 65 between 2010 and 2040 [5].

It is the objective of smart caring home installations to support independent living by offering specialized technology for self-management. By self-management, we mean strategies to cope with chronic diseases and/or age-related impairments, enabling the elderly to take a proactive role in managing health and well-being. Therefore, it is the aim of a smart caring home and self-management technology to enable prolongation of user's functional capacity, delay institutionalization, increase autonomy and prolong participation in society.

This paper describes ongoing research to develop a smart, caring home environment: the eWALL [6]. The eWALL is a modular software platform for the deployment of various care services to promote independent living and self-management of elderly users where a large central screen is used to provide rich, natural interaction. Specifically, the focus in this work is on the interaction between the user and the smart home. Our solution creates a smart home environment [7-9] oriented on elderly care, meaning an environment that senses and infers the wishes and needs of the person that lives in this house, providing unobtrusive daily support, notifying informal and formal caregivers when necessary and serving as a bridge to supportive services offered by the outside world.

Similar smart home technologies are discussed in Section 2, followed by a detailed motivation of our approach to self-management home care technology. Section 3 holds a detailed description of our approach and motivates the focus on *user-to-smart home* interaction. Section 4 describes the method undertaken for developing the eWALL system. It contains a description of requirements, system architecture and provided services within the scope of eWALL. In Section 5 we illustrate some examples of interaction with the eWALL system and we conclude by highlighting the importance of user-, and usability driven development of such caring home systems.

2 Background

Solaimani et al. conclude that the use of technology is considered a priority in a quantitative study regarding the process of developing Ambient Assisted Living (AAL) projects [10]. User studies and user-centric studies are becoming more frequently applied and integrated, often as part of developing technical requirements. A considerable effort is being put into adaptable technologies, which should fit the user's requirements in different life situations. Davidoff et al. developed principles of technology adaptation to daily family living, including: organic evaluation of routines and plans, coping with new or modified user behavior, understanding periodic changes, breakdowns, accounting for multiple coexisting and, sometimes, conflicting goals, and understanding the living space [11].

Human-Computer Interaction (HCI) was adopted, also in the case of AAL, by analyzing the intra-human thought processes, e.g. a seven stage model for deciding to take an action [11-12], and inter-human communication. Issuing commands with predictable outcome gives, to the user, the perception of control over the machine.

In contrast to this approach, Bellotti et al. [13] addresses interaction from the perspective of communication. Widely applicable in AAL systems, this approach is based on joint accomplishments from both the human user and the system. This implies that the system possesses capabilities to orient itself according to a sensed environment, inferred situation and classified pattern of causality, which allows it to compute possible outcomes of executing commands. In such case, a correct orientation may increase the user's trust in the system.

In both cases, user interaction plays an important role in AAL installations [14]. Primary user requirements vary and the level of technology intrusiveness is different in each implementation. We consider *intrusive*, hardware technology that requires frequent adaptation efforts from the users, whether worn on the user's body, or in very close proximity to the user. Intrusive technology requires the user to change her/his lifestyle in order to interact with it. This characteristic is influenced by various interfacing capabilities between modern technology and humans. Based on our survey, we distinguish two general approaches for offering feedback to the primary users: (1) the mobile follower, or robot approach, in which a technological personification follows its primary user within the home environment and (2) the fixed installation which consists, in most cases, of an enlarged control panel, allowing the user to choose whether he/she will interact or not with the caring technology.

An example of a lifestyle change in this case, is the user's need to accept and adapt to a robot [17-26] that follows her/him around the home. Good examples of this are the GIRAFFE robot, a telepresence application [20-21]; the Accompany robot that provides physical, cognitive and social support [22-23]; Mobiserv, a social companion robot [24-25]; and the Nao humanoid robot [26]. The robot provides the main feedback and system interfacing functionalities, but a more complex sensory infrastructure provides monitoring data. This implies a corresponding user adaptation to communicating with the technology and its intrusive behavior. Although providing helpful assistance [15], robots reduce the need for their user's mobility and create, in the long term, a greater dependency on the technology. Updates in robot functionality and, consequently, its form factors, will require a learning and adaptation process from the elderly user. Such limitations could hinder therapy and decrease long term acceptance [16]. One of the biggest limitations in today's state of the art robotic AAL systems is the reduced autonomous mobility outside the home environment. As such, these systems, as well as most other fixed installations, also provide a mobile device, such as Personal Digital Assistant (PDA), or smartphone, which can support similar interactions as most robots (speech recognition, touch gestures, GPS tracking) [8].

In an opposite approach, the AAL projects that adopt fixed feedback technologies such as projectors [8], all-in-one touchscreen PC's [27], custom home controllers like: the Gigaset home control [28], or DigiFlower [8]; or smart TVs [27, 29] are integrated tightly within the home environment. They have specific clear roles for offering feedback within a user initiated and control interaction episode, following more rigidly defined paradigms of use. They primarily implement the user issued command interaction type. Multimodal interactions are implemented with the constraint that they always occur in a fixed space within the household. Usually largely accessible rooms, like living rooms, support these installations. They mostly possess fixed forms and are not likely to dramatically change paradigms of use when updated. Opposed to the robot approach, the feedback mechanisms have tight integration with the home sensor network, giving the user a closely coupled sensory-feedback installation. The tight integration of these systems with the home environment is combined with a mobile device for outdoor use [8, 28-29], yet a complementary feedback mechanism (pairing mobile and home screens) is not a standard approach [8].

3 Approach

Smart caring homes are implemented in order to facilitate easy, reliable, and contextualized access to health care services. eWALL [33] is our approach to such a smart caring home which proposes a suite of self-empowering and self-management services, for elderly with age related frailty and multiple morbidities, and, in addition, care oriented services and healthy living assessment tools for informal and formal caregivers. As depicted in Fig.1, it consists of three main technological tiers: (1) the sensing installation for the primary end user (elderly), (2) the cloud infrastructure, for complex calculations and data storage, and (3) the front-end feedback consisting of: primary user main screen Graphical User Interface (GUI), primary user mobile GUI and secondary user (informal and formal care givers) portal GUI [7].

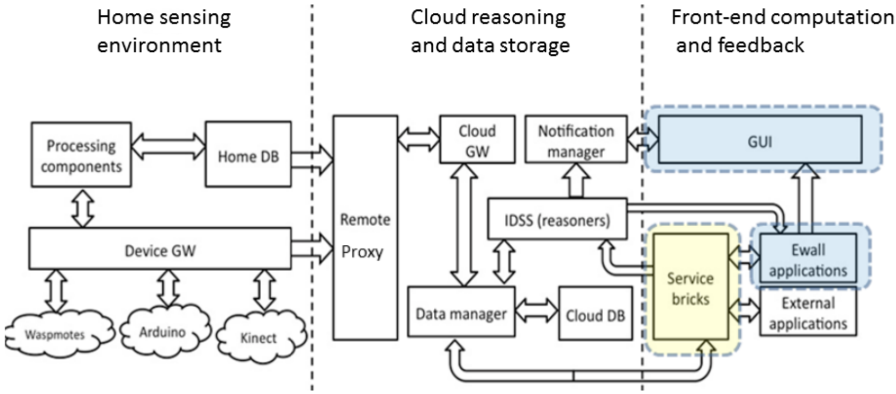

Fig. 1. Description of eWALL architecture divided in 3 technological tiers: the home sensing environment, the cloud reasoning and data storage and management and front-end computation (service bricks) and feedback (graphical user interfaces)

The eWALL installation for the primary user proposes a human-machine interaction paradigm which consists of two major components that complement each other in terms of functionality. The first component is the prefabricated wall containing a large screen (referred to as the main screen), installed in the primary user's home. It is immovable and allows complex interaction between the user and system. The second component is a smartphone that aims to provide relevant eWALL functionalities when the primary user is not within the home environment. Due to its nature, this system feedback component is highly mobile and can be considered as always reachable by the user, when eWALL functionality is needed outside the home environment. eWALL implements these two paradigms in a complementary way, by enabling the main screen to blend with the home environment, when no interaction is needed or being performed and keeping the smartphone widget set always reachable. Interface elements can be exchanged between devices through sliding gestures, or by button activated commands, e.g.: “send to phone”, “expand on main screen”.

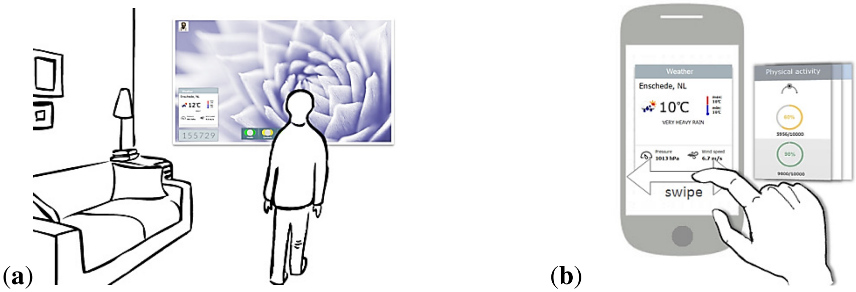

Fig. 2. a - Concept of the eWALL home screen displaying the active main screen interface; **b** - The eWALL mobile concept, reusing and adapting the main screen widget set

3.1 The “at Home” Interaction Paradigm

The home environment blending is done by implementing the “smart picture” metaphor, in which the main (large) screen will display a picture on its entire surface, overlapped by informative widgets displaying the current time and weather forecast (Fig. 2a). The widgets are positioned in a non-focal point area, giving value to the picture. Interaction is requested by eWALL, through a smart notification system. This system takes into account a complex set of parameters, some of which being: the therapy prescribed by the doctors, the person’s state of health and a history of compliance to the notification messages. Interaction can also be initiated by the primary user, simply, by approaching the wall.

When the primary user is within reach of the main screen, eWALL switches to its active mode. In this mode, the user has access to a number of applications targeting several aspects of one’s life. eWALL has initially three types of applications. First, eWALL targets independent chronic disease and frailty management through monitoring of physical and daily life activities. Maintaining and improving one’s state of health is achieved through physical activity coaching, training the respiratory system through home exercises, or cognitive training through fun games. The third type is healthcare support, consisting of applications that enable the primary user to communicate with informal and formal caregivers.

3.2 The "Outside of Home" Interaction Paradigm

The system revolves around the primary user, which means that we target disease and frailty management during most life situations. A large number of such life situations happen outside the home environment, with different constraints and, therefore, different functional requirements. eWALL adapts to the outside environment situations by offering relevant functionalities to continue and complement self-health management. The primary feedback device is a smartphone (Fig. 2b) and the sensor network consists of the smartphone's GPS, microphone, camera and a wearable physical activity sensor for accurate detection and quantification of different physical activities.

4 Method

The development of eWALL started with a study of the targeted users. Our study produced personas – which encapsulate typical features and behavior of homogeneous sub segments of the target population. Based on these personas we identified a set of system requirements. The identified requirements led to a set of functionalities (services) that eWALL must support and a home/cloud based software architecture to support them.

In designing user experience, the most important trigger towards making good decisions is an in-depth knowledge of the users. In eWALL we target elderly suffering from Chronic Obstructive Pulmonary Disease (COPD), mild dementia and age related frailty, as our primary users, as well as informal caregivers (with limited relevant medical experience), and professional care practitioners as secondary users. Fig. 3 describes the communication needs of our users such as: frequency of visits and frequency of communication cumulating: in person and remote (telephone, sms, e-mail, video conferencing) communication.

The relationships between these types of users are centered on the primary user. They are the target of eWALL therapy, coaching and assisted living services. The secondary users are trying to offer help in various ways for sustaining, improving and reinforcing eWALL's aims.

Personas are stereotypical characters that allow the stakeholders to focus the development on specific user needs and disambiguate requirements [30-32]. Through the use of personas, the functionality development is directed towards an in-depth search for the best solution for a subset of users, rather than a generalized approach with less efficiency.

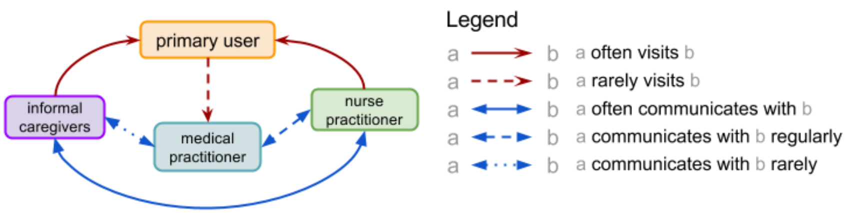

Fig. 3. A visual representation of the types of eWALL users and their complex communication needs

Our initial study resulted in the development of six primary user personas, described in Table 1. The secondary user personas consist of: a general practitioner, a visiting nurse and an informal caregiver, who is also the wife of one primary user with age related impairments.

eWALL targets three main service categories: *monitoring*, *coaching & training* and *healthcare support*. Monitoring allows the user to see all the tracked data relevant to her/his chronic condition, put into the context of daily life activities. The physical exercise monitoring is the main tool for tracking one's physical activity in a quantitative way. The daily activity monitoring shows daily life episodes interpreted from the user's home monitoring sensor network. Activities are chronologically ordered and separated by type. The sleep monitoring offers insights into the quality and quantity of the user's sleep (measures intervals of sleep and intervals of non-sleep during night, calculates patterns of sleep and searches for anomalous deviation from the sleeping patterns).

Coaching is essential for maintaining control over the state of the chronic condition. We approach coaching from two essential perspectives: training the body's robustness and expanding its adaptive capabilities (e.g. users with COPD will have periodic sessions of thoracic muscle training for a better ability to sustain the effort of breathing), and coaching the mind through fun games, in order to maintain a high level of cognitive stimulants.

The third service category refers to maintaining contact with other persons involved in the user's life, with the purpose of releasing the financial burden of both user, persons involved in the user's informal, or formal care and the health system itself. The *Healthcare* S*upport* service category is designed to enable communication through various channels with informal and formal caregivers.

In order to allow these services to coexist in a coherent way, a distributed computing architecture was developed, which consists of two major components: the home, or local, component – handling sensor data capturing and low level metadata processing, as well as high level feedback and interaction with the user, and the cloud component – as well as an extremely powerful network of processing blocks and storage entities. A semantic model, called the user profile, represents all the data needed by the system.

Table 1. Overview of the six primary user persona's developed in the eWALL project [33], describing their specific domestic situation, issues and needs

Name, Age & Gender	**Domestic situation**	**Issues**	**Needs**
Michael 67 ♂	Living at home with wife	Hypertension, Forgetfulness, Social Anxiety, Lack of Motivation, Social Isolation, Experience with modern technology	Physical activity monitoring, Physical activity coaching, Communication with caregivers, Notifications for wellbeing, System triggered alarms, User triggered alarms, Easy human-computer interaction
Simone 72 ♀	Lives alone, son lives far away	Reduced mobility, Social isolation, Hypertension, High cholesterol, No experience with modern technology	

Table 1. (*Continued*)

Petra 49 ♀	Lives with husband and one daughter	COPD Stage 2, Overweight, Heavy smoker, Can't commit to physical rehabilitation programs, Experience with modern technology	Physical activity monitoring, Sleep monitoring, Physical activity coaching (breathing exercises), Communication with caregivers, Notifications for wellbeing, System triggered alarms (including home air quality), User triggered alarms, Easy human-computer interaction
Bob 65 ♂	Lives alone	COPD Stage 3, Ex-Smoker, Underweight, Hearing problems, Has trouble sleeping, No experience with modern technology.	
Jane 74 ♀	Lives alone	Cognitive decline, Memory deficits, Sleeping problems, Anxiety, Avoid social contact, No experience with modern technology	Daily functioning monitoring; Physical activity monitoring; Sleep monitoring; Cognitive training/games; Communication with caregivers; Notifications for wellbeing; System triggered alarms; User triggered alarms; Easy human-computer interaction
Philip 66 ♂	Live with his younger sister	Suffered a stroke, Vision problems, Gaps in working memory, Social isolation, Low physical activity, Experience with modern technology	

5 Scenarios and Use Cases

Within eWALL, applications are designed for different contexts of use. Context parameters are: user's geographical position, the type of task to be undertaken by the user, the type of possible interaction between user and system, the estimated time of interaction (long time interaction at home or short time interaction, when mobile). The user geographical positioning influences the feedback and input device that will provide it. We consider that interaction with the system at home allows for richer, prolonged periods of interaction, as opposed to outside interactions that are considered to be short and concise. These factors influence the type of tasks that are able to be undertaken by the primary user.

An example is contacting secondary users for additional support. Whether the primary user intends to communicate with informal, or formal caregivers, eWALL offers several ways of building messages: written messages can be typed, or handwritten, spoken messages can be exchanged through audio-visual communication applications.

Outside of the home, eWALL widgets will offer shortcuts to contacting caregivers in case of emergencies. The mobile smartphone communication functions are used in a conventional way.

COPD management involves daily physical activity as well as daily respiratory system training. eWALL supports these types of self-managing practices by offering a set of clinically validated applications including home training videos in a sequence configured by the primary user's physiotherapist [34]. During the exercise sessions, the primary user will wear a sensor that records movement and other relevant body measurements (heart rate, oxygen saturation), which will be recorded by eWALL and processed for extracting relevant information regarding the primary user's performance, within the context of therapy. The measurement data will be aggregated in easy to understand visualizations, presented by monitoring applications.

The primary user receives also messages stimulating outdoor activity [35]. In this case, the eWALL mobile device acts as a personal real-time quantifier of performance, recording the outdoor activity captured by the on-body sensor and putting it in context of the primary user's therapy and daily physical activity goals.

Mild dementia users have a number of cognitive stimulation games that engage multiple senses and train for better attention, hand-eye coordination, logical progression, etc. The games function in the home setup, using the main eWALL screen 10 finger touch recognition capabilities for a rich experience. The frequency and level of difficulty for the game therapy sessions are set up by specialized formal caregivers.

Sleep monitoring is another important factor in determining influences on the primary user's state of frailty. Bed sensors will detect and record sleeping patterns and anomalies. This data will be available for both primary end user and secondary eWALL users with proper access permissions. The eWALL home installation aggregates and interprets the information provided by the eWALL reasoners into meaningful, clear statements describing the quantity and quality of each night's sleep.

Formal caregivers will use relevant parts of the collected data for health state assessment and future therapy recommendations.

6 Conclusions

In this paper we identified the current interaction approaches in the field of smart homes as being intrusive, by following the primary user around the home [19, 21, 23], or too unobtrusive, by being placed in a fixed position inside the caring home and letting the user decide the type and time of interaction with the system. We describe our approach as a complementary mix of immovable unobtrusiveness and mobile intrusiveness according to the context of use and user's therapy needs. A distinction was made by orienting the paradigms of interaction between the user and the system towards episodes of use within the home environment and episodes of use outside.

At home, the caring systems should provide rich, longer lasting interaction possibilities between the user and the system. Feedback can be complex and with a higher degree of immersion, because the user can focus on operating with the system. This allows for complex therapy approaches and various gamification features to be implemented in the home installation application. A large surface for feedback (e.g. a large screen) can fulfill all these requirements. Complex system calculations and intelligent processing can be performed in a cloud infrastructure allowing a significant reduction of processing workload within the caring home technology and reducing infrastructure building and support efforts, as well as costs.

Outside the home, the primary user will need fast access to present context information, such as: the current status of physical activity compared to the daily goal and activity pattern, fast access to informal and formal caregivers in case of emergencies and the possibility of getting context relevant notifications. Interaction paradigms for the outside do not require an elevated degree of interaction possibilities, or immersive feedback; rather a reduced set of functionalities that allow the user to quickly react and interact briefly with the system through the smartphone.

Both outside and inside systems record and reason on sensor data and provide several types of feedback mechanisms. These systems will complement each other by generating knowledge commonly stored in the eWALL user profile. This allows devices to share information about their user seamlessly and performing a task, such as physical activity, will not be spread into home training episodes and outside training episodes, but continued by passing feedback from the home context, on the main screen to the outside context, on the smartphone and vice versa.

eWALL aims to give value and integrate commonly understood and adopted technologies (such as mobile smartphones, wearable activity sensors, positioning sensor networks, home exercise equipment, etc.) with innovative input and feedback mechanisms through novel interaction paradigms centered around the primary user needs, the context of use and the goal to be achieved. At the moment of writing, the home installation main screen, including the proxemics switch mechanism, physical activity, daily functioning, sleep monitoring applications, notifications and alarms, is in its initial prototype phase, undergoing usability tests, while the mobile software prototype is in a conceptual phase.

Acknowledgements. The work presented in this paper is being carried out in the eWALL project [33] and funded by the European Union's 7th Framework Programme. The authors would like to thank all consortium partners for their valuable contribution to this research.

References

1. Harada, C.N., Natelson Love, M.C., Triebel, K.L.: Normal cognitive aging. Clin. Geriatr. Med. **29**(4), 737–752 (2013)
2. Bianchi, L., Zuliani, G., Volpato, S.: Physical disability in the elderly with diabetes: epidemiology and mechanisms. Curr. Diab. Rep. **13**(6), 824–830 (2013)
3. Kalyani, R.R., Corriere, M., Ferrucci, L.: Age-related and disease-related muscle loss: the effect of diabetes, obesity, and other diseases. Lancet. Diabetes Endocrinol. **2**(10), 819–829 (2014)
4. Afram, B., Stephan, A., Verbeek, H., Bleijlevens, M.H.C., Suhonen, R., Sutcliffe, C., Raamat, K., Cabrera, E., Soto, M.E., Hallberg, I.R., Meyer, G., Hamers, J.P.H.: Reasons for institutionalization of people with dementia: informal caregiver reports from 8 European countries. J. Am. Med. Dir. Assoc. **15**(2), 108–116 (2014)

5. van Rooijen, M., Goedvolk, R., Houwert, T.: A vision for the Dutch health care system in 2040: towards a sustainable, high-quality health care system. World Economic Forum, McKinsey & Company (2013)
6. Mihovska, A., Kyriazakos, S.a., Prasad, R.: eWALL for active long living: Assistive ICT services for chronically ill and elderly citizens. In: IEEE Int. Conf. Syst. Man, Cybern., pp. 2204–2209 (2014)
7. King, N.: Smart home – a definition (2003). www.housingcare.org/downloads/kbase/2545.pdf
8. Jiang, L., Llu, D., Yang, B.: Smart home research. In: Third International Conference on Machine Learning and Cybernetics, Shanghai, pp. 659–663 (2004)
9. Lê, Q., Nguyen, H.B., Barnett, T.: Smart Homes for Older People: Positive Aging in a Digital World. Futur. Internet **4**(4), 607–617 (2012)
10. Solaimani, S., Bouwman, H., Baken, N.: The smart home landscape: a qualitative meta-analysis. In: Abdulrazak, B., Giroux, S., Bouchard, B., Pigot, H., Mokhtari, M. (eds.) ICOST 2011. LNCS, vol. 6719, pp. 192–199. Springer, Heidelberg (2011)
11. Davidoff, S., Lee, M.K., Yiu, C., Zimmerman, J., Dey, A.K.: Principles of smart home control. In: Dourish, P., Friday, A. (eds.) UbiComp 2006. LNCS, vol. 4206, pp. 19–34. Springer, Heidelberg (2006)
12. Norman, D.A.: The Deasign of Everyday Things. First Doub. Doubleday/Curreny, New York (1990)
13. Bellotti, V., Back, M., Edwards, W.K., Grinter, R.E., Henderson, A., Lopes, C.: Making sense of sensing systems: five questions for designers and researchers. In: Proceedings of SIGCHI, vol. 1, no. 1, pp. 415–422 (2002)
14. Nehmer, J., Karshmer, A., Becker, M., Lamm, R.: Living assistance systems - an ambient intelligence approach. In: ICSE 2006, Shanghai, China (2006)
15. Rashidi, P., Mihailidis, A.: A Survey on Ambient-Assisted Living Tools for Older Adults. IEEE J. Biomed. Heal. Informatics **17**(3), 579–590 (2013)
16. Bevilacqua, R., Cesta, A., Cortellessa, G., Orlandini, A., Tiberio, L.: Telepresence robot at home: a long-term case study, pp. 73–85 (2014)
17. Renteria, A., Pastor, C., Gaminde, G.: Intelligent homes to assist elderly people. In: Proceedings of International Workshop on Ambient Assisted Living, Valencia, Spain (2010)
18. Nadrag, P., Maseda, A., Grosdemouge, C., Delarue, S., Villanueva, M., Mìllàn, J.C., Hoppenot, P.: Remote control of a real robot taking into account transmission delays. In: 11th IFAC Workshop, Prague, June 7–9, 2010. doi:10.3182/20100831-4-FR-2021.00012
19. Companionable project. http://www.companionable.net/
20. Bevilacqua, R., Cesta, A., Cortellessa, G., Orlandini, A., Tiberio, L.: Telepresence Robot at Home: A Long-Term Case Study, pp. 73–85 (2014)
21. GiraffePLUS project. http://www.giraffplus.eu/
22. Pérez, J.G., Evers, V.: D6.1: Robot Roles, Personality and Interaction Behaviours. ACCOMPANY Del 6.1 Report (2013)
23. Accompany project. http://www.accompanyproject.eu/
24. Nani, M., Caleb-Solly, P., Dogramadgi, S., Fear, C., van den Heuvel, H.: MOBISERV: an integrated intelligent home environment for the provision of health, nutrition and mobility services to the elderly. In: Proc. of the 4th Companion Robotics Institute, Brussels (2010)
25. Mobiserv. http://www.mobiserv.info/

26. Panek, P., Edelmayer, G., Mayer, P., Beck, C., Rauhala, M.: User acceptance of a mobile LED projector on a socially assistive robot. In: Wichert, R., Klausing, H. (eds.) Ambient Assisted Living. 6. AAL-Kongress 2013, Berlin, Germany. Springer Science & Business Media, pp. 77–91 (2013). ISBN 3642379885
27. Long lasting memories. http://www.longlastingmemories.eu/
28. Gärtner, L.: Siemens smart home solutions agenda – siemens smart home. In: Totally Integrated Home Conference, Brussels (2006)
29. Kamel Boulos, M.N., Lou, R.C., Anastasiou, A., Nugent, C.D., Alexandersson, J., Zimmermann, G., Cortes, U., Casas, R.: Connectivity for healthcare and well-being management: examples from six European projects. Int. J. Environ. Res. Public Health **6**(7), 1947–1971 (2009)
30. Van Velsen, L., Wentzel, J., Van Gemert-Pijnen, J.E.W.C.: Designing eHealth that matters via a multidisciplinary requirements development approach. JMIR Research Protocols **2**(1), e21 (2013)
31. Cooper, A.: The origin of personas. Cooper Journal, May 15, 2008. http://www.cooper.com/journal/2003/08/the_origin_of_personas.html
32. Goodwin, K.: Getting from research to personas: harnessing the power of data. Cooper Journal, May 15, 2008. http://www.cooper.com/journal/2002/11/getting_from_research_to_perso.html
33. The eWALL project, funded by the European Union's Seventh Framework Programme under grant agreement no 610658 http://eWALLproject.eu/
34. Tabak, M., Brusse-keizer, M., Van Der Valk, P., Hermens, H., Vollenbroek-Hutten, M.: A telehealth program for self-management of COPD exacerbations and promotion of an active lifestyle : a pilot randomized controlled trial. Int. J. COPD, 935–944 (2014)
35. op den Akker, H., Tabak, M., Marin-Perianu, M., Huis in't Veld, M.H.A., Jones, V.M., Hofs, D.H.W., Tönis, T.M., van Schooten, B.W., Vollenbroek-Hutten, M.M.R., Hermens, H.J.: Development and evaluation of a sensor-based system for remote monitoring and treatment of chronic diseases - the continuous care & coaching platform. (Invited). In: Proceedings of the 6th International Symposium on eHealth Services and Technologies, EHST 2012, Geneva, Switzerland, pp. 19–27. SciTePress - Science and Technology Publications (2012). ISBN 978-989-8565-27-3