SRS

Multi-Role Shadow Robotic System for Independent Living

Small or medium scale focused research project (STREP)

DELIVERABLE **D2.1**

Interim Report on Definition of Privacy Policy, Requirements and Usability Studies Based on Specific Needs of Elderly

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Table of Contents

Summary

The aim of the SRS research project is to prolong independent living of elderly persons. The project brings innovation to household service robots by involving human remote operators who teach robots new tasks which the robots currently cannot perform autonomously. With continuing teaching, remote operator's involvement will decrease and the robot's functional spectrum gets enhanced and adapted to the highly varying local environments.

This SRS interim deliverable "User Interaction Study of Remotely-Controlled Service Robots" reports on the work carried out so far in work package 2, tasks 2.1 ("Requirements for Shadow System Related Human-Robot Interaction", month 4-6) and 2.2 ("Psychological Dimensions Study, month 4-6).

Section 1 first outlines the overall design approach for work package 2. Usability tests will be carried out when prototypes have been produced as part of task 2.6. It then details the plan and necessary actions until month 8 where interface conceptual work will start.

Section 2 reports the results of the psychological dimensions study (task 2.2) which has been linked to WP1 user requirement studies for participant recruiting and involvement benefits. Therefore, this is a complementary analysis and the main part of the results is contained in deliverable 1. The goal of task 2.2 was to elicit psychological characteristics of all possible SRS user groups (elderly as local users, children and professional caregivers as remote users) including technology attitudes, privacy concerns, and emotional aspects with regard to the prospect of a robot in the home.

Section 3 presents a requirement assessment for SRS human-robot interaction (HRI). Requirements are derived from various sources and perspectives: from an HRI literature review, from a gerontology literature review, from the empirical data collected within SRS user requirement studies, and from a safety point of view. Also, this section contains recommendations for SRS privacy matters.

The following central themes have emerged from the requirements analysis:

- Graphic design and audio design adaptations for elderly: e.g. meaningful icons, fewer buttons, avoidance of certain colour combinations, low speech rates, adjustable volume
- Situation awareness: it is important for the SRS remote user to be provided with all information necessary and only with the necessary information in order to achieve a high immersion experience in the robot's environment
- Common ground: the robot and the user should share the same world model, e.g. the human should know which objects the robot recognizes in a scene
- Important robot functions: e.g. obstacle avoidance, map-based navigation, carrying heavy objects, reminder functions.
- Privacy: in particular authorization of remote control, avoidance of unintentional information disclosure, ability to turn the system off completely
- Safety requirements: e.g. speed limit of robot, emergency stop button, overturning prevention

1. SRS Usability Studies and Interaction Design Process

1.1. Methodological Framework

SRS interaction and user interface design is embedded in the user-centred design process - the most successful approach for designing usable and easy to learn human-computer interaction (HCI) (Beyer & Holtzblatt 1998; Burmester & Görner 2003; Gould & Lewis 1985; Hix & Hartson 1993; Mayhew 1999; Nielsen 1993; Rosson & Carroll 2002). Human-robot interaction (HRI) shows many analogies to HCI but also differences which will be outlined below (Adams, 2002, 2005; Forlizzi, 2005).

Figure 1 shows the process of user-centred design. It starts with the analysis of the context of use. Here, the different user types and roles are analysed and an in-depth task analysis is carried out. For HRI, the tasks of the human operator, the robot, and their collaboration need to be analysed. Also, the social, technical and physical environment must be carefully investigated. The results of the analysis are then transformed into requirements and usability goals. For HRI, the context of use analysis should account for situation awareness, vigilance, user workload (Adams, 2005), and user experience. During the design phase the interface will be conceptualised and developed. Here, several methods from HCI (e.g. scenario based design, Rosson & Carroll, 2002; participatory design, Muller, 2007) can be applied. In addition, design knowledge, principles, and rules (for HRI see Drury et al., 2004) as well as design patterns will be used. Prototyping is then necessary to make the designs testable. As a last step, the prototypic designs are evaluated and usability problems are identified. In an iterative process, based on the evaluation results, designs are optimised, prototyped, and again evaluated until they have reached the desired level of sophistication.

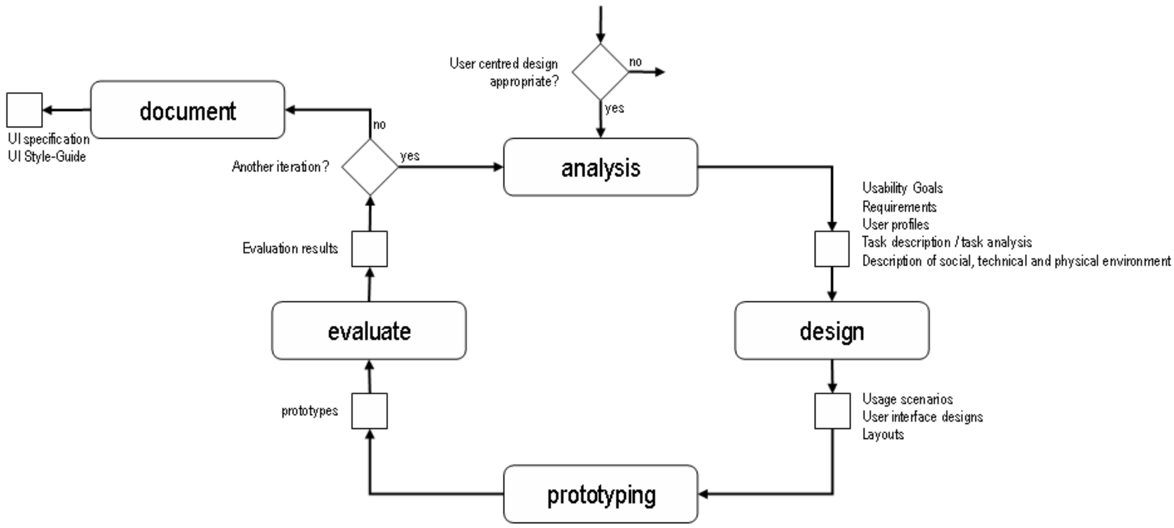

Figure 1: User-centred design process (adapted from Burmester, 2007)

The evaluation of human-robot interfaces comprises two main fields (Scholtz, 2002). First, situation awareness (Endsley 2000) must be measured. There are three main levels of situation awareness: (1) basic perception of information in the environment, (2) ability to understand the different pieces of information and relate them to the task goals, and (3) forecast future situation events. Query-based tools are available to assess the situation awareness of a user (e.g. SAGAT, Endsley 1988). The second field of evaluation focuses on interaction. It is closely related to classical usability evaluation, employing e.g. usability testing (e.g. Dumas & Loring, 2008). Here, effectiveness, efficiency and satisfaction are assessed. Furthermore, the detection and understanding of usability problems in order to optimise interaction is of central importance. Steinfeld et al. (2006) developed metrics for HRI. They include some metrics that can be used for evaluating user performance (e.g., situation awareness, workload, and accuracy of mental models of device operation). A third area of evaluation should be added: the evaluation of user experience issues (e.g. Hassenzahl & Tractinsky, 2006; Burmester, Hassenzahl, & Koller, 2007).

From a user experience perspective, HRI is characterised by a strong aspect of social behaviour. Robots collaborate with people and are perceived in a humanoid way. Therefore, the social experience will largely influence the perceived quality of the user experience. To achieve a positive user experience, social situations need to be understood by both, the robot and the human (Breazeal, 2005). As interaction involves mostly non-expert users, accessibility, ease of use, and reliability are particularly important. When designing HRI, it is necessary to move beyond task-based interaction and be attractive, affordable, and non-stigmatizing (Forlizzi, 2005). In addition, the human operator should perceive the robot as a credible device and possibly as a 'teammate' (Scholtz 2002).

1.2. Interface Design Plan for the First Phase

Figure 2 shows the process and decisions until the point where conception, prototyping, and iterative development of the human-robot interface will be commenced (month 8). Subsequently, the single steps are detailed. Other important steps already completed and not in the illustration were the user requirement study (task 1.1), technology assessment (task 1.3), and psychological dimensions study (task 2.2).

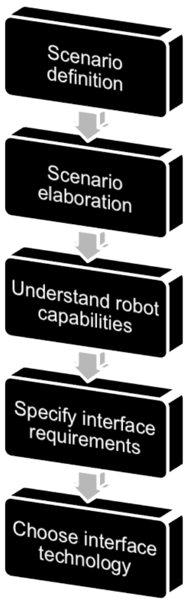

Figure 2: Work package 2 action items until the point of starting interface design

In addition to the illustrated steps, a user group definition will be finalized at the end of this process. There are currently several open questions, e.g. the role of the elderly person as a potential operator, the necessity for a 24h "call center" service of professional users as a last backup in the priority chain of user assistance, and the like. These decisions in part depend on technological parameters which still need to be determined (e.g., prospective complexity of the teaching process given the capabilities of the learning algorithms to be used). The user concept will eventually be part of a model of the human-machine system involving interfaces, actors, relationships, tasks, robot capabilities, etc. A proposal for a user group definition following user requirement study results has been made by HdM 19 July 2010, which is available as a separate document and under discussion at the time of writing.

Scenario definition

This step at the time of writing was largely completed as part of task 1.2 having received input from tasks 2.1 and 2.2. In the user-centred design process, scenarios are "living documents" under constant refinement throughout the design process.

Scenario elaboration

This step includes:

- Task and interaction analyses for each chosen scenario and alternative versions of it (completed)
- Create and consider alternative versions (completed)
- Elaborate on actors, roles, knowledge (ongoing)
- Identify connections between scenarios and scalability (completed)

Understand robot capabilities

This step mainly consists of information exchange with the consortium partners on current and anticipated hardware and software capabilities. It has been completed at the time of writing.

- Hardware: understand limitations (e.g. accuracy, force) and derive implications for interaction (both prototypes)
    - What objects can the gripper grab? E.g., paper, book, spoon
    - Two main limitations: only 1 arm and rough gripper
    - What I/O technology will work through the Internet / 3G
- Understand cognitive capabilities and limitations and derive implications for interaction
    - What can the robot do a) autonomously; b) semi-autonomously; c) fully remotely controlled?
    - Which input or information is required from user for which action?
    - Learning: How will learning work? What is realistic to learn and what will the robot not be able to learn? Regarding object recognition? Regarding navigation? Regarding arm and gripping movements? Problem solving (e.g., operating an electronic device)?

- o Training: e.g., user showed robot how to open a drawer. Is one time sufficient for executing it autonomously next time? Or additional training required? Interface needs to let user know next time that learning has not been completed.
- o Generalisation: If the robot can open one door, can it open any door? If it knows one Coke bottle, will it know other Cokes bottles? (this also needs to be communicated to user)

Specify interface requirements

Part of this work has been completed as part of the present deliverable (section 4). Further, a detailed interaction requirement analysis has been done and a proposal of specific interaction requirements has been made by HdM 19 July 2010, which is available as a separate document and under discussion at the time of writing.

Choose interface technology (after month 6)

This step belongs to task 2.3 (month 7-9). Interaction technology mainly needs to be defined for the remote user because the existing local interaction technology in the two SRS prototype robotic platforms will remain largely unchanged and is out of the scope of SRS. The chosen scenarios determine the tasks to be accomplished which determine the interactions necessary. The interactions determine the technology to be used (the technology best suited for the necessary interaction forms). Possible interaction technologies have been identified in deliverable 1.2 (e.g., speech, tablet computer, smartphone, augmented displays, 3D gesture interaction, accelerometer-based interaction, 3D mouse). The previously mentioned interaction requirement analysis will be the basis for choosing the appropriate interaction approach. It is currently under review by the SRS partners. The following table provides a general overview of interaction modalities:

Modality	**Input Device**	**Output Device**
Vision	Touch screen	Display, LEDs, Beamer
Speech	Automated speech recognition (ASR)	Text to speech (TTS) synthesis
Gesture	Gesture on touch screens, recognised by cameras, or haptic devices (e.g. Wii)	E.g. posture of the robot, gestures with manipulator arm
Gaze	Eye tracking systems using the eye movements of the user as input	When using anthropomorphic robots, movements of robot eyes can be used as output (e.g. to signal that robot is listening to user)
Audio	Sounds emitted by the user (e.g. clapping hands)	Sounds emitted by the robot (e.g. earcons, Brewster, 2003)
Olfactory	- -	Issuing aromatic output
Haptic	User movement (e.g., mouse, buttons, joystick, physical contact with the robot)	Haptic feedback from the robot, e.g. force feedback (Oakley et al., 2000)

Table 1: Interaction modalities

2. Results of Psychological Dimensions Study

2.1. Survey of Technology Use Questionnaire – SOTU

SoTU results about personal/social characteristic of the elderly that they perceive themselves being mostly independent (both in emotional and in physical field) and experiencing a high degree of well-being, while the majority of the others interviewed argue the opposite about independence and are mostly neutral about well being of their assisted.

Mostly of the interviewed stated that have high level of interaction with friends and family members when qualitative results obtained during focus groups and interview with the same people showed that they suffered of loneliness problems. This comes from the fact that the relation with friends and family is mostly good even if not too frequent, and elderly themselves know that their relatives are busy with work and managing of other component of their family (see D1.1 section 2 “Elderly people’s social and affective needs”).

About personal characteristics, elderly states to be mainly positive (thinking, persevering, motivated, patient, positive, tolerant, happy and calm). Half of them also state to be expressive.

Their relatives, caregivers and health professional do not totally agree with their assisted elderly people vision about personal characteristics in particular they give more neutral or negative responses (compared with the elderly ones for persevering versus discouraging; motivated versus unmotivated, patient versus impatient, happy versus depressed, calm versus anxious).

This comes in part, from the fact that many of the elderly interviewed were still enough ‘young’, well being while the other categories of people interviewed were reporting characteristics of their experience in assisting elderly ‘very old’ or with health and cognitive problems. However this results could make us reflect about the fact that elderly are not always able to objectively judge on their ability or capability as reported many times from caregivers during focus groups, and we should have in mind these differences in order to achieve the higher psychological and social acceptance for the systems we design. Specifically, regarding to the SRS system, different perceptions about autonomy and psychological well-being have to be taken into account in order to correctly specify the target users: elderly persons perceiving themselves as independent enough could actually benefit from the system proposed. In this case, attractiveness and social desirability of the system could be maximized in other to maximize acceptance.

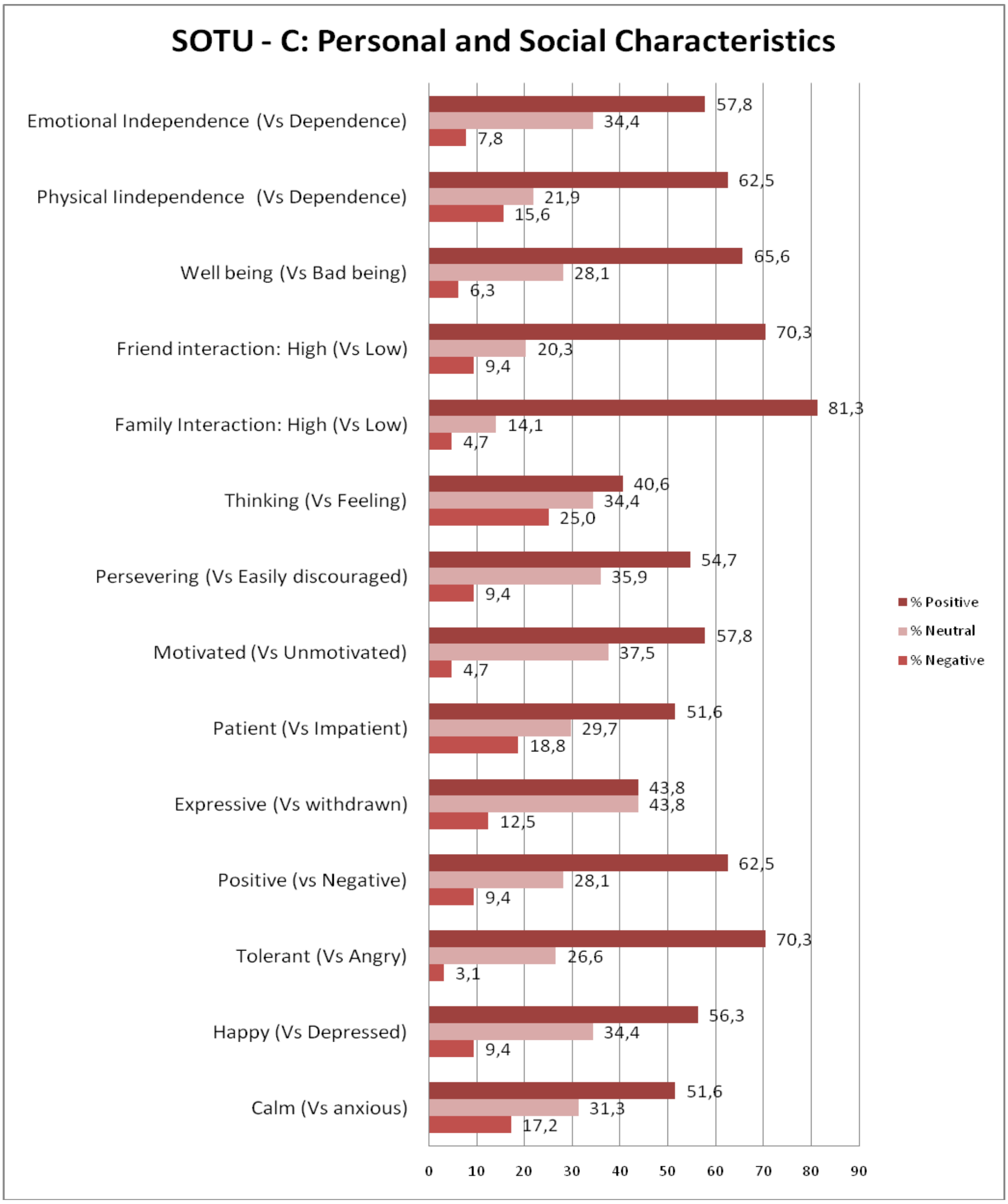

Figure 3. SoTU-C Results (elderly people) on personal and social characteristics.

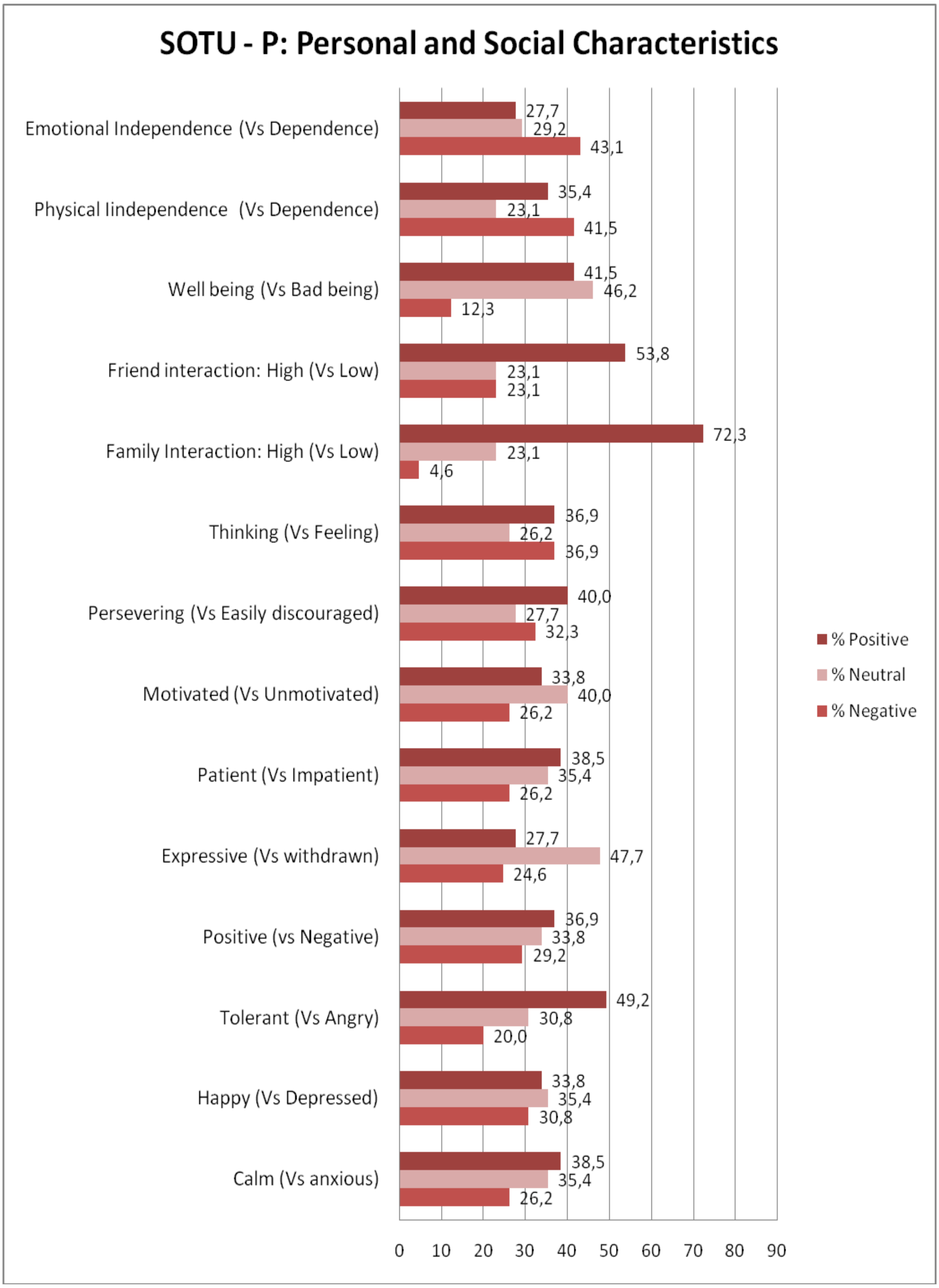

Figure 4. SoTU-P Results (family caregivers, professional caregivers and health professionals) on personal and social characteristics of the elderly persons.

Relations between those personal and psychological characteristics of the elderly person collected through both versions of the SoTU and other data about this topic collected in the individual interviews are described in section 3.2.

2.2. Subjective Dimensions

Development of understanding of how humans and robots can interact efficiently, taking advantage of the different abilities of the humans and machines, should take into account psychological dimensions. This is especially true under difficult circumstances, including interaction with frail elderly adults. In this regard, it has been shown that, although age seemed to be negatively related to technology, there is evidence that older adults are willing to accept technology in their home if they see the benefit of that technology especially regarding independent living. Ezer, Fisk, & Rogers (2009) asked participants about their willingness to have a robot and observed three task factors that differed by the interaction required: the first factor was composed of interactive tasks in which the user would need to be actively engaged with the robot; the second factor included tasks that would help the user but that would not be performed by the robot frequently; and the third factor included infrequent tasks performed by the robot; the third factor included frequent service tasks, in which the robot would interact with the human only as a servant. Willingness to let robots perform infrequent tasks was significantly greater than willingness to let robots perform service tasks, and to let robots perform service tasks was significantly greater than that of interactive tasks. In this study, technology experience, health, and living situation controlled for, age had a significant effect on the types of tasks that participants were willing to let robots perform in their home. Older adults indicated more willingness than younger adults to have robots perform critical monitoring tasks that would require little interaction between the robot and the human. In a similar way, in D1.1 we have observed that elderly adults acceptance on the system proposed is higher compared to responses from family caregivers and professional caregiver, and their qualitative comments suggest that they are more interested in the help received by the system in independent living than in their concrete features.

In this section, data presented in D1.1 regarding psychological and privacy issues are explained in further detail and complementary analysis of personal and emotional issues are included. As it has been pointed in D1.1, not only elderly adults have been included as potential end-users but also a sample of family caregivers, professional caregivers and health professionals. Important inputs were found in our study regarding family caregivers. Especially in the focus groups conducted, but also in the individual interviews, this target group informed of high levels of psychological burden. In our sample, participants taking care of their elderly relatives were highly concerned of their stress and anxiety levels, and reported that these levels were more important for them compared to physical and behavioral efforts. This input is especially relevant for the project if we take into account that, as pointed in D1.1, family caregivers valued positively the idea of the system and their opinion about the impact of the system in their levels of stress and independency were good, but they were somehow reluctant about being the remote operators if it implicates 24 hours availability.

Because of the importance of the full set of psychological perceptions about the system, but also of the concrete inputs of elderly adults and family caregivers, firstly we inform of bivariate correlation analysis (Pearson) including the whole sample (table 2) and then we specify perceptions of these groups on how they would feel using the SRS (tables 3 & 4). As in D1.1, these analyses have been carried out using SPSS 15.0 for Windows.

	Preference for a RO	Somebody close as RO	Professional as RO	Feedback about RO	Feedback about activities	Privacy risk	Safety risk	Trustfulness	Independency	Over control	Family relax	Social life	Housing problems	Positive Exp.	Positive Percept.	Positive Activities	Positive Per. & Psychol.
Preference for a RO	1																
Somebody close as RO	.435**	1															
Professional as RO	.458**	.412**	1														
Feedback about RO	.131	.414**	.091	1													
Feedback about activities	.124	.405**	.172	.732	1												
Privacy risk	.098	.017	-.083	.403**	.295**	1											
Safety risk	.084	.088	-.049	.334**	.383**	.575**	1										
Trustfulness	.110	.193*	.276**	.137	.077	-.247**	-.333**	1									
Independency	.146	.390**	.442**	.313**	.442**	-.116	-.077	.616**	1								
Over control	.074	.090	-.056	.139	.072	.438**	.261**	-.361**	-.160	1							
Family relax	.070	.173	-.004	.108	.251**	.010	-.001	.277**	.393**	.053	1						
Social life	.115	.231**	.411**	.018	.181*	-.136	-.088	.398**	.544**	-.156	.267**	1					
Housing problems	-.049	.112	.070	-.135	-.127	-.105	-.236**	.248**	.129	-.037	.149	.277**	1				
Positive experiences with tech.	-.194*	-.388**	-.196*	-.430**	-.327**	-.008	.058	-.320**	-.399**	.079	-.117	-.147	-.002	1			
Positive perceptions on tech.	-.079	-.267**	-.078	-.469**	-.444**	-.057	-.033	-.238**	-.384**	.112	-.123	-.214*	-.113	.600**	1		
Positive activities	-.048	-.210**	.024	-.307**	-.286**	-.045	-.097	-.151	-.206*	-.049	-.075	-.064	.032	.406**	.417*	1	
Positive personal and psychological matters	-.121	-.156	-.051	-.537**	-.366**	-.061	.031	-.184*	-.251**	.067	-.076	-.022	.015	.521**	.417**	.496**	1

Table 2. Correlations between subjective dimensions.

The relevance of psychological factors in the acceptance of the system is highlighted by the significant correlations showed in Table 2. We found a relation between trustfulness of the participants in a system like SRS (question C4) and a higher agreement with the potential impact of the system in independency (C5) and social life (C7) of the elderly persons and also with the levels of stress perceived by caregivers (C8); in the opposite direction, we found a relation between trustfulness and a lower perceived risk of being too controlled because of the system (C6).

About privacy, perceptions about privacy risks (question C2) and safety risks (question C3) are related to the need for an explicit agreement of the older user before somebody take the remote control of the system (question B27) and also related to the need for providing feedback to the elderly person about what actions is the system carrying on (question B28). Perceptions of safety and risks are, consistently, related to perceptions of trustfulness of the system, but also with the risk of being too controlled and the perceived inadequacy between the system and the place where the elderly persons live (C9); potential users perceive the relation between safety and housing conditions, highlighting the need for considering relations between safety in HRI situations and environmental conditions.

Considering independent living of elderly people not only related to functional abilities but also with sense of autonomy and selfsteem, it is interesting to highlight that we have found significant relations between the sense of independence expected from the system (question C5) and the highest preference for the remote control (question B24), for a closer person as a remote operator (question B25) and also for a professional service (question B26).

In the view of the results obtained about psychological dimensions and privacy issues are related to mean positive scores in the SoTU subscales explained in D1.1 and in the previous section of this document. Both positive experiences and positive perceptions about technologies are related to preference for the remote control, preference for asking the elderly user about the remote operator and providing feedback about activities carried on by the system, trustfulness and promoting sense of independency. Smaller but still significant relations have also been observed between positive opinions about activities and personal-psychological matters and these dimensions, except: a) between positive perceptions of activities and trustfulness, which is not significant; and b) between positive perceptions of personal-psychological matters and the preference for providing feedback about activities carried on by the system, which is the highest correlation in Table 2. The perceptions about personal and psychological adequacy of elderly people are related to the need for some kind of feedback about which activities are being done by the system.

As expected, very similar trends were observed, although in a contrary sense, between negative responses to SoTU and psychological dimensions studied.

Also similar patterns of significant correlations were found taking into account only data from the elderly adults group. In the questionnaire for elderly users we also included questions about how would they feel if they have a robot system such as SRS at home. Correlation analysis (Pearson) between these variables and those presented in the previous table are shown in Table 3. In general, psychological dimensions such as trustfulness, independency and impact on social life correlate with feelings such as calm, pleased, proud or interested. Interestingly, correlations are lower when we compare such feelings with privacy issues, especially perception of privacy risk and preference for asking them before somebody take the remote control of the system. These results underline that, as it was pointed in D1.1, for elderly adults the impact on independent living is much more important that applied matters related to technology, including privacy issues.

The same questions about feelings were asked to family caregivers, answering about how they would feel having a robot system such as SRS with their elderly relatives living alone. Correlations showed in Table 4 are lower, which can be partially due to the smaller size of the sample (see D1.1 for further details about sample description and participant recruitment). Significant correlations were only found for proud and happiness feelings: the prouder and happier the family caregivers expect to be having the system with their relatives, the more concerned they are about privacy and safety issues.

	Preference for a RO	Somebody close as RO	Professional as RO	Feedback about RO	Feedback about activities	Privacy risk	Safety risk	Trustfulness	Independency	Over control	Family relax	Social life	Housing problems
Calm - Anxious	,037	,311*	,268*	,237	,437**	-,175	-,204	,445**	,540**	-,272*	,255*	,438**	,170
Upset - Pleased	-,014	-,165	-,334**	-,121	-,308*	,250*	,220	-,428**	-,594**	,265*	-,134	-,383**	-,209
Proud - Ashamed	,109	,347**	,337**	,177	,372**	-,237	-,162	,354**	,543**	-,174	,192	,227	,179
Interested -Indifferent	,094	,315*	,215	,344**	,354**	-,082	-,191	,586**	,602**	-,255*	,212	,407**	,339**
Scared - Fearless	-,060	,207	-,314*	-,193	-,148	,264*	,283*	-,428**	-,520**	,328*	-,144	-,430**	-,363**
Frustrated - Successful	-,035	-,325**	-,250*	-,200	-,369**	,217	,251*	-,349**	-,535**	,123	-,258*	-,303*	-,134
Happy - Unhappy	,000	,248*	,326**	,201	,265*	-,309*	-,375**	,443**	,574**	-,153	-,258	,330**	,318**
Hostile - Friendly	-,239	-,278*	-,365	-,203	-,237	,252*	,264*	-,464**	-,560**	,259*	-,176	-,365**	-,258*
Attentive - Inattentive	-,248*	-,023	-,266	-,055	-,001	,022	-,154	,023	-,127	,129	,098	,017	-,088
Hopeful - Hopeless	-,051	,269	,209	,262*	,303*	-,108	-,289*	,518**	-,519**	-,228	,196	,359	,322**

Table 3. Correlations between subjective dimensions and expected feelings in the SRS sample of elderly adults.

	Preference for a RO	Somebody close as RO	Professional as RO	Feedback about RO	Feedback about activities	Privacy risk	Safety risk	Trustfulness	Independency	Over control	Family relax	Social life	Housing problems
Calm - Anxious	,132	,380	-,262	,359	,351	,380	,554*	-,250	-,327	,255	,361	-,382	-,194
Upset - Pleased	-,167	-,358	-,171	-,276	-,264	-,302	-,389	,309	,010	,003	-,672*	-,002	,286
Proud - Ashamed	,087	,236	,212	,567*	,599**	,286	,498*	-,221	-,011	-,229	-,072	-,243	-,498*
Interested -Indifferent	,054	,212	,395	,043	,090	,056	,000	-,075	,121	-,228	,325	,227	-,219
Scared - Fearless	-,011	-,085	,193	-,204	-,244	-,162	-,410	,263	,295	,118	-,267	,264	,075
Frustrated - Successful	-,130	-,273	,004	-,400	-,360	-,281	-,352	,034	,008	,183	-,350	,322	,266
Happy - Unhappy	,248	,349	,149	,592**	,559*	,502*	,519*	-,121	,120	-,073	,442	-,286	-,281
Hostile - Friendly	-,342	-,329	-,182	-,383	-,445	-,176	-,325	-,110	-,142	,077	-,265	,195	,416
Attentive - Inattentive	,110	-,061	,234	,012	,120	,156	,038	,159	,047	-,042	-,115	-,043	-,276
Hopeful - Hopeless	,054	,071	,000	,383	,360	,393	,357	-,151	-,121	-,304	,250	-,272	-,110

Table 4. Correlations between subjective dimensions and expected feelings in the SRS sample of family caregivers.

2.3. Conclusions

Results included in both section 2.1 and section 2.2 stress the potential role of the psychological factors, not only in well-know user-acceptance of technology processes, but also in specific issues targeted by this project, such as remote control possibilities (and acceptance) and privacy issues related to remote. Different psychological variables are highlighted, especially: a) Elderly adults' perception of needs, experience with technology and expected impact on independent living must be taken into account, and b) Psychological burden of family caregivers.

3. Requirements for SRS Human-Robot Interaction

3.1. Requirements and Recommendations Derived from HRI Literature

Several design principles, requirements, and recommendations have been derived from the human-robot interaction literature. Those relating to system usability can be considered preliminary and broad usability goals. Specific and quantified usability goals will be developed when the system specification is set. The following topics are related to robot interaction design specifically. In addition, general design principles of user-centred design (e.g., Norman, 1988; Galitz, 2007) will be followed.

Type	Description
Design principle	Establish high situation awareness: Situation awareness (Endsley, 2000; Scholtz, 2003) is the knowledge of "what is going on around you". A key question is: What information is important to attend to? It involves perceiving the right cues in the environment, the ability to integrate multiple pieces of information and determine the relevance to the goals the user wants to achieve, and to be able to forecast future situation events based on comprehension of the current situation. Since SRS employs remote control, it will be an important goal to achieve that the user is immersed in the robot's environment and is provided with all relevant and only with the relevant information about the situation. Scholtz (2003) mentioned different requirements for situation awareness depending on the role of the robot operator. SRS's teleoperator role mainly has aspects of a "supervisor" and of an "operator" role. Thus, the following information will be relevant to the SRS teleoperator: - the robot's world model - overview of the situation - the robot's plans - what actions are currently possible for the robot to carry out - current behaviours including deviations that may require intervention - the current status of robotic sensors - other interactions currently occurring - any other jobs that are currently vying for the operator's attention - the effects of any adjustments on plans and other interactions An important issue of situation awareness arises with learning robots. As they

	continuously acquire new knowledge, e.g. on their physical surrounding or task success, their capabilities can change over time. These changes should be communicated to all operators so that they know the current state of the robot (Scholtz, 2002).
Design principle	Establish common ground: Kiesler (2005) and Green et al. (2007) proposed the establishment of common ground as a design goal for HRI. “Common ground refers to the set of mutual knowledge, shared beliefs and assumptions that collaborators have. This process of establishing shared understanding, or “grounding”, involves communication using a range of modalities including voice, gesture, facial expression and non-verbal body language.” (Green et al., 2007). For example, the robot should communicate its understanding of the physical environment (e.g., objects detected) to the operator. The operator, in return, should communicate his understanding (e.g. by showing the robot objects it failed to detect). Common ground can be established through communication.
Design principle	Design according to mental models: Lee et al. (2005) showed that people build mental models of robots and their behaviour, similar to human-human interaction. Therefore, during the design of HRI, the mental models should be known. Interaction metaphors can then be designed accordingly.
Design recomm. / requirem.	Drury et al. (2004) and Yanco et al. (2004) note the following important requirements for the design of HRI: - Enhance awareness: Provide a map of where the robot has been. Provide more spatial information about the robot in the environment to make operators more aware of their robots’ immediate surroundings. - Lower cognitive load: Provide fused sensor information to avoid making the user fuse the data mentally. - Increase efficiency: Provide user interfaces that support multiple robots in a single window, if possible. In general, minimize the use of multiple windows. - Provide help in choosing robot modality: Provide the operator assistance in determining the most appropriate level of robotic autonomy at any given time. - The interface design should allow for adding more sensors and more autonomy later.
Design recomm. / requirem.	Approach directions preferred by users should be considered in path planning. Dautenhahn et al. (2006) investigated preferred directions a robot should approach a user in a seated position (from left, from center, from right side). There was strong agreement between study participants in disliking the frontal approach and in preferring the approach from the right.
Design recomm. / requirem.	Fong, Thorpe, and Bauer (2001) note several requirements for good HRI with collaborative, semi-autonomous robots. In summary, the robot should be: - self-aware - self-reliant - able to maintain its own safety - adaptive - have a dialogue capacity
Design recomm. / requirem.	Sheridan (1992) outlines the following important supervisory functions which are relevant for SRS learning: - planning what task to do and how to do it - teaching or programming the robot - monitoring the automatic action to detect failures

	- intervening to specify a new goal in the event of trouble or to take over control once the desired goal state has been reached - learning from experience.
Design recomm. / requirem.	Communicate intentions to local user: If a remote operator controls the robot who works in an environment with other people, the intentions of the robot should be communicated to the people in the environment (Kuzuoka et al. 2004; Green et al. 2007).
Design recomm. / requirem.	Achieve high user experience: When designing HRI, it is necessary to move beyond task-based interaction and be attractive, affordable, and non-stigmatizing (Forlizzi, 2005). In addition, the human operator should perceive the robot as a credible device and possibly as a 'teammate' (Scholtz 2002).
Design recomm.	Faucounau et al. (2009) carried out a user requirement study with caregivers and stress that the ability to switch off the robot (obtrusive if always on) and the ability to communicate with the elderly person by voice are particularly important to users. However, it must be noted that users usually are not aware of the present technological limitations of voice operation when stating such wishes.
Design recomm.	Use of augmentation: Several studies (e.g., Bowen et al., 2004; Green et al., 2007; Collet et al., 2006) have shown that the use of augmentation has the potential to improve robotic control performance, improve manipulator arm control, and to better communicate plans and states from robot to human operator. Therefore, for SRS this technique should be considered, e.g. for enriching the video image transmitted to the remote operator.
Design recomm. / requirem.	Forlizzi et al. (2004) specify the following design guidelines specifically for the design of HRI for elderly, stressing adjustment foremost: - Provide a natural, "walk up and use" interface - Allow the user to initiate product interactions - Provide more than one choice to complete any given task - Provide options for aesthetic appearance - Provide multimodal input and consistent lightweight output - Support universal access and use by the largest number of people in the ecology - Provide mutable functionality for different users and contexts - Consider scale and footprint - Consider placement in the home environment - Make the product portable and usable beyond home context - Use familiar product forms to inspire early adoption

3.2. Requirements and Recommendations Derived from Gerontology Literature

Taking into account age-related changes found in the revision reported in the Deliverable 1.1 Section 2.1, we can conclude some specific features for interface design. As it can be seen in the table below, requirements from the Gerontology review are mainly about sensory and motor changes, especially those basic requirements needed to allow usage in a basic level; nevertheless, some requirements taking into account information processing and processing styles are also included. Apart from the papers studied in D1.1, some references are included in the right column referring to more applied publications revised in the development of this task.

ID	Recommendation	Data source
RfG1	Icons simple and meaningful.	Echt (2002).
RfG2	Graphics relevant, not for ornamentation.	
RfG3	Concepts in application screens presented using an adequate combination of text and graphics. Audio when necessary.	
RfG4	Fonts in the application screens resizable in some way (because of the difficulties of elderly users with small fonts)	
RfG5	Boldface can be used to emphasize important texts or to increase the readability of text without increasing too much its size. Italics are not recommended	
RfG6	Condensed letters should be avoided	
RfG7	High contrast between the foreground and background.	Kurniawan & Zaphiris' (2005)
RfG8	Background screens should not be pure white nor change rapidly in brightness between screens.	
RfG9	Colour can be used to attract the attention but keeping in mind contrast as the most important factor when considering colours to be implemented in the applications (persons with difficulties to differentiate colours or persons who mix colours must be also able to run the applications without this feedback)	Morrell, Dailey & Rousseau (2003)
RfG10	Yellow, blue and green colours in close proximity should be avoided in order to avoid confusions.	
RfG11	Each application screen should have a text title identifying the purpose of the screen, since elderly users get lost easily	Fink, Kobsa & Nill (1997)
RfG12	Every application screen must offer a help option; it must be contextual and describe in plain words all the elements composing the screen, their functions and the way to use them.	
RfG13	For users with some kind of visual impairment the screen display should be enlarged and, in severe cases, consider the change of the presented information to audio output.	
RfG14	Audio feedback used with great care (it can become annoying and frustrating when it is too insisting)	
RfG15	Combination of visual and audio feedback should be used carefully (it can increase distractibility in elderly users, except for certain user profiles with severe visual impairments)	Jang et al (2009)
RfG16	Audio feedback can be useful when the system needs to get the attention of the user (i.e. a request come to the system in order to take the control of it, so it needs to ask the user who is doing another task somewhere) or to emphasize certain important tasks.	
RfG17	Speech rates should be kept to 140 words per minute or less.	Fisk et al. (2004)
RfG18	Artificial (synthesized) speech messages that do not closely imitate natural speech should be avoided.	

RfG19	For acoustic signals to attract attention, a frequency between 300Hz and 3000Hz should be used. Commercially available telephone bells and smoke alarms tend to have intensity peaks around 4000 Hz which are effective for younger users but these sounds are missed by older users.	
RfG20	Control of volume of audio output should be provided to the user, together with instructions regarding how to make volume adjustments.	Zajicek (2000)
RfG21	Background noise should be minimized.	
RfG22	The language used should be simple and clear, avoiding irrelevant information.	Díaz, Matellanes, & Montero (2006).
RfG23	Important information should be highlighted and concentrated mainly on the centre of the screen.	
RfG24	Screen layout, navigation and terminology used should be simple, avoiding the use of the 'qwerty' keyboard, which is illogical and difficult to follow for many older people.	
RfG25	When a critical action has been selected by the user (i.e. exit an application), the system must always clearly notify this circumstance to the user and request his or her explicit confirmation.	
RfG26	Since learning to use an interface through trial-and-error was very new to elderly users, the interfaces should provide backward and forward navigation. Whenever possible, processes must be sequential and one way.	
RfG27	Avoid parallel / simultaneous tasks and the use of complex navigation structures	
RfG28	The most frequent actions should be always performed in the same way (elderly users get usually confused when common procedures are changed from application to application)	
RfG29	To be sure that the system provides adequate responsiveness to the users' actions (Older adults are usually more conscientious, and are therefore more likely to be concerned with "doing things right"; they may tend to think that they have done something wrong, even when the system is working slower or not properly, which may make them get discouraged).	Graf, Li & McGrenere (2005)
RfG30	Interface to be intuitive enough to provide by itself enough guidance (learning style is usually a reception style instead of a discovery style, which means that guidance in learning is generally needed)	
RfG31	Graphical interface less sensitive to erratic hand movements (because of the slowness and lack of precision of movements)	Apted, Kay & Quigley (2006)
RfG32	Remote controller extremely simple and with few keys; size of the remote adequate to its planned use by the target users	

3.3. Requirements and Recommendations Derived from User Requirements Study of Work Package 1

This part of the document summarizes the overall findings of user requirements study of WP1 explained and discussed in detail in D1.1, in order to provide technologists to start with development of the system. Each functional requirement is presented with some practical examples raised by the main needs that emerged during focus groups and interviews and in particular some of these examples are drawn from scenarios presented in D1.1, which already have been created considering the results of WP1.

ID	Functional SRS requirement / recommendation	Examples	Data source	Prototype
R01	The system **moves** around **recognizing and avoiding obstacles**	a door; a chair left in the house in the wrong place	Motor domain: all	1, 2
R02	The system **recognizes different environmen**t of the house	kitchen; living room; bedroom; bathroom;	Motor domain: all	1, 2
R03	The system **recognizes the user position** in the environment	user sat on the sofa in the living room; user in bed;	Motor domain: all	1, 2
R04	The system **recognizes and identifies objects**	shapes; colors; *letters on food boxes; numbers on microwave display*	Motor domain: all	1, 2
R05	The system is able to **grasp objects**	Glasses, bottles, books	Motor domain: all	1, 2
R06	The system **brings objects to the user avoiding contact** with potential dangerous parts	Serving operation on the static tray (prot.1) Bring the object nearer using the platform (prot.2) (Note: Elderly don't like too many interaction with the machine - from FGs and discussions)	Motor domain: all	1, 2
R07	The system is **able to manage objects** *with care*	open/close door by handle; open/close oven door; open/close drawer; putting object in a shelf ; choosing an object on a shelf	Motor domain: Reaching objects Opening bottles Shopping (Note: Elderly are jealousy of their things, they are	1, 2

			afraid the system could damage furnishings -from FGs and discussions-)	
R08	The system is **able to maneuver in narrow spaces**	small houses; houses full of furniture;	Motor domain: all (Note: Usually elderly lives in small apartments - from FGs and questionnaires-)	1, 2
R09	The system is able to bring objects in **difficult places to reach** for elderly people	Reach a book on a high shelf;	Motor domain: Reaching objects	1, 2
R10	The system is able to helps the user in **choosing** an object in a difficult place to reach	Choosing a book between many on a high shelf while showing the options to the elderly sited on the sofa	Motor domain: Reaching objects Sensorial domain: Attend the visual problems	1, 2
R11	The system is able to **handle** objects with a weight of **five kg** with **different shapes**	Bottles of water, books	Motor domain: Reaching objects	1, 2
R12	The system is able to **transport** objects with **five kg**	Boxes full of shopping items	Motor domain: Carrying heavy objects	2
R13	The system **allows communication** between **user and remote operator**	Through: Displaying written messages; allowing voice communication; video calling;…	Social domain: Communication	1, 2
R14	The system **receives and executes orders from user**	Through: Telecontrol; voice control; simple keys on the system itself...	Motor domain: all Sensorial: Attend the visual problems and hearing problems Notes: Cognitive domain: Simple interface (from FGs and questionnaires) l	1, 2

R15	The system **receives and executes order from remote controller**	Through: Telecontrol, mobile phone; Personal Computer Personal Digital Assistant;...	motor domain: all Sensorial: Attend the visual problems and hearing problems Cognitive domain: Simple interface	1, 2
R16	The system **provides to the user a simple navigation tool** through different functions	(display, touch screen, internet, few keys..) selecting food to make shopping; selecting dinner menu;	motor domain: all Sensorial: Attend the visual problems and hearing problems Cognitive domain: Simple interface	1, 2
R17	The robot **supports the weight of a man** in a **getting up task**	by an handle integrated in the system	Motor domain: Falling management (avoiding)	2
R18	The system **monitors activities** and **recognizes the user position**, and the **time spent in the same position**	TV camera; sensors	Motor domain: Falling management (avoiding)	2
R19	The system **can be programmed** in order **to make autonomously some operation during different times of the day**	At programmed dinner time the system autonomously arranges the table;	Motor domain: all Cognitive domain: Forgetfulness	1? 2
R20	The system **communicates with the remote operator** in order to make operations at determinate times or under determinate circumstances	At programmed dinner time the system calls the operator in order to make the complex 'cooking operations'	Motor domain: all Cognitive domain: Forgetfulness	1, 2
R21	The system executes the operations under the control of the remote operator **but using also its intelligence**	avoiding obstacles while the operator is navigating the system through the environment; avoiding a frail object while the operator is executing a fetching operation;	Motor domain: all Cognitive domain: Forgetfulness	1, 2
R22	The system **alerts a remote operator** when an emergency has	The system sends a high priority	Motor domain: Falling	1, 2

	occurred	calls to the relative or to the service operator when a fallen is detected and shows the situation through TV camera	management o	
R23	The system can be programmed in order **to reminds the user** to do things at determinate times	Through Synthetic voice and/or Visual Displayed information it : Remembers to drink enough water; Remembers and display a particular appointment; Remembers it is time for dinner;	Cognitive domain: Forgetfulness	1, 2
R24	The system **reminds the remote operator** to do things at determinate times	Through a call, or through a sms: Remembers to the operator to ask to the elderly if he needs something	Cognitive domain: Forgetfulness	1, 2
R25	The system **stores information** and **recalls it for next activities**	While the remote operator through the system is managing shopping in the afternoon and putting everything at its place, the remote operator also stores information into the system. In this way at dinner time, food menu results updated	Motor domain: Shopping management Cognitive domain: Forgetfulness	1, 2
R26	The system **remembers the past activities** and **manage autonomously the information** when needed and uses them for next activities	In the afternoon SRS brings the bottle of water to the user in his bedroom and leave it there.	Motor domain: Shopping management Cognitive domain: Forgetfulness	1, 2

		At dinner time, during the table arranging, it remember having left the water bottle in the bedroom and goes to take it		

3.4. Privacy Policy and System Design Requirements for SRS Based on SRS Psychological Dimensions Study

Privacy is an important and complex issue in human-computer interactions. Privacy concerns should be taken seriously because their legal implications, but also because they influence the way a system is used/misused/unused. Among older adults, preventing misclosures in ubiquitous computing environment such as smart-homes has been pointed to be critical in order to preserve privacy (Caine, 2009). ETHICBOTS Project (http://www.ethicbots.na.infn.it/) identified 28 ethically sensitive items in robot development. At least 6 of them are strongly related with SRS project:

- technologies providing remote actions,
- learning robots specificities,
- autonomous service robots acting in the environment of humans who are not robot experts,
- position of humans in the control hierarchy,
- developing effective and acceptable human-robot interfaces,
- human-robot interaction paradigms and examples of the use of robots in human care.

Examples of the use of robots in human care includes facilitate the life of old and disabled persons and implies well-known bioethical about caregiving. Within the SRS project, implications of robot use in human care must be expanded taking into consideration remote operation solutions proposed. In this regard, remote operation technologies facilitate actions but, at the same time, could elicit forms of abstraction and moral disengagement by avoiding sense of responsibility (Christaller, Mock, Laschi, Salvini, Tamburrini, Veruggio, & Warwick, 2006).

Apart from the remote control implications, the highest risk of these kinds of systems is the disclosure of information to a third party by a personal robot. As it has been pointed by Syrdal, Walters, Otero, Lee Koay & Dautenhahn (2009, p. 2), “a personal robot may need to store information regarding the lay-out of a home and its contents as well as housekeeping styles and preferences of its users, so that it can perform its everyday tasks to the satisfaction of its users -…-.This means that information directly related to the private sphere of the lives of its users is collected.” The disclosure of information can be intentional (i.e. a personal robot companion could shop for groceries online, disclosing information regarding credit card accounts to trusted vendors), but there is also the possibility of accidental or unintended information disclosure. From a psychological perspective, Caine (2009) considers that a disclosure is the act of revealing personal information to others and a misclosure the act of revealing information in error. When information is disclosed in error, or misclosed, privacy is violated in that information not intended for a specific person is revealed to that person.

As in previous studies (Syrdal, Walters, Otero, Lee Koay & Dautenhahn, 2009), results presented in D1.1 show that participants' attitudes towards privacy was one of a tradeoff between the utility and the how sensitive the nature of the information was. In this regard, elderly adults seem to be especially concerned with utility issues and health professionals with the nature of the information processed. Health professionals present the higher agreement to authorization request and feedback about robot activity during the study, in part because their professional experience is wider than personal experiences of the caregivers, in part because their higher education (i.e. formal knowledge about elderly people's rights, bioethicals,…). Potential users also showed some afraid of intrusion in their private life, the more intimate part of which they spend at home, although as it has been pointed before, receiving an adequate help is seen as more important than privacy issues.

In general, attending to the high relevance of privacy in user acceptance and also to the potential safety issues related to the topic (i.e. an unauthorized person accessing to the system and opening the door of the house), all comments about privacy matters have been observed in this section. Not only safety issues related to privacy have to be observed (i.e. avoiding non authorized access to the system), but also privacy requirements promoting psychological engagement and comfort with the system. In this regard, both elderly users and health professional clearly pointed that elderly people have to be explicitly informed about when anybody else has access to the system, in order to give them the opportunity to adapt his or her behaviors to the person having access to their private life.

ID	**Privacy requirements and recommendations**
PR1	Only authorized persons to have access to the remote control of the system
PR2	Authentication procedure as a protection of the access to be included for both family caregivers and professionals.
PR3	Possibility of external and non authorized intruders to be avoided by a robustness security system
PR4	Avoid possibility of access to the system without explicit consent of the elderly, including non authorized access of authorized remote operators
PR5	If remote operator changes within one session, the elderly user must be also informed
PR6	Unintentional, not authorized disclosure of information related to the life of the users has to be prevented by restricting access to the information stored in the system.
PR6.1	Storage and management of personal information related to behaviors and preferences of the users have to be done in safe, restricted databases
PR6.2	Storage of personal information related to behaviors and preferences of the users will be limited to that information relevant for the functionalities of the system. Non relevant information processed if not necessary.
PR7	Unintentional, not authorized disclosure of information related to the life of the users to be prevented by including agreements of confidentiality for authorized users.
PR8	Verification of the plans of action by asking the elderly user before it starts acting.
PR9	Communication of action outcomes during performance of the robot, in order to maximize the awareness of the elderly user. Communication as continuous as possible.
PR10	An "on/off" mode to be implemented in order to protect privacy in very personal

	moments. The access to the "on/off" mode could be adaptable attending to the specific frailty of the elderly user.
Other relevant	
Access of well-known persons and relatives are highly agreed, *even though family caregiver would like to avoid 24 hours availability*.	
Preference for professionals as remote operators is also high, *although some professional caregivers do not see themselves as optimal remote operators*.	

3.5. Safety Requirements and Recommendations.

About specific issues for SRS setup concerning user interaction and safety, in principle there are two main groups of user interaction:

(a) (direct) control of robot system via remote control by remote operator,
(b) interaction between robot and the primary user at robot site.

From safety aspect one major problem – and also the main difference between SRS and most of the known robot setups for industrial and service site – is that the primary user does not know what the next activities of the robot (remote controlled or in automatic mode) are. On the other hand the remote operator needs sufficient information about the environmental situation at the robot site in order to ensure safety of the commands sent to the robot. Known problems with remote robot control (such as limited feedback from use site to remote site, time delay between command and execution and/or between sensing of environmental change and display of this information to the remote operator) increases complexity and needs to be considered about their influence to system safety.

About standards and regulations, a new standard for non-medical personal care robots is currently in definition phase – this standard also will include additional regulations concerning safety and interaction. As long as this standard is not ready, one of the standards to consider is ISO 10218-1 and 2 "Robotics and robotic devices". For a setup like SRS this standard is only partly relevant because main safety rule for industrial robots still is to separate working area of robot and of involved humans. Some of the (partly) applicable regulations from this standard are the ones dealing with robot programming, program testing and maintenance, because in these situations of industrial robot systems a direct (physical) interaction between robot and user is unavoidable. Some safety regulations from this operation phase which can be used for SRS can be summarized as follows:

- Limited speed of the robot (effector) movement (maximum: 250 mm/s); REMARK: SRS setup is based on a combination of a mobile platform with a manipulator arm so that the speed of the effector is a combination of particular speed of manipulator and base
- Emergency stop button
- Confirmation buttons for movement
- Safety circuit for all safety related components

For any service robot application – and thus also for SRS – it should be added, that the classical emergency buttons need to be considered with caution. It must be considered that such a button will be pressed also in many situations which are not really "critical" – an easy and complication-free continuation of the process after releasing the emergency button should be foreseen. Also the need of a permanent activation of a confirmation button should be considered with caution. Such a setup for sure shows a high safety level – but the acceptance from user side and thus also the relevance for a typical use scenario is rather questionable. One important regulation from ISO 10218 is that no robot movement should happen without initial confirmation by the user who is in direct physical contact with the robot. This situation is also very common but also critical for the SRS setup, so that this regulation finally should be considered to some extend for the SRS interaction setup. On the other hand, there should be a clear indication on the robot side if the robot is in autonomous mode or in remote controlled operation.

Some other important and safety related measurements or requirements can be outlined from the aforementioned and related standards (and also will be included in a similar manner in the new standard for person care robots).

- User interaction shall reduce mental stress to the user, especially to the primary user on-site
- Controls, signalling and data display elements shall be designed so that they can be understood easily in order to allow a clear and safe interaction between the robot and the user(s) (cf also EN 614-1, EN 894-3, ISO 6385, EN 13861, and others)
- Loss of communication shall result in a protective stop (REMARK: for SRS we might think about any safety related behaviour other than a complete stop, e.g. robot movement and working speed adjusted to the sensed proximity of humans or obstacles)

Despite of these safety measures which are directly related to the direct (or “desired”) user robot interaction – i.e. bidirectional information exchange between user and robot – there is another area of such human-robot interaction, namely the (in the most cases unintentional) physical interaction. As already described in Deliverable 1.2, this area – although representing only one particular aspect of HRI - has been analysed in several projects recently. In addition to the safety measures listed above, the following requirements can be taken from existing and/or upcoming standards and are relevant to SRS:

- Robot shape avoiding hazards relating to squeezing, cutting, beating; avoiding sharp edges, openings which change size during robot movement and/or ensuring minimal size according to ISO 13854
- Robot design ensuring sufficient mechanical stability in each use context (no overturning, falling, etc)
- Sufficient stability in case of power failure or (unintended) shutdown
- Especially for mobile platforms: measurements for avoiding down-leading steps
- Sensors for obstacle detection and measures for obstacle avoidance
- Limitation of working area by means of software/hardware limits; REMARK: SRS setup is based on a combination of a mobile platform with a manipulator arm so that such a limitation of the workspace can only be realized partially.

Literature also describes application of force limits. This is a very problematic field as such tolerable forces very much depend on the scenario and on additional factors. Such a safety measure cannot be generalized and must be analysed in more detail during a case-specific risk analysis.

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