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Inclusion of service robots in the daily lives of frail older users: A step-by-step definition procedure on users' requirements

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ABSTRACT

The implications for the inclusion of robots in the daily lives of frail older adults, especially in relation to these population needs, have not been extensively studied. The "Multi-Role Shadow Robotic System for Independent Living" (SRS) project has developed a remotely-controlled, semi-autonomous robotic system to be used in domestic environments. The objective of this paper is to document the iterative procedure used to identify, select and prioritize user requirements. Seventy-four requirements were identified by means of focus groups, individual interviews and scenario-based interviews. The list of user requirements, ordered according to impact, number and transnational criteria, revealed a high number of requirements related to basic and instrumental activities of daily living, cognitive and social support and monitorization, and also involving privacy, safety and adaptation issues. Analysing and understanding older users' perceptions and needs when interacting with technological devices adds value to assistive technology and ensures that the systems address currently unmet needs.

1. Introduction

Robotics is getting greater attention nowadays as a promising field to support older adults with a range of different activities and to address the challenges associated with ageing, enabling them to live independently in their homes (Mitzner, Chen, Kemp, & Rogers, 2014; Smarr et al., 2014). Robots fulfil a growing number of roles in today's society, ranging from factory automation and service applications to medical care and entertainment (Feil-Seifer & Mataric, 2009). The development of service robots has been divided into two sectors: (a) non-manufacturing productive sectors such as agriculture, the boating industry, the mining industry, or medicine; and (b) the personal service sector, including personal assistance, cleaning, monitoring, education, entertainment, etc. (Aracil, Balaguer, & Armada, 2008).

Prototype robots have been developed to support independent living, in order to help older adults who try to live in their homes for as long as possible, even when the user is functionally disabled. Several personal service robots have been developed, including Aibo (Fujita, 2001), Care-O-bot (Graf, Han, & Schraft 2004; Graf, Reiser, Hägele, Mauz, & Klein, 2012), Pearl (Pollack et al., 2002), iCat (van Breemen, Yan, & Meerbeek, 2005), Robocare (Cesta et al., 2007), Robot-Era robots (Cavallo et al., 2014), or Hobbit (Fischinger et al., 2016). In addition, the robots Huggable (Stiehl et al., 2006), Paro (Wada, Shibata, Musha, & Kimure, 2005), Companionable (Badii et al., 2009), Giraff (Coradeschi et al., 2011) and GiraffPlus (Coradeschi et al., 2014), amongst others, have been developed to provide emotional support and other companion functions. Under this context, some studies have considered the optimal companionship that robots could provide (Taggart, Turkle, & Kidd, 2005; Wada, Shibata, Saito, & Tanie, 2003). However, the implications of the inclusion of robots in the daily lives of frail older adults (in terms of these frail older adults' needs and requirements, and the relationship between ethical implications and technical possibilities of such inclusion) have not been as widely studied until recently (Sharkey, 2013; Smarr et al., 2014; Sorell & Draper, 2014).

It is well known that people aged 65 and over represent the fastest growing age-group worldwide. In the United States and in Europe, high proportions of adults over 65 years old (58.7% and 66%, respectively)

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have chronic illness or health problems that prevent them from living autonomously (European Commission, 2014, 2015). Whilst there is no causal relation between ageing and disability, age can be a key risk variable related with several health problems and frailty (Mitnitski et al., 2015). Frailty is characterized by the concurrent loss of several capabilities. Older adults commonly become frail in a general sense that includes unstable health conditions, reduced reserve capacity for dealing with stressors and increased socio-economic difficulties (Avila-Funes et al., 2009; Jung et al., 2010; Rockwood, Fox, Stolee, Robertson, & Beattie, 1994; Schuurmans, Steverink, Lindenberg, Frieswijk, & Slaets, 2004). Furthermore, older adults usually experience deficits sequentially or concurrently, thus becoming frailer in a general sense (Clegg, Young, Lliffe, Rikkert, & Rockwood, 2013; Schuurmans et al., 2004).

In order to fill the gap between inclusion of robots in the daily lives of frail older adults, and to provide support to frail older populations, a project entitled "Multi-Role Shadow Robotic System for Independent Living (SRS)" focused on developing and prototyping of remotely-controlled, semi-autonomous robotic solutions in domestic environments. The system developed comprises an automatic task planner that produces proactive robotic behaviours based on updated semantic knowledge and executive control for coordinating activities at the level of sensing and action (Qiu et al., 2012). The robot was a wheeled mobile platform equipped with a robotic arm, capable to be operated through remote control to perform several tasks (such as grabbing objects, carrying objects and using adapted electric devices) for supporting older adults in a frail condition to cope with problematic homeostasis and vulnerability to stressors, and ultimately to improve their health condition. The systems can help with daily living activities such as reaching, fetching and carrying objects that are heavy or out of reach (Pigini, Facal, Garcia, Burmester, & Andrich, 2012).

Development of the SRS project was user-centric and iterative. The aim of the present study is to define in detail the step-by-step procedure used to identify and prioritize a set of user requirements. Taking into account the large amount of documentation generated in the project covering the assessments procedure (Mast et al., 2012; Pigini, Facal, Blasi, & Andrich, 2012), our main research question was: what type and which are the frail older user requirements' to accept the integration of robotic solutions in their daily lives and homes? The current study presents the whole procedure for gathering the requirements throughout the SRS project instead of going deep into exhaustive descriptions of the actions and materials (for this purpose, several supplementary documents have been included as Supplementary materials).

2. Design and method

2.1. Participants

215 participants were recruited through different SRS procedural phases for identifying user requirements (Table 1). All the participants took part in the study voluntarily and signed an informed consent in which their participation, rights and use of the data was described.

Focus groups were attended by 67 participants. A total of 22 frail older adults (77% female), with a mean age of 80 years-old (range: 65–90 y.o.) participated in 4 focus groups in all the three countries. Seventeen relatives of older adults (88% female) with a mean age of 55 years-old (range: 46–64 y.o.) participated in 3 focus groups in Germany and Spain. Twenty health professionals (80% female) with a mean age of 46 years-old (range: 30–61y.o.) and 8 professional caregivers (5 women, 3 men) with a mean age of 51 years-old (range: 27–60 y.o.), participated in 4 focus groups in all the three countries.

Individual interviews were held with 129 individuals comprising 64 frail older adults (47 females, 17 males; 65–92 years old), 19 family caregivers (17 females, 2 males; 28–69 years old), 22 professional caregivers (21 females, 1 male; 29–62 years old), and 24 health professionals (17 females, 7 males; 27–57 years old). In the first and second phases, frail older adults were recruited (in Germany, Italy and Spain) from among non-institutionalized people experiencing initial difficulties in activities of daily living (ADL), usually classified as frail older individuals.

Table 1
Different assessment methods used.

N = 230		Frail older adults	Primary caregivers	Professional caregivers	Health professionals
Phase 1	Focus groups	5 M, 17F	2 M, 15F	2 M, 14F	5 M, 8F
Phase 2	Individual interviews	17 M, 47F	2 M, 17F	1 M, 21F	7 M, 17F
Phase 3	Ethnographic study	4 M, 14F			
	Total number	104 (26 M, 78F)	36(4 M, 32F)	38 (3 M, 35F)	37 (12 M, 25)

M = Male; F = Female.

Frail participants were identified in each country by means of being categorized as frail by the different services involved in each country having heterogeneous conditions: hip, wrist or leg fractures, pain, mobility problems and other comorbidities.

Family caregivers (in Germany and Spain) were individuals with personal experience in caring for a relative or friend and who performed these duties *pro bono*.

Professional caregivers (recruited in Germany and Italy) were caregivers paid to perform a variety of professional skills in older adults' care: some had nursing and first aid qualifications, and others worked as home helpers or personal assistants. All of them had more than 5 years of experience.

Health professionals (in Italy and Spain) were professionals involved in health attention both directly (medical doctors, occupational therapists, physiotherapists, etc.) and/or indirectly (health service administrators, advisors).

In a final round, 18 frail older participants (10 in Italy and 8 in Spain) took part in the ethnographic study (14 females, 4 males; 75–93 years old).

2.2. Materials

There are several procedures available within the social sciences methodology that can be applied to design. The present study was carried out in line with other similar methodologies used within the UCD, such as USERfit (Poulson, 1996) and the RESPECT User Requirements Framework (Maguire, Kirakowski, & Vereker, 1998). We selected three different procedures in order to meet the users' needs from different perspectives: (1) focus groups for gathering a broad point of view on their interests and opinion about our foreseen solutions; (2) interviews for qualitative and quantitative definition of users' characteristics and needs, including Likert-type closed questions, but also "why" and "how" questions open questions; and, (3) an ethnographic procedure, based in a home visit, for having a qualitative daily life understanding of users' needs and behaviour.

In each phase of the study, the materials comprised, respectively, a focus group script, a semi-structured interview and an ethnographic interview. In the focus group approach, the planned script was designed to elicit the users' needs and pragmatic scenarios of use from the perspective of different users and beneficiaries. Group discussions were directed through questions on specific topics to discover participants' feelings, attitudes, and ideas about these topics. The following topics were included throughout the discussion: 1) basic ADLs (BADLs) and instrumental ADLs (IADLs) (i.e.: difficulties in carrying out daily tasks); 2) assistive technology (technology currently in use and future technology the interviewed people wish to use); 3) human-robot interactions (how the people interviewed imagine robot features and uses); and 4) privacy issues related to the use of assistive technologies (see Supplementary materials 1 for the Focus Group script for frail older adults; similar scripts were developed for primary caregivers, professional caregivers and health professionals).

The semi-structured interview involved one-to-one collection of sociodemographic information (about participant's age, gender, and educational level) and two additional sets of questions that focused on the topics highlighted in a preliminary focus group study on older users' needs and perceived usefulness of personal robots (see Supplementary materials 2 for the complete Interview for frail older adults; similar interviews were developed for primary caregivers, professional caregivers and health professionals). In the first section of the questionnaire, 21 Likert-type items (1 to 5) were used to assess the user needs in the daily life in the following group of activities: mobility (walking, getting up, lifting and carrying heavy objects, getting into a bath or shower, fetching items, reaching objects, risk of falling, shopping); housework (cleaning windows, cleaning the floor, cooking and preparing food, opening bottles or tins, washing crockery, clearing the table, tidying up the room, washing clothes); body care (getting dressed, bathing and washing); "other" (operating electronic devices, taking medicines, reading small print, forgetfulness, loneliness and lack of social interactions). In the second section of the interview, each participant answered questions administered on a 5-point Likert scale in response to a sketch assessing 1) the level of acceptance of the remote control mechanism, and 2) the perceived benefits or risks and privacy concerns regarding use of a remotely controlled robot. Likert-type items were complemented with "why" and "how" questions, where relevant, as shown in Supplementary materials 2.

To gather a qualitative perspective, an ethnographic approach was carried out in order to consider new specific contextual requirements. The ethnographic study protocol comprised a set of questions included in a planned script for use by the researchers in a scheduled home visit and a daily-life capture task (Zamora et al., 2011) (see Supplementary materials 3). The following information was also obtained within the home visit: participant description and social context, health conditions, environmental description, difficulties in daily living, user-desired robotic conditions, ethical concerns, preferences and the family point of view.

2.3. Procedure

Based on the User Centred Design (UCD), with sequential procedures targeting the user's perspectives, the SRS project encompassed different but closely linked steps: 1) description of the targeted users, 2) identification of user requirements (by means of: a broad literature review on the main older people needs and the most used scales for assessing impairment as a list of difficulties in the daily activities, focus groups, interview and ethnographic approach; each procedure used the homonym instruments described in the previous section), 3) prioritization of user requirements and analytical procedures, 4) system design and testing, and 5) iteration from step 2.

Participants were then recruited according to the inclusion criteria. In order to ensure trustworthiness of data, triangulation was performed by means of carrying out several different data gathering procedures: Focus groups, individual interviews and an ethnographic study were conducted with different, but not mutually exclusive samples. The strategies used to identify user requirements produced several results with different levels of specification depending on the quantitative or qualitative nature of the approach. The focus groups were formed based on the main points extracted from the literature, which were subsequently collated and discussed to produce the second group of requirements. The group sessions lasted about two hours and each group was coordinated by a moderator who was responsible for maintaining the focus of the group on the issues of interest included in the script. These user requirements were again collated and included in a questionnaire concerning the frequency and impact of the requirement in the individual interview and questionnaire phase. In order to consider specific contextual requirements, an ethnographic approach was carried out through field visits, ranging from 40 to 60 min in a unique session.

Regarding to the ethical and legal framework that served as an information source from the three countries involved in the study, due to the different legal constraints in relation to personal data and user involvement in each country, the most restrictive approach was applied. A document with the terms and conditions of user involvement was elaborated and presented to the ethical committees that had approved the study. This document was further presented to the users, together with the informed consent that the user had to sign to participate in the project.

2.4. Prioritization analysis

A multidisciplinary team, including psychologists, psychogerontologists, biomedical engineers and mechanical engineers, conducted the prioritization process. Initial prioritization was carried out (to produce a manageable amount of data and to assess the preference of specific conditions and demands) in terms of impact (the importance of the requirement in their life and the event frequency) and percentage of users that addressed the requirement. According to Dumas and Redish (1999) and Rubin and Chisnell (2008), the relevance of user requirements can be structured as follows:

- high, for extreme requirements (i.e. if not accomplished the product will fail; frequent, re-occurring and broad; or may other requirements may depend on it);
- medium, the requirement will be difficult for some participants (i.e. not coping with this requirement can cause frustration or confusion in most users and the requirement might also affect other tasks);
- low, a few participants might experience frustration and confusion, or it is an isolated requirement.

In the present study, following the prioritization logic and the different format of the items, the relevance was determined on the basis of the impact (subjective judgement about consequences of requirement and the event frequency) or frequency (% of users that address the requirement).

Based on the impact and frequency criteria, each score was considered High, Medium or Low priority, thus generating a first set of prioritized requirements for each country, followed by a cross-country prioritization. For final prioritization of the requirements considering the three countries as a single group, the requirement was deemed high priority even when only one country considered it so. In the other cases, the majority criterion method (two out of three) was followed according to García-Soler et al. (2012) (Table 2). This procedure made it possible to homogenize information collected from different sources, different methodologies and different countries.

A list of prioritized requirements was obtained by prioritizing the interview results. The requirements gathered in an exhaustive description were ranked as high, medium or "nice to have". A separate prioritization procedure was carried out for the qualitative data obtained in the ethnographic approach using the same ranking labels.

3. Results

From the literature analysis, we identified a list of 19 user requirements related to basic (BDL) and instrumental (IADL) activities of daily living. These primary requirements were checked then through focus groups, interviews and ethnographic approach. Finally 74 requirements with different levels of specification, depending on the nature of the approach (qualitative or quantitative), were found and

Table 2
Example of prioritization procedure from each country to a whole sample priority.

Items	Germany		Italy		Spain		Whole sample
	Mean	Priority	Mean	Priority	Mean	Priority	
Walking	3.07	L	2.54	M	1.71	H	H
Getting up	2.57	M	2.21	M	1.59	H	H
Using the bath	3.25	L	2.47	M	1.76	H	H
Cleaning the floor	3.25	L	2.26	M	2.41	M	M
Opening bottles	3.46	L	2	H	2.47	M	H
Reaching objects	3.71	L	2.47	M	2.82	M	M

Easiness mean (0–5); Priority based on the mean: L (3–5), M (> 2 and < 3), H(0–2).
L = Low; M = Medium; H = High.

Table 3
Requirements identified in the Focus Group (FG) discussions.

Robot Features (RF)	
(FG/RF1)	Correct size
(FG/RF2)	Understandable voice/speech
(FG/RF3)	Control-related requirements
(FG/RF4)	Support with mobility
(FG/RF5)	Support with meals
(FG/RF6)	Support with housework
(FG/RF7)	Cognitive/psychological support
(FG/RF8)	Emergency/security
Remote Control Features (RC)	
(FG/RC1)	Maintain privacy
(FG/RC2)	Usable user control
(FG/RC3)	Family members control (not increasing the burden)
(FG/RC4)	Usable physician control

elaborated. Thus, 12 requirements were identified in the focus group discussions (Table 3). On the basis of on the information gathered in these discussions, the interviews extracted 31 user requirements with a high degree of specificity involving the following topics: robot environment (4 requirements), support for activities of daily living (6), emergency (4), housekeeping (1), memory and activity support (2), social support (1), privacy and safety (13) (Table 4). Testing the system in different use case scenarios led to the identification of 25 requirements for specific tasks (e.g. the robot should be able to help the user to get in and out of the bath or shower; the robot should be able to do laundry and hang, fold, and put clothes away) (Table 5). Information in it considers the extensive list of scenarios that emerged from the SRS focus groups and were subsequently rated for usefulness in the SRS survey. The ethnographic approach identified 6 user requirements with a high degree of specificity for the performance of tasks in daily life environments of older adults (Table 6). Finally, a summarization of the requirements obtained through different methodologies was conducted (Table 7).

4. Discussion

In this paper, we present the procedure used to identify, collate and prioritize the functional requirements of frail older adults in relation to receiving help and support from a semi-autonomous robotic assistive system. User Centred Design (UCD) method and prioritization techniques were used to generate user requirements, realistic usage scenarios and to maximize alignment with users' needs, perceptions, feelings and rights. The approach was based on the premise of involving the user through the whole process, by means of identifying user requirements and iterative design. The list of user requirements was ranked according to impact, number and transnational criteria. The list included high-level requirements related to physical tasks involving basic and instrumental activities of daily living, cognitive and social support and motorization, as well as aspects related to privacy, safety and adaptation.

This list of requirements presented can be used in the future for the specific development in the fields of applied gerontology and service assistive robotics. In this regard, the users were more interested in having an electronic device that would provide support in tasks that they could no longer perform autonomously rather than having a smart-interactive machine. This finding is in agreement with current definitions of frailty in older adults in which the core concept is the loss of capabilities (Avila-Funes et al., 2009; Jung et al., 2010; Rockwood et al., 1994; Schuurmans et al., 2004). Although basic activities of daily living have traditionally been considered key to user requirements (Rockwood et al., 1994), the users in this study were more interested in receiving support for instrumental activities of daily living. This interest can be related to privacy aspects of some basic tasks (Caine, Fisk, & Rogers, 2006), such as personal hygiene and going to bed, but also to the well-known wishes of older adults to adapt to carrying out basic activities according to their limitations and to get support for instrumental, leisure and social activities.

The results obtained should be interpreted within the scope of a project that already aims to provide a support solution for a specific

Table 4
Technical requirements identified in the Individual Interviews (II)Table 5 Requirements identified by testing different scenarios.

Robot-Environment (RE)	
(II/RE1)	The system should be able to maneuver narrow spaces
(II/RE2)	The system should be able to recognize the user position
(II/RE3)	The system should be able to recognize different rooms
(II/RE4)	The system should be able to avoid obstacles
ADL Support (AS)	
(II/AS1)	The system should be able to recognize shapes, colours or codes
(II/AS2)	The system should be able to reach objects
(II/AS3)	The system should be able to grasp objects of different shapes
(II/AS4)	The system should be able to handle differently shaped objects up to 3 kg
(II/AS5)	The system should be able to carry heavy objects
(II/AS6)	The system should be able to manage objects with care
Emergency (E)	
(II/E1)	The system should be able to cope with falling or other emergencies
(II/E2)	The system should be able to monitor activities
(II/E3)	The system should be able to alert a remote operator
(II/E4)	The system should be able to provide support in getting up
Housekeeping (H)	
(II/H1)	The system should be able to store and display task information
Memory and Activity support (MA)	
(II/M1)	The system should be able to remind the user about tasks
(II/M2)	The system should be able to be programmed to carry out tasks by itself
Social Support (SS)	
(II/M1)	The system should allow direct communication between the user and a remote operator
Privacy (P)	
(II/P1)	Only authorized persons should be able to access the remote operator
(II/P2)	An authentication procedure should be required
(II/P3)	Robust security system should be developed to avoid malignant uses
(II/P4)	The user should be informed if the remote operator changes
(II/P5)	The user should be able to override the remote control
(II/P6)	Storage of personal information storage should be in safe databases
(II/P7)	Collection of information should be restricted to useful information
(II/P8)	The system should have a customizable and accessible on/off system suited to the specific user needs
Privacy/Safety (PS)	
(II/PS1)	The user should have to verify plans of action before the system starts acting.
(II/PS2)	The system should communicate the task performance in real time.
Safety (S)	
(II/S1)	The system should be able to bring objects to the user avoiding contact with potentially dangerous parts
(II/S2)	No robot movement should occur without initial confirmation by the user
(II/S3)	There should be a clear indication on the robot as to whether it is operating in autonomous mode or in remote-controlled mode

Table 5
Requirements identified by testing different scenarios.

(RS1)	The system should be able to provide assistance in case of falling
(RS2)	The system should be able to remind the user about appointments
(RS3)	The robot should be able to remind the user to take medication
(RS4)	The robot should be able to wipe surfaces and vacuum the floor
(RS5)	The robot should be able to read aloud small letters on food packaging, medical leaflets, books, etc.
(RS6)	The robot should be able to open containers like food cans, bottles
(RS7)	The robot should be able to retrieve objects that are difficult to reach (e.g. high on shelf or on the floor)
(RS8)	The robot should be able to help operate electronic devices like TV
(RS9)	The robot should be able to clean windows.
(RS10)	When shopping is delivered, the robot should be able to open door, accept delivery, open boxes, place purchases on shelf, in fridge, etc.
(RS11)	The robot should be able to do laundry, hang, fold and put away clothes
(RS12)	The robot should be able to fetch and carry items
(RS13)	The system should allow videoconference
(RS14)	The robot should be able to support the user in getting up
(RS15)	Tidy up. The robot should be able put objects back in place
(RS16)	The robot should be able to carry heavy objects
(RS17)	The robot should be able to load and unload the dishwasher
(RS18)	The robot should be able to help to climb bathtub or shower
(RS19)	The robot should be able to clear away things from the table
(RS20)	The robot should be able to play board games
(RS21)	The robot should be able to help with bathing
(RS22)	The robot should be able to help with cooking
(RS23)	The robot should be able to help with dressing
(RS24)	The robot should be able to assist with walking
(RS25)	The robot should be able to talk and provide companionship

Table 6
Requirements identified in the Ethnographic approach (EA).

(EA1)	The systems should be able to provide direct support to people with severe motor impairment and low social support
(EA2)	The system should be developed to respect furniture and carpets
(EA3)	The system should be able to give support in heavy tasks (carry objects)
(EA4)	The system should be able give support in sequential tasks (cooking, cleaning and housekeeping)
(EA5)	Taking into account that people prefer human contact, the robot should be able to perform in automatic mode or to be directly manipulated by the user.
(EA6)	The system should be able to have the capacity for enhanced communication for people with diverse communication needs

Table 7
Summarization of requirements obtained from different data sources.

User requirements	Source
1. Motor impairments are highlighted in the potential users, and so they require broad support with physical tasks.	FG, EA
2. The users require support with Instrumental Activities of Daily Living, especially with sequential tasks and housework (i.e. carrying heavy objects, cooking).	FG, II, TS, EA
3. The users require support with Basic Activities of Daily Living (i.e. getting up, reaching the things climbing bathtub).	FG, II, TS
4. The users require Cognitive Support (i.e. arranging and reminding appointments, reminding medicines intake).	FG, II, TS
5. The users require Monitorization in case of Emergencies.	FG, II, TS
6. The users require Social interaction and communication with others (preferring human to robotic).	II, TS, EA
7. The users want their Privacy to be respected, but each user has different privacy interests.	FG, II
8. The users want Safety in their caring process.	FG, II
9. Suitability to the environment (robot–environment interaction)	FG, RE, EA
10. Customization and adaptation: the users' needs are dynamic and can change.	EA

Note: FG- Focus groups; II- Individual Interviews; TS- Testing Scenarios; EA- Ethnographic approach.

field of ageing-related impairment (Qiu et al., 2012). The procedure of identifying functional requirements was intentionally aimed towards collecting a portion of all requirements; however, this should not hinder the integration of the results with other studies in other fields such as cognitive or perceptive impairments. Since robotics has the potential to assist older adults across several categories of needs, the requirements in different fields should probably not simply be aggregated but adapted to the older adults' varying needs (Mitzner et al., 2014). Older adults with different levels of functionality will need different levels of assistance and, accordingly, different patterns of preference for robot assistance (Smarr et al., 2014).

In the context of applied research about assistive technologies designed for frail older adults, it is difficult to identify single items, representing a concrete user requirement, due to the different outcomes that different items can bring. This paper is centred in the description of a prioritization process which led us to a manageable amount of data that permits to choose and evaluate single requirements based on that prioritization and then to translate them into feedback for technical developers, harmonizing information from three different European countries and based on different qualitative and quantitative methodologies. This procedure makes it possible to address the generalizability of the data, providing a common ground for the interpretation of the data through different countries Regarding limitations, this study represents a descriptive approach in which several methodologies (quantitative and qualitative) were used to obtain a broad knowledge of the old users from different points of view. It was difficult to homogenize data from different levels and formats. Future studies should include the final data categories into well-designed assessment protocols in order to make it possible to analyse data in the same levels. Finally, assistive technology developers should address the issue of design usability as a dynamic rather than a static feature. Users' needs change over time. In addition to processes that become impaired during the ageing process, we should take into account rehabilitation, increased or reduced social contact, privacy concerns and whether or not the different generations of older users adapt to the system. In this way, analysing, understanding and adapting frail older users' perceptions and needs when interacting with technological devices adds value to the development of assistive technologies.

Conflict of interest

None.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.archger.2017.10.024.

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