"Maybe it becomes a buddy, but do not call it a robot" – Seamless Cooperation between Companion Robotics and Smart Homes

Claire Huijnen[1], Atta Badii[2,] Herjan van den Heuvel[1], Praminda Caleb-Solly[3,] Daniel Thiemert[2]

[1] Stichting Smart Homes, P.O. Box 8825, 5605 LV Eindhoven, The Netherlands
{c.huijnen, h.vdheuvel}@smart-homes.nl
[2] Intelligent Systems Research Laboratory, University of Reading, White Knights Campus, Reading, RG6 6AY, United Kingdom
{atta.badii, daniel.thiemert}@reading.ac.uk
[3] Bristol Institute of Technology, University of the West of England, Frenchay Campus, Bristol BS16 1QY, United Kingdom
praminda.caleb-solly@uwe.ac.uk

Abstract. This paper describes the findings arising from ongoing qualitative usability evaluation studies on mobile companion robotics in smart home environments from two research projects focused on socio-technical innovation to support independent living (*CompanionAble* and *Mobiserv*). Key findings are described, and it is stated that the robotic companion, the smart home environment, and external services need to be seamlessly integrated to create a truly supportive and trusted system. The idea of *robot personas* is introduced, and based on our empirical observations, it is argued that the robot persona, rather than the physical embodiment, is the most important determinant of the degree of users' acceptance in terms of users' perceived trustability and responsiveness of the robot and therefore their sense of enhanced usability and satisfaction with such personal assistive systems.

Keywords: companion robotics, smart homes, ambient assisted living, independent living, human-robot interactivity, social robotics, man-machine mixed initiative taking, user-centred co-design, UI-REF, robo-humatics

1 Introduction

Independent living, enhanced quality-of-life, wellbeing, and not feeling isolated or alone are generally viewed as amongst our shared values and goals. As life expectancy in the EU and other countries is continuously increasing [1], the percentage of older adults in the population is growing, and more and more older persons live alone and desire to age at home. The move from 'home' via 'protected living' to 'nursing home' is often regarded as heralding a trend towards reduced independence which is not viewed positively by most since staying as independent as (long as) possible gives satisfaction to individuals and reduces societal costs.

ICT can play an important role in responding to the personal and societal needs for prolonging this (active) independent living and improved quality-of-life and health outlook [2]. Smart home technology proved to have positive impacts on people's lives as well as on the lives of the informal caregivers [13]. In this paper, we focus on the seamless semantic integration and cooperation between social assistive robotics with smart home environments.

2 Robotics and Smart Homes

An emerging trend in smart home technology is that such environments become increasingly capable of inter-operation with many assistive devices and services within and outside the home [3]. A personal assistive robot could be one of these devices. Such robots are becoming a realistic expectation of user-adaptive assistive technology of the future, supporting comfort and companionship within the home; particularly for older or impaired persons but potentially for all citizens. There are a number of related national and European projects; e.g. *Care-O-Bot*, a mobile service robot focussed on the execution of fetch-and-carry tasks to support the personnel of older persons nursing home in their daily tasks [4]; *RoboCare,* a multi-agent human assistance system, composed of a robotic agent, sensors for continuous monitoring, and additional reasoning systems [5]; *K-SERA,* a social robot that monitors, helps and alerts persons with COPD during their daily activities, to facilitate effective self-management of their disease [6]; and *Florence*, a robot with existing home automation infrastructures and local and remote communication services, to improve home care for older persons [7]. Similarly, projects like *CompanionAble* [8] and *Mobiserv* [9] recognize that the next frontier towards close and sensitive cooperation between a smart home and a social companion robot would be via improving natural and inspiring interaction, and addressing more user needs in a trusted manner. Due to the nature of this close cooperation, interaction possibilities will be numerous. The user would expect to interact through touch screens around the home and on the robot, as well as through other interaction modalities, e.g. through voice or gestures.

3 The Companions

The vision motivating the authors' work under the *CompanionAble* and *Mobiserv* research programmes is to design and validate an architecture for semantically integrated companion robotics and ambient intelligence technologies so as to provide for a socio-technically acceptable assistive companion environment. Using a robot that understands you when you speak and engages in a meaningful dialogue seems more motivating, engaging, and fun than using a (tablet) screen. Moreover, another dimension is added when the possibilities of embodiment are exploited.

Our work has included advanced relationship-centred co-design approaches (e.g. UI-REF [8]) requiring close contact with end-users, their proxies, and end-user organisations in several European countries. Accordingly, the insights gained through extensive user-centred research (such as cultural probes, focus groups, semi-structured interviews, use-context studies) have build a consistently integrated

requirements formalisation and usability evaluation of the resulting smart-home companion systems. From these results and through several user-centred design cycles, in both projects a set of key functionalities have been defined.

Fig. 1. CompanionAble Robot 'Hector'

Fig. 2. Mobiserv Robot 'Kompaï'

CompanionAble serves the needs of persons with mild cognitive impairments (MCI) and provides a cognitive assistive companion to support their wellbeing, life-style management and security. This includes a range of use-cases such as cognitive training, games, social inclusion mechanisms, home-care such as intelligent day-time-management, context-aware reminders for medication intake and appointments, safety reminders, analysis of emotions, prevention of dangerous situations, recognition of distress signals, and the ability to remotely control the robot.

Mobiserv is targeted at older persons with early dementia and/or physical disabilities and provides health-care support, wellness monitoring, safety protection, and social support through nutrition assistance and dehydration prevention. This includes a health-coach providing a self-check platform and motivational advice for physical activities as well as games for social and cognitive stimulation responsive to the user's emotions. Mobiserv also provides a mobile remote control for the home and a panic responder with audio/video communication to a service centre, family/friends.

4 User trials

Extensive trials were conducted with the two prototypes integrated with a smart home environment. Both trials took place in a fully functional smart home, including living room, kitchen, etc. [10]. A range of potential end-users took part in the trials and their views on the performance and usability of the systems were elicited.

For *Mobiserv*, realistic video prototypes of the functions were shown to the test participants on the actual robot prototype. Participants performed basic tasks with the autonomously running robot. Five persons participated in this trial (age; 67 – 76).

For *CompanionAble*, a partly autonomous robot prototype was used in combination with a 'Wizard-of-Oz'-controlled smart home. A number of scenarios where conducted: welcome home, medicine reminders; wellbeing monitoring, fridge-door-left-open warning, cognitive training, remote control. A total of ten MCI persons participated in these trials (age; 52 – 88). Through analysis of the feedback from 25 trial sessions, key findings were as follows:

Interaction and Usability: The perception of comfortable interactivity-usability was associated with factors such as the quality/tone of voice, dialogue style (reminding or encouraging), turn-taking behaviour i.e. optimal control of robotic pro-activity in man-machine initiative taking [9,10] and the level of surprise / predictability in user-system interactions.

Being a Companion: The perceived level of companionship was strongly influenced by the capability of the system to adapt to the situated preferences of the user in the given use-context. This implies context-aware responsiveness; i.e. knowing when to react, what to do and how to best present information to a given user based on their abilities and preferences. Smart dialogue management and different 'characters' of the companion system where strong user needs.

Control and Trust: The perceived level of trust influences the potential for user-system inter-working. Cooperation and co-design of the system involving the professional carers can build trust. Furthermore, expectation management, offering appropriate support, intelligent dialogue, and positive reinforcements increase the feeling of enhanced autonomy and trust. Trust is relationship-based and as is the case with human relationships, it is experientially informed; e.g. already during the two hours of the user trials, users indicated that they gained trust in the system.

Acceptance and Privacy: Privacy protection assurance and technology acceptance are needs influenced by the capability of the system for social situation awareness, context-sensitive and helpful responses, as well as transparency of the interactivity logic (e.g. the system making it clear to the user the reason for its recommendations/ actions/state in a given context). This includes context-aware privacy, as privacy dynamically depends on the time, place, purpose, social setting, and conditions.

5 Conclusions

Companion robotics pose a number of challenges as well as opportunities. Our user trials with such systems have led to the following observations:

Advanced Interactivity: The users' expectations of such companionable systems are much more exacting than the capabilities of current ICT technologies. Challenges include a safety and security protective operation, advanced personalisation, highly responsive context-and-privacy-awareness, emotionally-intelligent dialogue, safe navigation, mixed-initiative taking, and invitational tone of voice, and pro-active and context-sensitive assistance (e.g. reminding, alerting).

Powerful Synergy: The above capabilities can be best realised given the semantic integration of ambient devices within a smart environment. Companion robots, when part of a bigger infrastructure of external sensors and actuators, become empowered to deliver their functionalities more intelligently and effectively. It is of utmost importance that the smart home and the robot are fully integrated and are thus both aware of the status and needs of the inhabitant(s), social setting and the outside world.

Robot Personas: Obviously users differ in their personal preferences regarding the roles, responsibilities and thus the type of persona they would like to see in their companion robot [10]. Therefore there is a need for the companion robot to be capable of (re)instantiation of its own character to match user-specified robot personas. Note the differences in the style of a companion as a butler/servant, a friendly helper, an entertainer, or a guardian angel. Our empirical evidence, based on our user trials, suggests that users care significantly less about the robot's design and physical embodiment, than about its functionality and 'character' or interaction style.

Future Work: There are several areas of outstanding challenges relating to the co-design of user-centred companion-social robot personas and their graceful integration

with smart homes. For example, technically, it is feasible to tell a person where the keys that he may be looking for are located. We should question ourselves, as to whether we are really giving them what they need or just what they want. There may be occasions when the deeper value of such assistive intervention may lie in a smarter dialogue that triggers users to deploy their own intellectual resources.

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