Chapter 8
Ambient Assisted Living Systems in Real-Life Situations: Experiences from the SOPRANO Project

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8.1 Introduction

The challenge of an aging population requires innovative approaches to meet the needs of increasing numbers of older people within society (Sixsmith & Sixsmith, 2008). In particular, there is a need to move from a health and social agenda that emphasizes dependency to one that promotes active aging and creates supportive

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environments to enable healthy aging in the settings where older people live (Sixsmith et al., 2010). Emerging information and communication technologies (ICTs), such as pervasive computing and ubiquitous computing, have considerable potential for enhancing the lives of many older people throughout the world and helping them to age in place (Sixsmith & Sixsmith, 2008). Ambient Assisted Living (AAL) refers to ICT systems, products, and services that integrate sensors, actuators, smart interfaces, artificial intelligence, and communications networks to provide more supportive environments for frail and disabled older people (Mokhtari, Khalil, Bauchet, Zhang, & Nugent, 2009; van den Broek, Cavallo, & Wehrmann, 2010). AAL has been an important emerging area of research over recent years involving collaboration between domain experts (health sciences, rehabilitation, gerontology, and social sciences) and technical experts (engineering, computing science, robotics). Research and development within AAL has aimed to develop applications and systems to facilitate independence (van den Broek et al., 2010), such as activity monitoring to detect potential emergencies, reminder devices for supporting and encouraging mobility and activities of daily living, monitoring activity patterns as indicators of change in cognitive and physical status, and smart interfaces to help people control their everyday environment. The European research project SOPRANO (Service-oriented Programmable Smart Environments for Older Europeans) developed supportive environments for older people based on the concept of AAL.

The SOPRANO system is an innovative integration of several new smart functionalities in the homes of older people. These functionalities allow the SOPRANO system to be used for various purposes in different situations. However, it is intended that users have a seamless experience in the sense that they perceive that they are supported by a single system. A major aim within the project has been to move away from technology-push and problem-focused approaches to user-driven approaches and how to explore, visualize, and map out an AAL system that will have practical benefits for users in their everyday lives.

In the final, field trials stage of the SOPRANO project, the subject of this chapter, the focus was on evaluating the possibilities of the integrated system and on demonstrating the spectrum of factors that influence the use of SOPRANO. The field trials consisted of two parts: *full function trials* and *large-scale field trials*. During the full function trials, the entire SOPRANO system was tested. Since the development was not completed for every single part of the SOPRANO system, feedback from users was gathered either as input to the design process and/or as evaluation on the

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functionality of the total SOPRANO system. Since some innovative parts of the SOPRANO technology and services were still in the design process and were not yet proven to be reliable, to reduce participant burden, the full function trials were conducted in research facilities.

During the large-scale field trials, a subset of the SOPRANO system was installed in homes of end users. Different service levels were used to provide support to the users during the trials.

Acceptance is a key issue during field trials and is based on multiple factors that are described in the Smart Home Technology Acceptance Model (Bierhoff, 2011). It is important to differentiate between the acceptance of users exposed to the system for a short duration in a laboratory during the full function trials and the acceptance of users who experienced the system in their natural environment and daily life in the large-scale field trials.

This chapter starts with a description of user involvement, the SOPRANO system itself, and the use cases that were developed. This is followed by a description of the methodology and the framework used for analyzing the field trial results. In the next section a description of the field trial sites and the different stakeholders that participated in the field trials is given. This is followed by a description of the preparatory work for the field trials and the results of both the full function and the large-scale trials. The chapter concludes with an overview of lessons learned from the SOPRANO project.

8.2 SOPRANO User Involvement, Use Cases, and System

The SOPRANO project adopted a user-driven approach to ensure that technological development was usable, useful, and acceptable in the everyday life context of older users. Research, development, and design by, with, and for users were implemented at all stages of the product development life cycle. The focus on in situ use of SOPRANO facilitated the move from a health and social agenda that emphasized dependency to one that promotes active aging and creates supportive environments to enable healthy aging in the settings where older people live.

8.2.1 Iterative User Involvement

Users were actively involved at all four stages of the SOPRANO development process (see Fig. 8.1). The aim of the first stage, the elicitation of basic service requirements, was to find out which situations in daily life threaten the independence of older people or perceptibly limit their quality of life. Starting with an inventory drawn up by experts, situations that can threaten the independence of older people were collected. The inventory was complemented with information

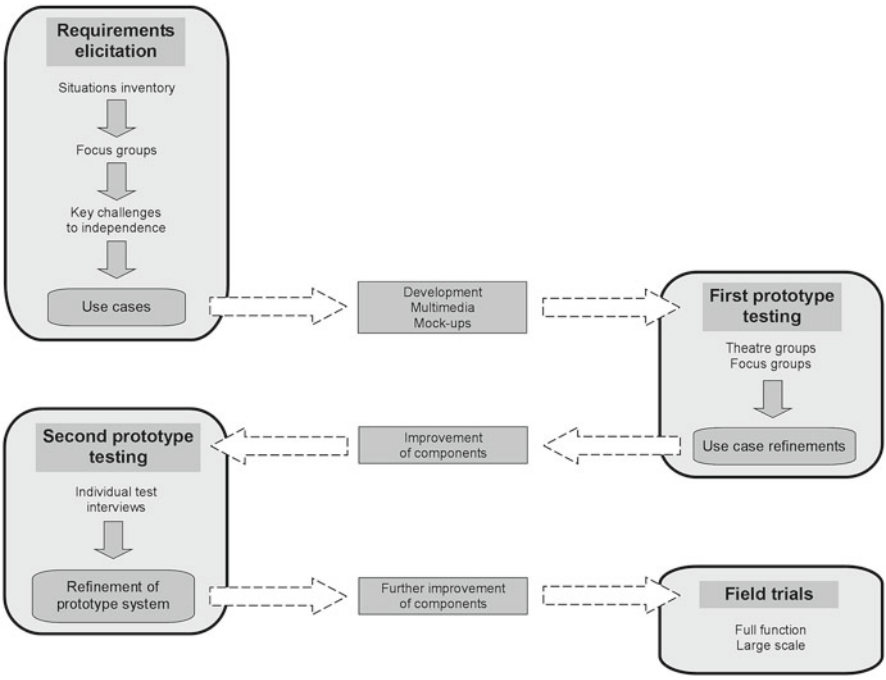

Fig. 8.1 Iterative development process in the SOPRANO project

from focus groups carried out with older people. Scenarios of new ICT-based services to address key challenges to independence were then developed. These included *use cases*—descriptive models—of how an AAL-based service can interact with a user in relation to a particular problem scenario (e.g., reminding a person about medication). Their purpose was to reflect not only the functionalities of the technical system under design but also the processes, actions, and interaction with the system of various actors/agencies: informal and formal carers, service provider agencies, GPs/hospitals, and the assisted older person her/himself.

Multimedia mock-ups and theater plays were developed to show the use cases to users during the first virtual prototype tests. Feedback from these was used to refine and improve the components in the use cases. The improved components were the subject of a second set of prototype tests that led to further improvement of the components. In the last stage were field trials where the system was installed and tested in laboratories (full function trials) and home settings (large-scale trials).

8.2.2 SOPRANO Use Cases

SOPRANO use cases do not merely reflect the development of a technical system and components but include a strong reference to the social world within which the person lives. This is crucial as the key to creating useful and acceptable technology-based services is to understand how they are embedded in a person's everyday life. The following use cases were used in the SOPRANO field trials (the type of trial in which each was used is shown in parentheses).

Medication reminding (full function and large-scale field trials): addressed the needs of older persons experiencing light to moderate forgetfulness who have to take medication at regular intervals and was targeted at improving adherence. For many older people, the ability to remain independent in their home depends on their ability to manage a complicated medication regimen (Dorman Marek & Antle, 2008). The full benefit of the many specific medications that are available can only be achieved if patients follow the prescribed treatment regimes reasonably closely (Osterberg & Blaschke, 2005). Poor adherence to medication regimes, particularly for older people, contributes to substantial worsening of quality of life, disease, death, and increased healthcare costs (Dorman Marek & Antle, 2008; Hayes et al., 2009; Osterberg & Blaschke, 2005). Reminders have been found to improve adherence (Hayes et al., 2009; World Health Organization, 2003). Older people can understand reminders spoken in a synthetic voice, provided the prompt texts are well designed, use familiar words, and incorporate redundancy (Wolters, Campbell, DePlacido, Lidell, & Owens, 2007).

> *At pre-set times (set by the person in charge of the medication regime) a reminder buzz will sound to alert the older person to take the medication from the dispenser. Additionally a reminder is either displayed on the TV (when turned on) accompanied with a synthetic auditory reminder. If the dispenser is not opened, repeated alerts will be activated by the system and after a certain period of time, an automatic message will be sent either to a professional carer or an informal carer.*

Remembering (full function and large-scale field trials): addressed users who experience increased forgetfulness in daily life situations, such as leaving the house without closing the windows or door, forgetting the house key or leaving appliances (TV, lights, etc.) running, and also forgetting important appointments. From research, it appears that older persons worry about their diminishing memory (Commissaris, Ponds, & Jolles, 1998), feel less in control of their memory functioning than younger people (Dixon & Hultsch, 1983), and are more upset when they forget run-of-the-mill events (Cavanaugh, Grady, & Perlmutter, 1983). A number of authors identify the loss of personal independence as a major concern for most elderly people (Bayer & Harper, 2000; Mynatt, Melenhorst, Fisk, & Rogers, 2004; Shafer, 2000; Starner, Auxier, Ashbrook, & Gandy, 2000). More and more AAL projects address these needs by designing applications that explicitly aim at increasing safety and well-being for elderly users (Röcker, Ziefle, & Holzinger, 2011).

> *When the user opens the front door to leave the house, SOPRANO checks the installed peripherals to determine if anything was forgotten to be switched off. If there was something still running, an alert message is displayed on the touch screen informing the user of the*

things that are not in order. The user can confirm that the warnings are read by touching the button 'I took care of it'. In case the user doesn't touch this button a message will be sent to an (in)formal carer. The user can also actively check the status of the house via the SOPRANO menu on the TV. Further to this, the user or a family member living in the household can enter important appointments into the system, via the user interface, and the user will be reminded of these appointments by SOPRANO.

Exercise facilitation (full function and large-scale field trials)*:* focused on helping older people to improve their general fitness level by regular physical exercise. In order to improve cardiorespiratory and muscular fitness, bone, and functional health and to reduce the risk of noncommunicable diseases, depression, and cognitive decline, the World Health Organization (2010) recommends adults aged 65 years and above perform at least 150 min of moderate-intensity aerobic physical activity or 75 min of vigorous-intensity aerobic physical activity per week, or an equivalent combination of moderate- and vigorous-intensity activity. In SOPRANO an avatar was used to show how the exercises should be performed. Several recent studies (Kim, 2004; Ortiz et al., 2007) have concluded that conversational avatars are a good tool for obtaining a more natural communication with a user.

Whenever the exercises are due, SOPRANO will remind the user and, when s/he has given their consent, the exercises performed by an avatar will be displayed on the TV for the user to follow. The first time the exercises are performed, a carer/physiotherapist will be present to introduce the user to the new procedure.

Fall detection (full function trials): addressed older persons who are vulnerable and at risk of experiencing falls in the home. About 30 % of people over 65 years living in the community fall each year (Gillespie et al., 2008); 40 % of the people above the age of 75 need medical treatment after a fall (Davis, Robertson, Ashe, Liu-Ambrose, & Khan, 2010).

In case of a fall, the system will become active and first ask the user whether s/he is OK, and if the user confirms, the alarm is cancelled. If not, an alert message will be sent to the informal carer or professional carer (depending on the pre-set protocol) informing them about the situation and asking them to look after the user. During the whole procedure, SOPRANO will communicate to the user the steps it is taking to give them reassurance that help is on the way.

Entertaining (full function trials): addressed users who are becoming less and less active and are experiencing increasing boredom and loneliness. Loneliness and social isolation are often associated with older age and have been identified as risk factors for a number of health (both physical and mental) and related problems (Byles, Harris, Nair, & Butler, 1996; Grenade & Boldy, 2008; Savikko, Routasalo, Tilvis, Strandberg, & Pitkälä, 2005; Sugisawa, Liang & Liu, 1994; Walker & Beauchene, 1991). When providing interventions, it is important for service providers to acknowledge and accommodate individual differences (Findlay & Cartwright, 2002; Hicks, 2000).

The system is configured by the care provider to include a profile of the user's interests including leisure time activities, favorite TV shows, local community events, etc. *The system is also configured to accommodate how often the user should be contacted, to ask how they feel and if they need any suggestions for activities for the day.*

Activity monitoring (full function trials): addressed older people experiencing deterioration in their overall health status due to unfavorable changes in nutrition. The prevalence of malnutrition is relatively high in older people affecting over 10 % of the population aged 65 years and above (Baeyens, Elia, Greengross, & Rea, 1996).

The system supports the user in developing more favorable daily routines by reminding of meal times and suggesting recipes to be cooked.

Safety monitoring (full function trials): addressed users experiencing difficulties related to sleeping who get out of bed and walk through the house at night, to make a cup of tea or to watch TV. For many, aging is associated with decreased total sleep time, increased sleep latency, and more awakenings particularly in the latter stages of the night (Baskett et al., 2001). In terms of sleeping disorders, the focus in SOPRANO was on sleep apnea.

When the user wakes up at night and gets out of bed, the SOPRANO system detects this via the bed occupancy sensor and will turn on the light beside the bed to prevent the user from stumbling and falling. After a predefined time of absence from the bed, the system will check if the user is OK, or otherwise, send an alarm to the carer. This check will be based on data from appliances (e.g. cooker on or off). Depending on the outcomes of the check, the system will contact the user to ask if everything is OK and send an alarm to the care provider if necessary. Sleep apnea can be detected without a person having to wear something on the body by a radar that is installed above the bed.

8.2.3 SOPRANO Prototype System

For the use cases developed, a common hardware setup was created. This setup supported both the complete SOPRANO system shown in laboratories and the subset of the system installed in real homes.

In the labs, all use cases were installed and shown in detail to the participants. In general terms the use cases were divided into three categories:

1. Fully SOPRANO integrated (memory facilitating, fall detecting, medication reminding)
2. Content based (exercise facilitating, activity monitoring, entertaining)
3. Very innovative (safety monitoring)

The home installations were comprised of a subset of the SOPRANO system: a selection of use cases that were selected based on security and reliability, user-system interaction, inclusion of carers, frequency of need, and the development of devices. The system subset supported the following use cases: medication reminding, memory facilitating, and exercise facilitating. A selection of the equipment used for the in-home large-scale field trials is presented in Fig. 8.2.

Besides the equipment displayed in Fig. 8.2, a SOPRANO PC was supplied that ran the services. Other additional devices were the TAPIT module to connect the Connect+ to the SOPRANO PC, a video cable to connect the SOPRANO PC with the TV, a TV tuner/frame grabber to feed the TV signal to the iTV module running

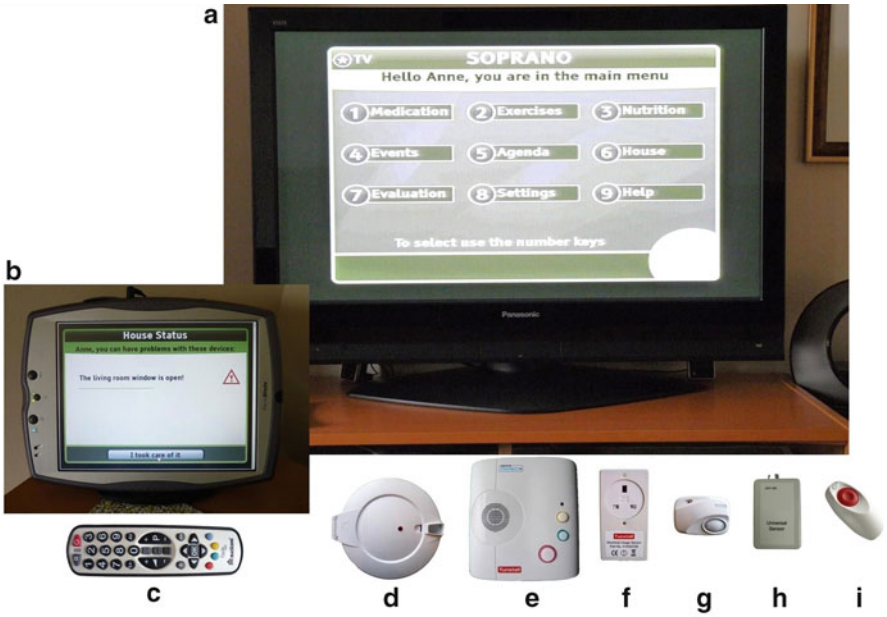

Fig. 8.2 Selection of equipment used for large-scale field trials. (a) SOPRANO main menu available on the TV. (b) Touchscreen installed next to the main entrance displaying warning messages when leaving the home in case home appliances are still running or windows are open. (c) Remote control used to operate the SOPRANO menu on the TV. (d) Medication dispenser. (e) Home telecare platform (Connect+) that receives messages from medication dispenser, electrical usage sensor, fall detector, universal sensor and security red button. (f) Electrical usage sensor to monitor the electrical consumption of home appliances. (g) Fall detector. (h) Universal sensor to detect if a window or door is open. (i) Security red button

on the SOPRANO PC, and a remote control interface that received input from the SOPRANO remote control.

8.3 Methodology for Field Trials

To decide which methods of evaluation to use in the full function trials and the large-scale field trials, the well-established theory of care quality by Donabedian (1969) and its extension into three quality perspectives by Øvretveit (1992) offered a fruitful approach. This model of evaluation defines a service in terms of inputs, process, and outcomes to be evaluated from the perspectives of the clients (patients), professionals, and managers. These three perspectives refer to the three central stakeholders in care provision and allow quality to be evaluated from three perspectives:

Table 8.1 SOPRANO multi-method approach to user-driven research

Stakeholder/ perspective	Inputs	Process	Outcomes
Older person (client, patient)	*Personal characteristics*: Psychological Physical Cognitive	*Acceptability*: Is the assisted person prepared to accept the system in everyday living context and what features are preferred or disliked?	Well-being Perceived independence Remain living at home Increased participation
	Contextual factors: Home environment Neighborhood	*Usability*: How user friendly is the system, what barriers exist in its use, how well does it fit the social and living context of the person?	
Informal carer	Support network	Involved in some SOPRANO use cases. Also sees the effects on the older person	Reduced anxiety Reduced stress
Care professional (formal carer)	Care services	Involved in some SOPRANO use cases. Also sees the effects on the older person	Improved quality of service
Care management	Financial resources	Integration of SOPRANO use cases in care provision	Reduced costs, e.g., reduction in hospitalization
Building/technical	Buildings	Integration of SOPRANO system in new and existing buildings	Improved market value of property

1. *Patient quality*: the service provides patients with what they want and expect, during and after the service.
2. *Professional quality*: the service follows procedures and methods which are thought to be most effective in meeting patients' clinical needs, as assessed by health professionals.
3. *Management quality*: the service uses available resources in the best way to achieve patient and professional quality, without waste and within higher level requirements.

This model was used to frame the evaluation of the SOPRANO system. Although SOPRANO did not focus on clinical care, the service-oriented approach of the model was still applicable. However, due to the nature of service delivery in the home environment, additions were made to the list of perspectives. The perspective of the informal carer was added because in the home environment, care provision is often divided between self-care, informal care, and formal care. Furthermore, since the SOPRANO system needs to be installed in the home, the perspective of building

stakeholders, for example, a housing association or a property developer, is also relevant. The chosen multi-method approach is displayed in Table 8.1.

8.3.1 Full Function Trials Methodology

SOPRANO aimed to find out how users accepted a very complex, integrated system. To do so, in the full function trials, users were invited to laboratories where they could experience the whole integrated system and give feedback. In the laboratories, use cases were used to explore the possibilities and show the added value of the SOPRANO system. By doing so, it was also possible to show the connectivity between different parts of the system. Participants in the full function trials took part in a guided exploration of the SOPRANO system, with some limited possibilities for free exploration, or took part in an in-depth analysis of specific parts of the SOPRANO system.

The full function trials started with a pretest to evaluate (1) the equipment and use cases, (2) protocols, and (3) the questionnaires. Testing the equipment and use cases explored the integration of the components and the manner in which the use cases could be presented. Besides the technical integration, it was also important to decide how the interconnectivity between all components could best be shown to future participants. Pretesting of the protocols and the questionnaires was completed in two steps. First, the plans for the guided tours and evaluation materials were assessed by experts and their comments were taken into account. Second, before the guided tours commenced, a group of older persons was invited to give their comments on a preliminary version of the guided tour.

The participants for the subsequent guided tours included representatives from the five stakeholder groups described in Table 8.1. The majority were older persons who would be the main users of the SOPRANO system. The inclusion of stakeholders who do not directly interact with the system, but who play a role in service delivery, was a significant departure from previous research cycles.

In a second part of the full function trials, an in-depth analysis was conducted of the graphical user interface (GUI) on TV and touch screen. The main aim was to test how alterations, based upon improvements suggested by participants in previous research cycles, were perceived. Additionally, some tests were performed on the Admin GUI, which provided informal and formal carers with the possibility of uploading information to the SOPRANO system.

8.3.2 Large-Scale Trials Methodology

To find out how users accepted the system at home in their own environment, user homes were equipped with a subset of the SOPRANO system. To prepare for the in-home trials, each site set up a test environment. The purpose was twofold. First, the trial site would gain experience in setting up the system and could check if the system met their own standards for installing technology in homes of service users. Second,

when the system was running, potential participants could be invited to see it before they made a final decision about whether or not to participate in the large-scale trial.

The large-scale trials involved older persons, informal carers, care organizations (focus on user and technical aspects), and local installers. They each played a specific role in the implementation process of the SOPRANO use cases in real homes. The following are the steps in the process and the participants involved (in parentheses):

- Setting up the test environment (care organization): This step involved the setup of a test environment at each large-scale trial site.
- Visit to test environment (care organization, older persons, informal carers): Users might have difficulties in imagining how the system would work. Therefore, it was decided to invite them to the test environment and show them the system to help them with their decision to participate in the trial.
- Technical checklist (care organization, local installer): This included a technical assessment of the home, covering aspects such as Internet connection, TV set, TV signal, and telephone line.
- Acquisition questionnaire (older person, informal carer): These questionnaires contained the inclusion/exclusion criteria, and were used during the recruitment process, in order to derive an appropriate sample of persons that could participate in the large-scale field trials.
- Installation visit (care organization, local installer): In cooperation with the user, carer, and local installer, a date was set when the SOPRANO system would be installed.
- Preinstallation interview (older person, informal carer).
- Post-installation interview (older person, informal carer).

The preinstallation interview was an in-depth individual interview focused on the attitudes, expectations, and technical experience of users and their informal caregivers. The post-installation interview focused on users' and informal caregivers' overall impressions of the SOPRANO system, expectations, attitudes, and feelings towards the system, perceived benefits and added value, and utility of the SOPRANO system. Older persons reported upon their own experience trying out the SOPRANO system. Informal carers commented on how they interacted with the SOPRANO system and about the way the older person they cared for felt about the SORPANO system, the changes it had made in the daily life of the older person, and whether or not the older person was overstrained by the system.

8.4 Framework for Analyzing Results from Field Trials

During the field trials, a variety of responses from participants were collected. The Smart Home Technology Acceptance Model presented below was used as the framework for analyzing the information collected. A mix of quantitative and qualitative methods was used to evaluate these trials.

8.4.1 Smart Home Technology Acceptance Model

The Smart Home Technology Acceptance Model (SHTAM) shown in Fig. 8.3 is based on three models. The first, the *USE-Model* (Dewsbury, Sommerville, Rouncefield, & Clarke, 2002), considers the concept of home as an interrelationship among three overlapping spheres—the user, the system, and the environment. The second was a model of the acceptability of assistive systems developed by McCreadie and Tinker (2005), the most important aspect of which is what the authors call *felt need for assistance.* Felt need depends on several user characteristics, the housing type and design, and the interaction of these variables. The third model was a reformulation of the Technology Acceptance Model (TAM) (Davis, 1989) that takes into account other theories about technology and behavior adoption as the Theory of Planned Behavior and Uses and Gratifications Theory (Venkatesh, Morris, Davis, & Davis, 2003). TAM suggests two factors as the principle antecedents of attitude towards a system: perceived usefulness and perceived ease of use. Many studies (Gardner & Amoroso, 2004; Lu, Yu, Liu & Yao, 2003; Nyseveen,

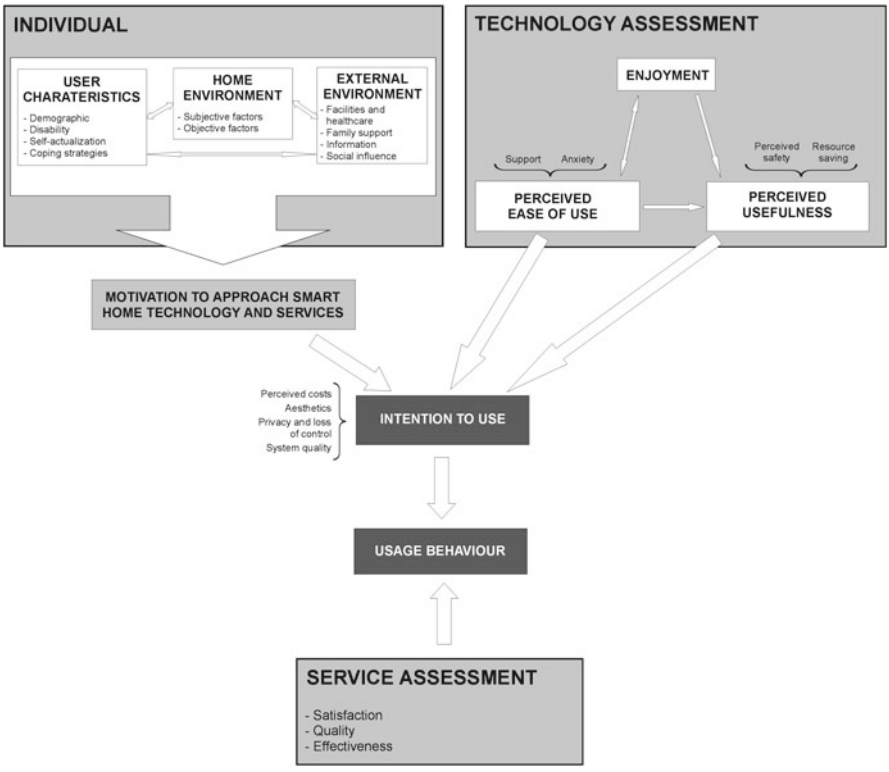

Fig. 8.3 Smart Home Technology Acceptance Model (Bierhoff, 2011; Conci, 2008)

Pedersen, & Thorbjørnsen, 2005) confirm that a more situation-specific model needs to be added to the TAM.

The SHTAM model is divided into three parts: *individual*, *technology*, and *service* related. The individual part of the model combines the characteristics of the user, the home environment, and the external environment. User characteristics include demographic information and also information about the psychological and physical condition of the person. The home environment part of the model includes subjective factors related to the perception of safety and comfort in the home and objective factors related to accessibility. The external environment part concerns facilities, services, family, and other sources of support and social influence.

The conjunction level, between the individual and the intention to use smart home technology and services, is called *motivation to approach smart home technology.* It is a transaction state that could be compared to the felt need for assistance of McCreadie and Tinker (2005). The characteristics of the user, the home environment, and the external environment together influence the motivation of the user to approach smart home technology and services. Motivation is related to expectations, attitudes, and feelings towards the system, in this case, the SOPRANO system, before actually using it.

The technology part of the model refers to the actual use of the system and its functionalities. The basis for this part of the model is the TAM with the two main factors: perceived usefulness and perceived ease of use (Davis, 1989). A third factor is added, namely enjoyment, which refers to the extent to which the activity of using the system is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated (Davis, Bagozzi, & Warshaw, 1992). Enjoyment is influenced by ease of use and will influence perceived usefulness (Kwon & Chidambaram, 2000; Yi & Hwang, 2003). Perceived ease of use is defined as the degree to which a person believes that using a system will be free from effort (Davis, 1989) and is influenced by support (Phang et al., 2006; Venkatesh & Morris, 2000) and anxiety (Venkatesh & Morris, 2000). Perceived ease of use influences perceived usefulness as an intention to use the system (Legris, Ingham, & Collerette, 2003). Perceived usefulness in this model consists of the benefit and added value of the system and is influenced by perceived safety against unexpected events and resource saving related to cost and time (Phang et al., 2006). A significant body of TAM research has shown that perceived usefulness is a strong determinant of intention to use a system (Venkatesh & Morris, 2000).

Intention to use the system is influenced by the motivation to approach the smart home technology and services (Gardner & Amoroso, 2004; Lu et al., 2003; Nyseveen et al., 2005), perceived costs (Kleijnen, Wetzels, & de Ruyter, 2004), aesthetics (Veryzer, 1995), privacy and loss of control (Wilkowska & Ziefle, 2011), and system quality (Kleijnen et al., 2004). System quality is composed of reliability, flexibility, integration, accessibility, and timeliness (Wixom & Todd, 2005).

Intention to use the system is reported to have a significant relationship with actual usage (Legris et al., 2003). The actual use of the system also depends on the whole chain of steps that occur behind it. It is not possible to evaluate a technological system without also taking into account the network of people that need to offer assistance. In

other words, evaluating a smart home system requires an assessment of all other factors that it is related to, i.e., service providers and provided service. In the model, the assessment of service provision is influenced by satisfaction, quality, and effectiveness.

8.4.2 Data Collected During Field Trials

During the full function trials, every participant filled in an acquisition questionnaire before visiting the laboratory. The questions included in it were based upon the individual-related part of the Smart Home Technology Acceptance Model. During the introduction of SOPRANO, which was the starting point of the guided tour, the project and the use cases were explained in detail. Participants asked clarifying questions and commented on the use cases. After the demonstration of a specific use case, each participant filled in an assessment questionnaire covering the technology and service assessment part of the model as well as intention to use. During the demonstration of the use cases, much attention was devoted to discussing the perceived usefulness, perceived ease of use, intention to use, and service provision. Minutes were taken of the discussions. During the usability tests, data were collected by making notes of comments and observing participants' actions when they performed tasks while thinking out loud during a detailed walk through.

Additionally, during the large-scale trials, every participant filled in an acquisition questionnaire before the subset of the SOPRANO system was installed in their home. Information regarding their technical experience, their expectations, and their attitudes towards the SOPRANO system was collected during the pre-interview with older persons and informal carers. The post-interview examined how the older person and the informal carer used SOPRANO and how it impacted on their lives. Besides these formal procedures, the user and technical experts from each trial site made notes of their own experiences related to their own role in the implementation process of the SOPRANO use cases in real homes.

8.5 Field Trial Sites and Participants

This section describes the locations for the field trial research and the participants who took part in the field trials.

8.5.1 Field Trial Sites

The full function (laboratory) trials were conducted in three different geographic locations in Europe. Consortium partners of SOPRANO were responsible for the lab at each site. Smart Homes was the consortium partner responsible for the lab in

Eindhoven, Netherlands; INGEMA in San Sebastian, Spain; and the London Borough of Newham for the lab in Newham, UK. For the large-scale trials (home installation), there were four sites. Archipel was the consortium partner responsible for the homes in Eindhoven, Netherlands; Fundación Andaluza de Servicios Sociales (FASS) for the homes in Malaga, Spain; the West Lothian Council for the home in West Lothian, UK; and the London Borough of Newham for the home in Newham, UK. The following figures provide an impression of activities at the different field trial sites (Figs. 8.4, 8.5, and 8.6).

8.5.2 Field Trial Participants

Participants who took part in the field trials for SOPRANO were experts from the consortium, local installers, older persons, informal carers, formal carers, and other stakeholders. Involving a broad range of stakeholders was seen as important for establishing the impact of SOPRANO from the multiple perspectives of those involved in delivering care.

A distinction can be made between experts from the consortium who took part in the user-related research and experts who were involved as technical experts. Professionals who work in the field of assistive technologies and user-system interaction experts were involved in assessing the integrated SOPRANO system. They were responsible for the final check of the SOPRANO system before other stakeholders were invited to take part in the field trials.

Experts in user-related research were an interdisciplinary team of researchers consisting of user-system interaction specialists, psychologists, and gerontologists. Their role was to fine-tune the way the use cases would be shown and implemented and to have a detailed look as to how the suggested methods would work out in practice with the current status of the SOPRANO system.

To set up the full function sites as well as the test environments at the large-scale sites, a local technical expert was engaged. The technical expert was in close contact with SOPRANO technical partners when setting up and testing the SOPRANO system. Problems related to the functioning of the use cases and practical installation issues were detected and solved.

In preparation for the installation in older persons' homes, the local technical expert visited each property to assess if the home was suitable to take part in the SOPRANO research and to make sure that all technical preconditions were met before the actual installation. Local installers were responsible for equipment installation and ongoing support during the trial period.

The other stakeholder groups who participated in the field trials represent the multi-method approach to user-driven research as presented in Table 8.1 and are described below.

A total of 189 older persons took part in the SOPRANO field trials; their mean age was 74. When asked if they experienced any aging-related problems, 31 % indicated that they did not. Among the participants who did face problems, most were

Fig. 8.4 SOPRANO full function trials in Eindhoven, Netherlands (*top photo*), and San Sebastian, Spain (*bottom photo*)

Fig. 8.5 SOPRANO full function trials in Newham (*top photo*) and large-scale test environment in Eindhoven (*bottom photo*)

Fig. 8.6 SOPRANO large-scale research in Malaga (*top photo*) and West Lothian (*bottom photo*)

related to declining physical health and mobility, fear of crime, forgetfulness, and financial difficulties (see Fig. 8.7).

Only a few people took no medication ($n = 19$). The majority of participants (45 %) took more than four types of medication (Fig. 8.8). Participants were aware of the reasons that they needed to take medication. Most health problems

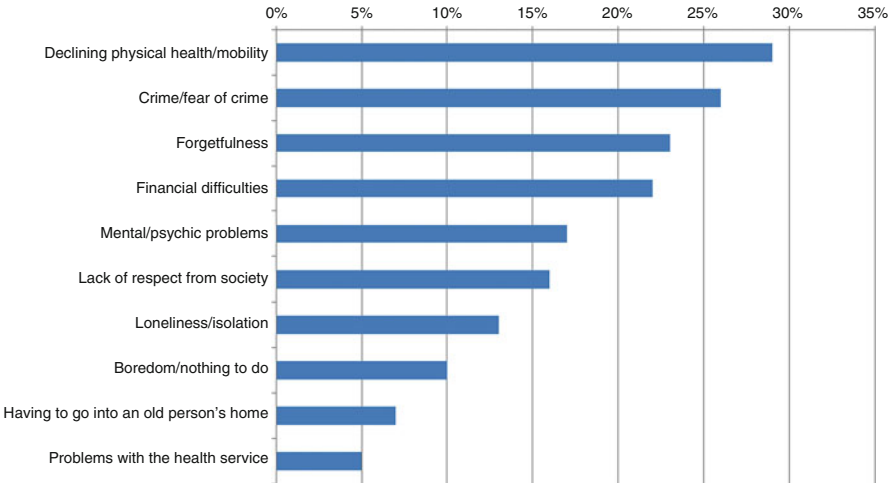

Fig. 8.7 Problems experienced by older persons ($n = 137$, use cases in general)

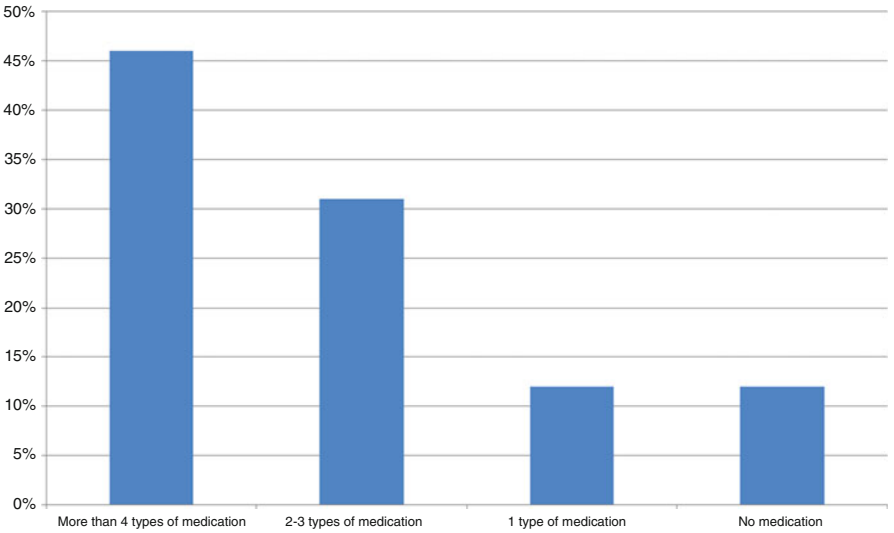

Fig. 8.8 Number of medications taken ($n = 166$, use case medication)

reported were related to high blood pressure, high cholesterol, heart rhythm disorder, and diabetes.

Regarding self-reported forgetfulness (Fig. 8.9), categories were as follows: 1 = never or a few times per year, 2 = a few times per month, 3 = a few times per week, and 4 = every day. The number of participants who reported some form of

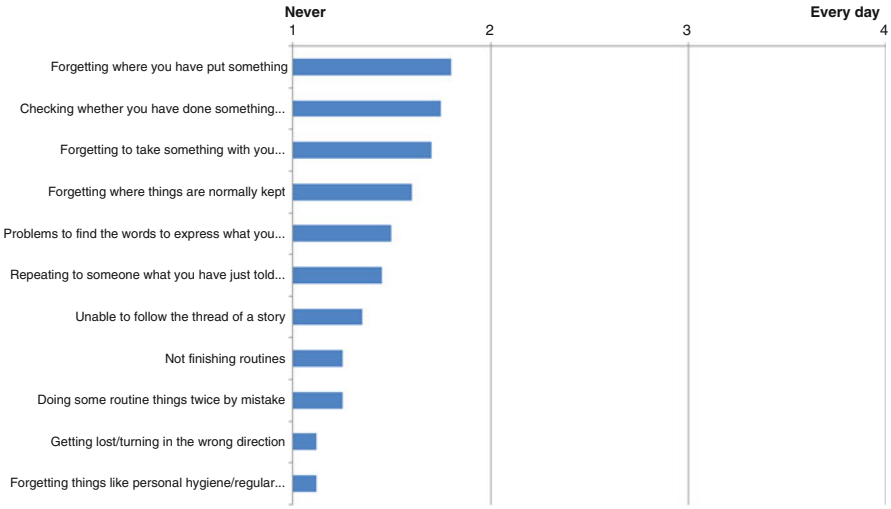

Fig. 8.9 Forgetfulness among the older people (self-assessment, $n = 131$, use case = remembering)

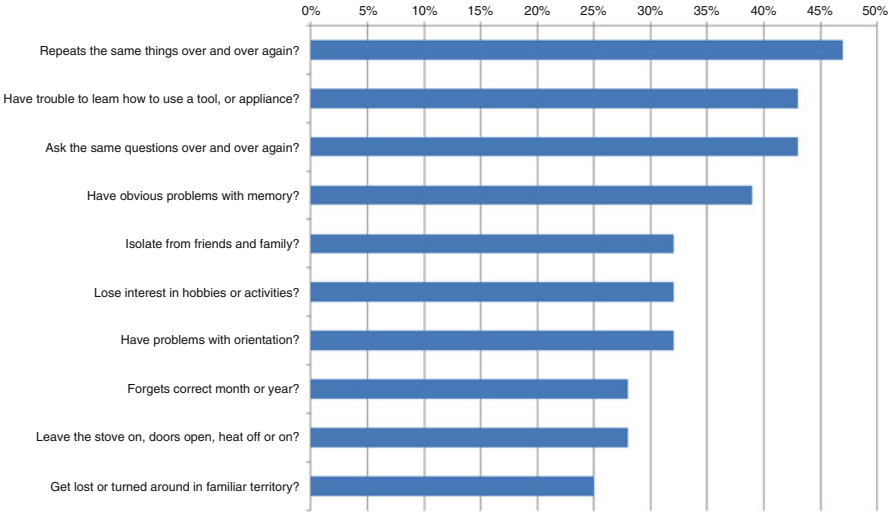

Fig. 8.10 Forgetfulness among the older people (assessed by their informal carers, $n = 28$, use case remembering)

memory problem was very low. Among those who did report problems, the most common were "forgetting where you have put something" (mean = 1.81; s.d. = 0.88) and "checking whether you have done something that you meant to do" (mean = 1.74; s.d. =0.69).

In addition to the older persons' self-assessment of forgetfulness, the informal carers were asked to provide a more "objective" external judgment. According to

the informal carers (see Fig. 8.10), the assisted persons most often tended to repeat the same things (46 %) and questions (43 %) over and over again. It is also worth mentioning that 43 % of the carers had trouble learning how to use a tool or appliance.

The average age of the 28 informal carers who participated was 55 years. In relation to the relatives whom they looked after, a significant number of informal carers either lived in the same home ($n = 10$) or resided less than 5 km away ($n = 11$). Most informal carers visited and/or called their relative daily or at least several times per week. The majority of informal carers (63 %) reported that they "do not feel strained" in caring "for and about" their relative, whilst 15 % indicated that they felt very strained by caring for and about their relative.

The group of formal carers ($n = 24$) who took part in the full function guided tours represented a diverse group. In terms of expertise, the following jobs/disciplines were represented: care and service consultants, case managers, specialists in gerontological nursing, psychologists, geriatric physiotherapist, and occupational therapists.

The care management group ($n = 11$) consisted of representatives from care provider organizations, decision-makers responsible for establishing care strategies, and those responsible for administering and managing budgets. The building/technology group ($n = 10$) consisted of representatives of installation companies, housing organizations, property developers, builders, and suppliers of smart home technology.

8.6 Field Trial Results

This section highlights the key findings of the SOPRANO field trials. It starts with a description of the delicate process of moving the SOPRANO system from a laboratory environment into real homes. The results of the field trials are then presented using the Smart Home Acceptance Model as the conceptual framework. When analyzing the results, an equal amount of attention was paid to similarities as well as to differences between the trial sites, since differences are equally important when it comes to implementing technology in real life.

8.6.1 From Laboratory to Real Home

The process of moving technological innovations out of the laboratory into real homes is very delicate and must not be underestimated as the following examples highlight.

Several pretests were planned for the full function trials. Testing the equipment and use cases focused on the integration of the components in the demonstration home and the way the use cases could be presented. Specific attention was paid to the integration process of the available technology. Results of this test were valuable

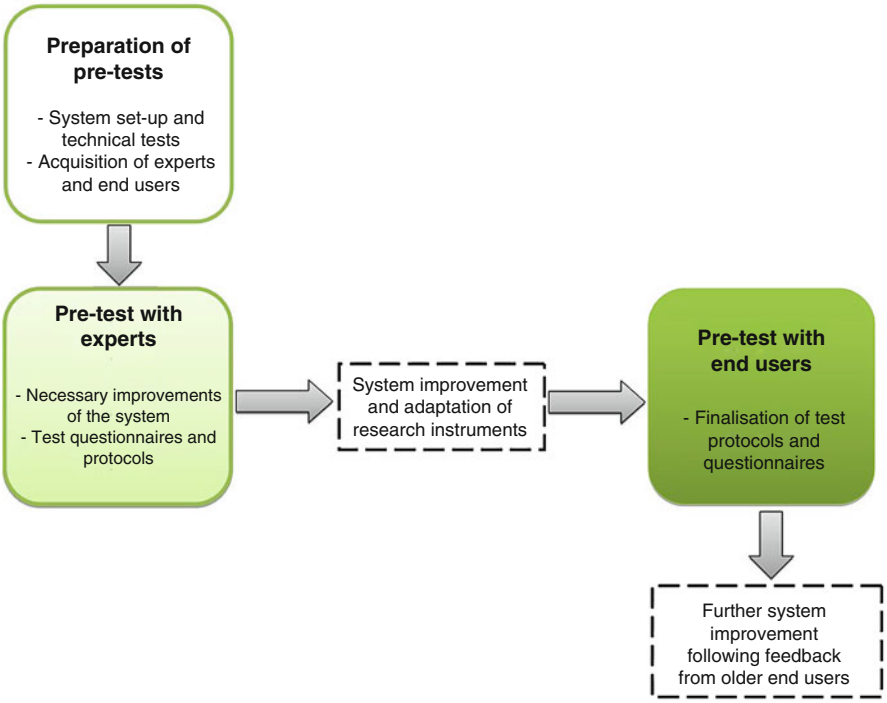

Fig. 8.11 Full function workflow pretest

not only for the full function trials but also for the large-scale trials. Besides the technical integration, it was also important to decide how the interconnectivity between all components could be shown in the best way to future participants. With respect to the actual conduction of the research, the pretest focused on the test protocols and the questionnaires. The workflow for the full function pretests is shown in Fig. 8.11.

During the integration process, it became apparent that components communicated with each other but the fine-tuning was missing. Some of the actions required were just simple tests to check for inconsistencies and to make sure that those details were covered in the technical components; others were more serious and related to the stability of the system. Initially it was anticipated that issues and problems with the SOPRANO system would be identified and overcome during the full function trials. In practice, while some issues concerning the integration of the components and stability of the system were resolved, others, mainly related to the stability of the system, remained. During the full function research, integration issues could be overcome by the use of simulating techniques, and stability issues had a minor impact due to the fact that a moderator showed the use of the use case. However, these solutions could not be used in the large-scale trials where the SOPRANO needed to run as a stable system 24/7 without any interference by a moderator.

Each large-scale trial site set up a test apartment to gain experience with setting up the subset of the system and to check if it met their own standards for installing technology in homes of service users. After this check, potential participants were invited to visit the test apartment. Older persons were very engaged and curious during the visit and reported having a greater sense of confidence in being able to use the equipment after the visit. Informal carers felt that the visit gave them a deeper understanding of how the system worked and how it could support their loved ones.

The work of the local technical experts was vital to the success of the field trials. They were the local contact point for participants and care personnel, solved minor issues, and cooperated with SOPRANO technical experts in case of major issues.

With respect to the actual installation, it became clear that each home was different. All sites reported that in most cases the technical checklist was sufficient to meet the preconditions but it was not detailed enough to cover all the differences between individual homes.

8.6.2 Individual

The characteristics of the older persons who participated in the field trials, and comments made by other stakeholder groups, indicated that the SOPRANO system would be of most benefit to older people who were in the early stages of decline, yet retained medium to high levels of mobility and independence, although requiring some level of care support.

Older persons saw their home as an important place, evoking a strong sense of identity through feelings of attachment, familiarity, and belonging. Home was somewhere they wanted to remain and evoked happy memories. Therefore, it was very important that the system did not take over the environment and that the characteristics of the home remained as they were before the installation. People were also worried about assumptions that visitors might make upon seeing the system, creating a stigma that they were in need of care.

A general comment was that buildings are often not suitable for the current demands of their residents. In relation to the fall use case, formal carers commented about the importance of removing loose carpets and about placement of furniture, and wires, in preventing falls.

Older people had the feeling that technology could help support their independence: "*I am always relying on others and my family. Technology means I can move from dependency to independency.*" Informal carers living at a distance indicated that technology could give them peace of mind when they are not able to visit. However, family members also valued the role of service centers and care organizations in ensuring that there was assistance and intervention when required.

Figure 8.12 shows the support older persons currently received. They expected the system to help them to live longer into old age through supporting them to live independently within their own homes. They had high levels of motivation for

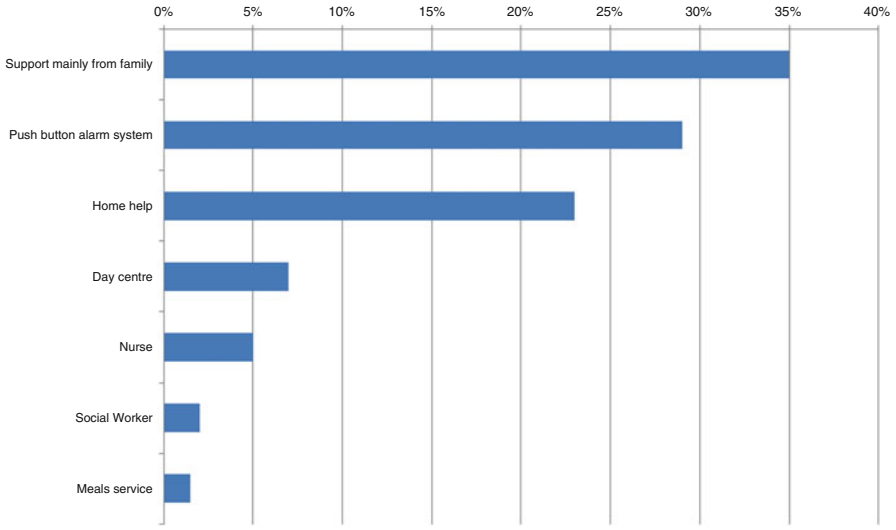

Fig. 8.12 Services received by the older persons ($n = 137$)

involvement in the trial. This originated from a feeling that they were being involved in something that would benefit them and other older people in the future. They envisioned the system to be easy to use and responsive even in the event of breakdown and expressed the need to have access to a local contact should the system fail. Informal carers reported high levels of motivation arising from the potential that the technology would provide an extra layer of support for the people they were caring for.

8.6.3 Technology Assessment

With respect to enjoyment, all participants showed enthusiasm for being involved in the trials and in trying something new. Furthermore, they responded enthusiastically to features of use cases they found appealing. For example, an older person responded to the exercise use case: *"It's like I've got a personal trainer in my home!"*

In terms of the perceived ease of use of the interfaces, the usability tests and actual use in real homes indicated that the participants had a positive perception regarding the ease of navigation through the menus on the TV and touch screen, the use of the remote control, and comprehensibility of the icons and text on the displays. Difficulties were experienced by informal carers when filling and programming the pill dispenser and with manually putting data into the administrator module. Additional support was needed for performing those two tasks. Related to the content of the use cases, some participants clearly described the interconnectivity between the different system components which promoted ease of use and

prevented unnecessary alerts. For example, "*If the medication is taken you won't get the notification on TV, so they communicate. I think that is good.*" Also recommendations were made to improve ease of use: "*The instructions aren't clear enough for some of the specific exercises. This can be dangerous and an older person could fall*." Participants did not initially feel anxious about using the SOPRANO system. However, increased levels of anxiety were reported due to the false alarms, system malfunction, and interference with the Internet and television.

While the general opinion was that this was a good system that satisfied older persons' needs, during the large-scale field trials, many users found it difficult to evaluate the perceived usefulness of the SOPRANO system because the system was unstable and there were frequent crashes, while other functions did not work at all. However, users felt that there was significant potential in the system in supporting them to live independently when it was functioning efficiently. A striking difference was noted in the fall detection use case. A person who has fallen once commented: "*From previous experience this seems pleasant.*" A person who had not fallen commented: "*Very useful if you are ready for it*." It seems, in other words, that people have to cross a certain threshold to admit that they need the fall detection subsystem. On the other hand, the SOPRANO system was seen as having potential to increase the security and safety of older people and reduce property crime: "*I thought I had closed the windows. However the SOPRANO system triggered an alarm when I left home, making me come back and close the window*."

8.6.4 Service Assessment

A major issue about service assessment was related to the question "*who is responsible for what?*" The following example highlights some of these concerns in relation to the medication use case. Experts, (in)formal carers, and older persons raised the question of who would be responsible for filling the pillbox. Care management commented that it would be: "*Difficult from a practical point of view. Who will take care of filling the pill dispenser? Home care employees don't have permission to do it*." Older persons commented: "*The person who fills this must know what is needed*." The medication use case also needed to be responsive to changes in the medication plan. Weekly changes were often made to prescriptions and these would need to be reflected in the medication use case. One participant commented: "*what in case of sudden changes to the medication plan?*"

A second point raised was that the focus should be on integrating SOPRANO services in the entire palette of service provision towards an older person. Participants felt that it was currently difficult to align the work of general practitioners, healthcare professionals, and formal carers and that the introduction of the SOPRANO system added another layer of complexity.

Thirdly, participants felt that there was a need to ensure that a procedure was in place in the case of a system breakdown, whereby technical support would visit to repair any problems. There was a need for this service to be responsive, to ensure that the safety of the older person was not compromised.

8.6.5 Intention to Use and Usage Behavior

A key aspect mentioned in relation to the intention to use the system was the notion of personalization. Older persons felt that the SOPRANO system needed to be tailored to the individual needs of the user. This would ensure that redundant aspects of the system were removed if they were not needed and that these elements could be added if the needs of the older person changed.

Participants were concerned about who would bear the responsibility for the costs of the system. Costs included ongoing energy costs, hardware costs, maintenance, and updates. It was difficult for older people to determine if the costs outweighed the benefits, especially for those who reported higher levels of mobility and positive health: "*You don't know at this moment if it's worth the investment.*" Care management and representatives from the building and technology sector stated that they were convinced that by integrating these kinds of systems in buildings and care provision, money could be saved on installations, costs of buildings, and costs of care provision. Dependency on technology was an issue raised by participants. There was concern that the system may suffer a malfunction and that the older person would be endangered if they were dependent on it for daily functioning: "*You get dependent from all of this, for instance what happens in case of an electricity failure?*" In the large-scale trials, participants had initial concerns that the system might be "doing the thinking" for them and that it would replace independent decision-making. However, when engaging in the trial, older persons indicated that they did not see the reminders as losing a sense of control; rather they welcomed the suggestion to do exercise, thereby encouraging independent action, as opposed to dependency. Informal carers felt that future technologies might help when caring for older people, enabling them to remain at home longer. However, they stressed that: "*Technology shouldn't replace people. People need people*."

All participants had the intention to use the system, but actual use varied across participants. High levels of acceptability were reported because they could access it at any time of the day. The flexibility of having a system within the home environment, which they could use in and around their everyday commitments, was welcomed. User ratings of whether they would use the SOPRANO system in the future were affected by the ongoing instability of the system. For example, an older person at one of the large-scale trial sites commented: "*If reliability issues are resolved I would consider having it long-term.*"

Figure 8.13 shows some of the participants taking part in the field trials of SOPRANO.

8.7 Lessons Learned from the Field Trials

All stakeholders who took part in the research demonstrated a willingness to be involved in the application and development of the SOPRANO system. They demonstrated high levels of motivation when using the technology and being

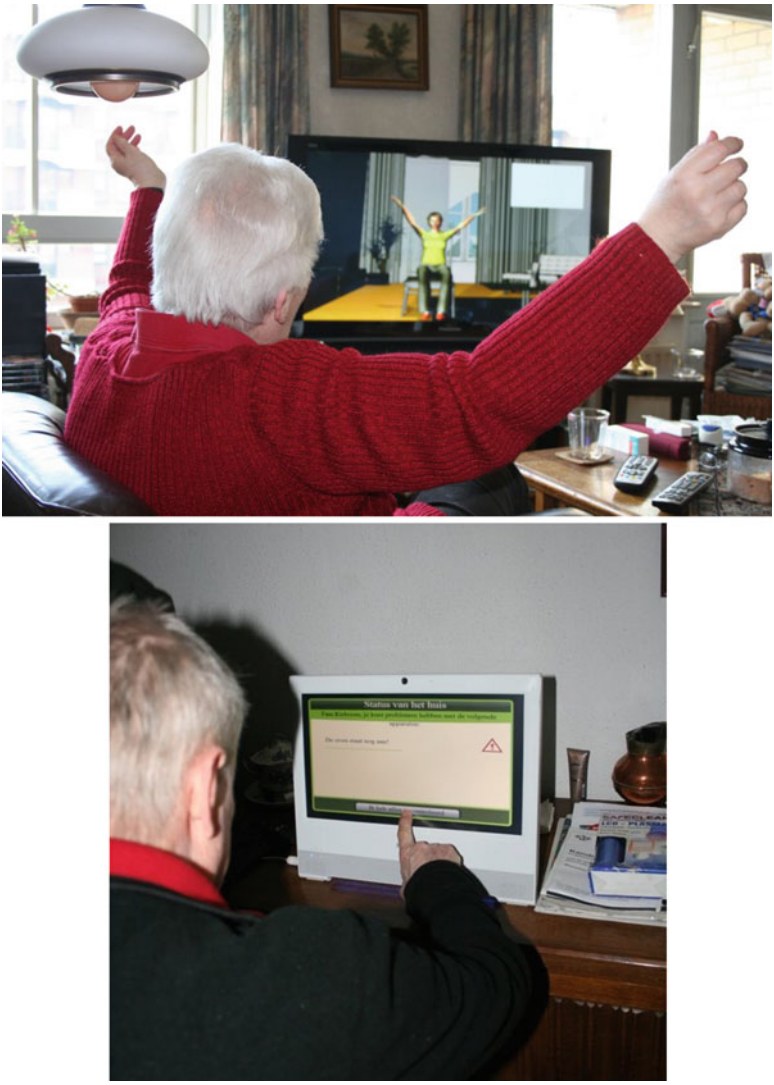

Fig. 8.13 SOPRANO field trial participants, using an exercise avatar (*top photo*) and touch screen technology (*bottom photo*)

engaged in the research. This originated from an enthusiasm to assist in research that might potentially benefit older persons to live independently in their own homes.

Older persons felt that an increased sense of independence resulted from the ability to undertake activities of daily living and technology was perceived as an intervention to assist them in that. Yet, older people revealed a dilemma in retaining a sense of independence while realizing the need for intervention and care. Independence and dependence are not fixed and often had to be negotiated as the needs of the older

person change. This is closely linked with the issue of personalization to ensure that services are suitable to the unique and changing needs of the older person. Furthermore, a flexible approach to care is needed, making it possible to easily switch between levels—self-support, assistance of an informal carer, and assistance of a formal carer. Ongoing issues with the reliability of the SOPRANO system prevented the concept of independence and personalization from being explored further. However, based on these observations, further work on the influence of the amount of personalization and adaptability on perceived usefulness is expected. This is strengthened by the fact that most of the participants indicated that they were not ready to use a system like SOPRANO yet, as it provided more support than needed at the moment.

Another variable in the Smart Home Acceptance Model that is in need of further investigation is aesthetics. Several comments, especially during the large-scale trials, were made concerning the stigma associated with assistive technology and the negative assumptions visitors might have when seeing the system.

Participants identified the potential for SOPRANO to bring about changes in existing modes of care delivery. Older people felt that such a system could enable them to be more independent, alleviating the care burden upon informal carers. However, they did not want this to result in less face-to-face contact with informal carers, as this was an important source of social support. Informal carers reported that assistive technology would help alleviate the worry and stress of caring for older people, providing an extra layer of safety and security. The technology also had the potential to increase the quality of time that informal carers spent with older people as it reduced the burden upon them to be caring for the older person.

In relation to service delivery, additional attention is needed to align the responsibilities of all involved in care delivery to an older person. A precondition for this is that a focus on integrated care should include technological possibilities. Procedures should also be in place for maintenance and problem handling.

8.8 Conclusion

The focus of the SOPRANO project was on promoting active aging and health by moving away from dependence. Participants indeed reported that a greater sense of independence for older persons could be achieved when using SOPRANO. However, many felt that they did not need the system right now.

By starting the user-centered design process and looking at key challenges to independent living, the approach was very much problem oriented. An addition to that approach could be one that focuses more on things that make people happy and are considered to be leisure and fun.

There is often the assumption that a system operating effectively within a lab environment will do so within the home, yet there are a number of situational and contextual factors which impact on system reliability. A simplified and evolutionary approach to trialing new technology would be one that allows participants to learn

and use individual components, progressing to an advanced stage only when the older person feels comfortable and when the operability of the system can be guaranteed. This gradual installation process could start with leisure-oriented services.

With respect to adoption of the developed technology and service after the conclusion of the research project, care organizations should consider offering services not just because the client is in need of care but because the client is willing to pay for additional comfort.

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