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Niccolò Casiddu
Claudia Porfirione
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Ambient Assisted Living

Italian Forum 2017

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Preface

Part of the difficulties related to the management of disabilities and problems related to the ageing of the population could be overcome by exploiting the potential of new Information and Communication Technologies (ICT) and innovative support services with a view to developing Ambient Assisted Living (AAL). However, the availability on the market of such solutions and related services is far from optimal, as well as the training of professionals and technicians working in the field: the potential of ICT and assistive living environments has yet to be fully developed throughout Europe.

The eighth Italian on Ambient Assisted Living Forum affirms the importance of an annual meeting for discussion and consolidation of best practices research AAL.

Comparing promoted Italian Forum on Ambient Assisted Living of 2017 allowed designers and researchers participants to widen their perspective to create a true community of different and complementary skills, together with the operators involved, in various ways, the assistive technology sector.

The 2017 Edition is dedicated to using the latest technologies to make assisted living comfortable, affordable and pleasantly acceptable, as a result of meeting and integration between different disciplines and research approaches.

2017 Forum was held on 14–15 June in the Department of Architecture and Design (DAD) of the University of Genoa; for over thirty years, it has been doing research in this field. The 2017 Edition has involved students and young architects and designers, sensitized towards themes and design culture AAL. Among the results was the multidisciplinary comparison as a key element to address the draft AAL aimed at seniors, particularly fragile sector of the population.

The attention of this Forum to simplified many aspects of life, not just for the weak, constitutes a cultural heritage and infrastructure projects of the professionals working in the country.

This book presents the proceedings of ForItAAL 2017, a review of the current state of research, technologies and the most recent and authoritative results achieved in that field which demonstrate how research should continue to move towards the integration of disciplines that revolve around the user services.

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Radar Sensing of Vital Signs in Assisted Living Applications

Giovanni Diraco, Alessandro Leone and Pietro Siciliano

Abstract In order to be accepted by users, one of the most important requirement for any assisted living technology is unobtrusiveness. This is particularly true when this technology is intended for continuous monitoring of vital signs, since traditional approaches require the subject to be tethered to measurement devices. The radar sensing is a very promising technology, enabling the measurement of vital signs at a distance, and thus meeting both requirements of unobtrusiveness and accuracy. In particular, impulse-radio ultra-wideband radar has attracted considerable attention in recent years thanks to many properties that make it useful for assisted living purposes. The aim of this paper is to investigate such radar technology for vital signs monitoring in assisted living scenarios. An algorithmic framework for the detection of respiration and heart rates during various activities of daily living is presented, including a method for compensation of movements of both the monitored subject and a second person present in the same environment (e.g., family member, caregiver, etc.). Experiments are carried out in various conditions that can be frequently encountered in assisted living scenarios. The reported results show that vital signs can be detected also while carrying out ADLs, with accuracy varying according to the level of movements and kind of involved body's parts and postures.

Keywords Patient monitoring · Vital signs · Radar · Ultra-wideband
Non-contact sensing · Assisted living

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1 Introduction

In the context of assisted living, there is an increasing demand for unobtrusive sensing of human activities and behaviors as well as physiological parameters, suitable for detection of dangerous situations (e.g., falls [1]) and even for early prediction of health disorders (e.g., illness or functional decline [2]), in order to actually provide timely medical assistance and alerts to caregivers. Nevertheless, in this context, the emphasis on unobtrusiveness is especially important. In fact, as it has been assessed in [3], older adults are more likely to accept in-home sensing technologies when these are unobtrusive, i.e., they do not demand to wear any device, not interfere with daily life, not require to learn new technical skills and, above all, not capture video images. By the way, it is only by means of a good acceptability that it is possible to provide a continuous monitoring, essential to produce long-term health data from which informative patterns can be extracted.

Among vital signs, respiration rate (RR) and heart rate (HR) are fundamental physiological parameters whose alterations may be correlated, especially during ageing, with the progress of physical illnesses (e.g., sleep-disordered breathing [4], congestive heart failure [5], subclinical inflammation [6]) as well as mental and neurodegenerative diseases (e.g., major depressive disorder [7], Parkinson disease [8, 9]).

The golden standard for measurement of the heart activity is the electrocardiograph (ECG) [10], which involves various kind of electrodes (i.e., conventional Ag–AgCl suction, adhesive gel, etc.) attached to the skin on the chest and limbs. Whereas in regards to the respiration activity, the standard measurement technique is the transthoracic impedance plethysmography (IP), requiring skin electrodes placed on the chest of which at least two must be ECG electrodes [11].

Focusing on the measurement of basic parameters, such as RR and HR, slightly more comfortable approaches may involve the use of textile dry or capacitive ECG electrodes, elastic bands around abdomen and/or chest (e.g., respiratory inductance plethysmography), optoelectronic sensors (e.g., Photoplethysmography—PPG), and even pressure or accelerometer sensors. However, all these approaches still require the subject to be tethered to a body-worn or closely located measurement device, resulting uncomfortable and unpractical for continuous monitoring in assisted living scenarios.

Remote sensing techniques offer a more suitable alternative by which RR and HR can be unobtrusively detected and measured at a distance (ranging from tens of centimeters to meters). Such techniques may exploit either optical or radio waves, leading to camera-based photoplethysmography (cbPPG) and radar sensing respectively. The working principle of cbPPG is to detect small changes in the skin color due to cyclic variations of blood volume in arteries and capillaries under skin, and thus to estimate the PPG signal which is proportional to such skin color changes [12]. Instead, the remote sensing of vital signs using radar is based on detection of small movements induced by the heartbeat and respiratory chest-wall motions [13].

The cbPPG technique, unlike the radar-based one, allows to estimate also the blood oxygen level (SpO2), but radar sensing is more accurate in estimation of RR and HR (particularly in presence of multiple heartbeats and cluttered scenarios with obstacles) [14] and, additionally, it has some characteristics that make it a promising technology for assisted living applications. First of all, it is a fully privacy-preserving sensing technology, since captured information is outside the human sensory capabilities (unlike cbPPG that captures images), and thus not directly usable for obtaining privacy-sensitive information. Secondly, it is a multi-purpose technology whose application range spans from detection and measurement of vital signs to localization, movement detection, critical event detection, and even secure high-throughput wireless communication, and all these features are available in non-line-of-sight (NLOS) and through-wall (TW) modalities [15].

The remainder of the paper is organized as follows: Sect. 2 analyses the state-of-the-art of vital signs detection, highlighting related works based on radar systems; Sect. 3 starts by giving an overview on IR-UWB radar technology adopted in this study and, afterwards, describes the processing framework, then continues detailing the experimental setup. The achieved experimental results are shown and discussed in Sect. 4. Some conclusive remarks are, finally, provided in Sect. 5.

2 Related Work

Radar-based vital sign sensing caught the interest of researchers from the 70s, when the first experiments were carried out aiming to detect remotely RR [16–18] and HR [19] parameters. The measuring principle of vital signs with radar exploits tiny chest movements caused by the respiratory and circulatory motions (contraction and expansion) which induce changes in electromagnetic (EM) wave returning back to the radar system once reflected by the subject's chest.

Such changes contain information about RR and HR of the subject, and they essentially may occur in terms of frequency, phase, and arrival time of reflected EM wave [20]. The frequency-changing effect is used in the Doppler radar which is one of the earlier radar-based approach for vital sign detection [16], and also successfully adopted for long-range (up to 69 m, in line-of-sight) detection of RR and HR [10, 21–23]. The phase-changing effect is normally exploited in the interferometric radar, recently demonstrated also for vital sign detection achieving highly accurate measurements although at the price of a greater complexity and expense [24]. Regarding the third changing effect, i.e., arrival time, it governs the working principle of impulse radar systems which, thanks to generated train of ultrashort EM pulses, can operate over a larger bandwidth and wider range of frequencies than continuous wave (CW) systems.

Impulse radars are generally referred to as impulse radio (IR) ultra-wideband (UWB) radars and, together with Doppler radars [25], are the most investigated for physiological function monitoring [26]. Since Doppler radars typically are CW narrowband systems, they can accurately measure the velocity of targets (i.e., high

Doppler resolution) but not their position (i.e., low spatial resolution), making it difficult the cancelation of motion artefacts caused by the subject or by other nearby people as well as the detection of vital signs from more than one person. Instead, IR-UWB radar sensing provides additional features over CW systems [27], particularly useful in assisted living contexts. The sub-millimeter range resolution (i.e., high spatial resolution) and high penetration power enable accurate target localization even through obstacles (e.g., TW/NLOS sensing). The shorter pulse duration, lower than the total travel time of the wave even in case of multiple reflections, is helpful to deal with multipath effects particularly insidious in indoor environments. The very low power spectral density (−41.3 dBm/MHz) prevents interferences with other radio systems operating in the same frequency range (typically, from 3.1 to 10.6 GHz), and guarantees a low probability of interception; enabling secure high-data-rate communication in short range (e.g., up to 500 Mbps at 3 m).

Although by now radar-based monitoring of physiological functions such as HR and RR is well understood and established in experimental and clinical settings as well as rescue searching and military operations [14, 25, 28–30], there are still questions about its effectiveness in assisted living contexts that should be properly addressed. Indeed, assisted living technology aims primarily to support senior citizens and frail people performing their activities of daily living (ADLs) within their living environments, in families or community homes. In such contexts, monitored subjects do not spend all day in a bed, motionless and alone, but on the contrary they are often in motion performing ADLs, sometimes receive visits, enjoy the company of a pet, and so on.

Thus, the assisted living setting poses new challenges to radar sensing of vital signs, which can be mainly ascribed to the possibly presence of "multiple people," "slight movements of the monitored subject's body," and "presence of occluding obstacles." In presence of multiple people, the radar sensor should be able to distinguish between monitored subject's vital signs and those of other nearby people, and should be able to work properly also if nearby people move. The radar sensor should be able to still operate even in presence of slight (random) movements of the subject's body not correlated with cardiopulmonary ones, and also under different body's postures. In home environments, the presence of obstacles is very common, such as walls, doors, closets or other piece of furniture; nonetheless, measurement of vital signs should not be compromised by occlusions or NLOS conditions.

Some of these issues have been partially addressed in [31], suggesting an interesting radar technology (essentially, CW Doppler) for vital signs monitoring in smart homes. The authors reported good results in both HR and RR detection with accuracy ranging from 90 to 99% in various scenarios such as different distances (up to 8 m), TW, multiple people (up to 3), and during quasi-static activities (e.g., typing on laptop, watching TV, sleeping). However, this study shows several limitations, for example, the multiple-people scenario required a minimum person-to-person distance of 2 m, and common ADLs (e.g., dressing, feeding, locomotion, etc.) as well as critical circumstances (e.g., post-fall phase and recovery during which the subject may be on the ground) were not taken into account.

On the other hand, using UWB radar systems, some other studies reported better results in multi-target vital signs detection [32, 33]. Actually, the fine spatial resolution obtainable through UWB technology allowed to accurately discriminate HR ad RR of multiple people within a radius smaller than 1 m. Moreover, UWB radar was successfully used for monitoring of vital signs in environments containing other motion (i.e., nonstationary clutter suppression) [34], and even to detect the RR of a moving subject (i.e., movement compensation/suppression) [18, 35, 36]. Another common issue arising in radar-based vital signs detection concerns the breathing signal harmonics which may be several times stronger than the heartbeat frequency. Also in this case, a viable solution (i.e., harmonic canceller) has been demonstrated by using UWB radar [37].

Despite the many properties that make UWB radar useful for assisted living purposes (i.e., compact size, high penetration capability, high spatial resolution, low EM interference, low multipath interference, low power consumption, low specific absorption rates), to the best of the author's knowledge, IR-UWB radar technology has not been fully investigated for vital signs detection in assisted living contexts.

3 Materials and Methods

3.1 System Overview

The detection system, of which a schematic representation is given in Fig. 1, is composed of two IR-UWB radar units, namely the Time Domain Pulson® P410 [38], connected via USB to a laptop computer which run the computational framework described in the following section.

The P410 is a state-of-the-art UWB radar sensor, working from 3.1 to 5.3 GHz centered at 4.3 GHz, covering a distance range of about 30 m, with good object penetrating capabilities and compact (7.6 × 8.0 × 1.6 cm) board dimensions. It is equipped with an omnidirectional antenna, which in this study has been modified by adding a planar back reflector in order to reduce the azimuth pattern to around 100° (also referred as FOV—field of view—in the following). Range data coming from the P410s are stored and later analyzed in MATLAB® software R2014a (The MathWorks, Inc.).

3.2 Algorithmic Framework for Vital Signs Detection

The algorithmic framework, enclosed within the dashed area in Fig. 1, includes the following six main parts: (1) IR-UWB radar P410, (2) bandpass filtering, (3) clutter removal, (4) micro(μ-)motion spectral analysis, (5) empirical mode decomposition (EMD), (6) vital sings extraction.

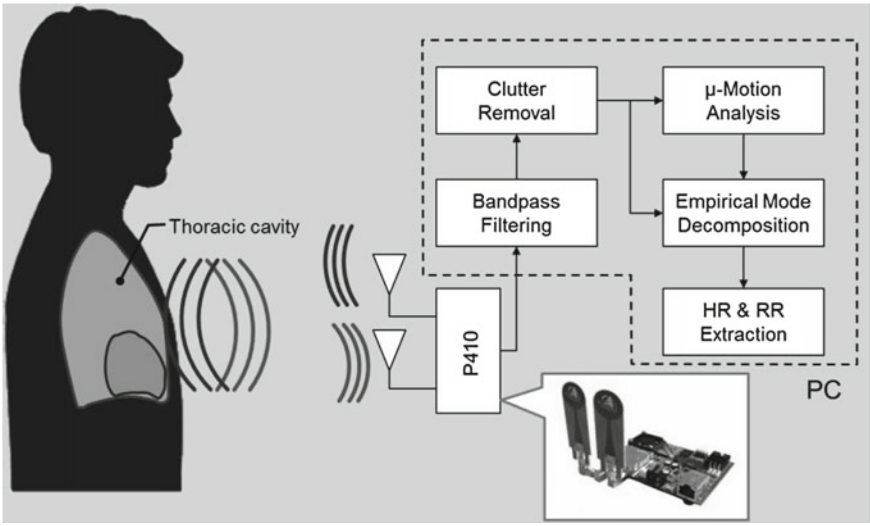

Fig. 1 System overview

In order to suppress the unwanted signal/noise frequencies out of the operative band (i.e., 3.1–5.3 GHz), a bandpass filter has been included in the first stage of the pipeline. At this end, a 16th order IIR (infinite impulse response) Butterworth bandpass filter has been applied to the radar signal in the fast-time. Similarly, unwanted signals or noise generated by periodic sources (e.g., fans, motors, curtains/doors motion, etc.) can be removed in order to ease the post processing of signals reflected from the monitored subject's chest useful for vital signs estimation. Thus, a second bandpass filter has been implemented, namely a 6th order IIR Butterworth in slow-time with a passband from 0.2 Hz (corresponding to a minimum of 12 breaths/min) to 3 Hz (corresponding to a maximum HR of 180 beats/min).

The clutter removal stage is devoted to the attenuation of signals reflected from static structures included in the environment (i.e., walls, furniture) whose energy can be several orders magnitude larger than signals reflected from the moving chest cavity. For this task a Singular Value Decomposition (SVD) [39] based approach has been adopted. Following this approach, the signal matrix was SVD decomposed obtaining a diagonal matrix whose first 'few' descending-ordered singular values conveyed the largest amount of clutter energy. By setting these singular values to zero and reconstructing the signal matrix, the clutter energy was removed and the signal-to-noise ratio (SNR) improved.

Since the UWB radar sensing of RR and HR is demoted due to non-cardiorespiratory body movements (i.e., random movements) done by the monitored subject, i.e., during the execution of ADLs, a preliminary stage for the compensation of such movements is required. For that purpose, the micro-Doppler effect has been exploited [15]. The micro-Doppler effect accounts of the relative micro-motion between radar sensor and target in terms of frequency shifts related to the radial velocity (i.e., there is a positive shift when target moves away from the radar and negative otherwise) and small motion of non-rigid parts (i.e., body parts). Exploiting the high distance resolution of IR-UWB radar, the Doppler spectrogram has been segmented in regions characterized by different kinds of motion (i.e., using the cross-correlation metric) on the basis of their spatial position with respect to the radar sensor. For each segmented region, the associated radar signal has been decomposed via EMD into a series of intrinsic mode functions (IMFs) each of which represents the oscillatory character of the original signal in a different frequency scale [40]. After that, IMFs were k-Means clustered and the IMFs associated with the subject's vital signs were selected as those falling into the frequency range from to 0.2 to 3 Hz. For the sake of example, the vital signs, RR and HR, extracted by using the EMD approach are reported in Figs. 2 and 3, respectively. It is important to note that the described micro-motion/EMD approach allowed to compensate slow random movements of both limbs (up to 5 cm/s) and torso (in the order of 5–10 cm max.), as well as motion artefacts caused by the presence of other people moving near the monitored subject (at a minimum distance of 1 m).

In the remaining of this section, the micro-motion analysis and EMD-based vital sign measurement are further discussed in detail, with a special focus on Doppler spectrogram processing given its importance in motion detection and compensation.

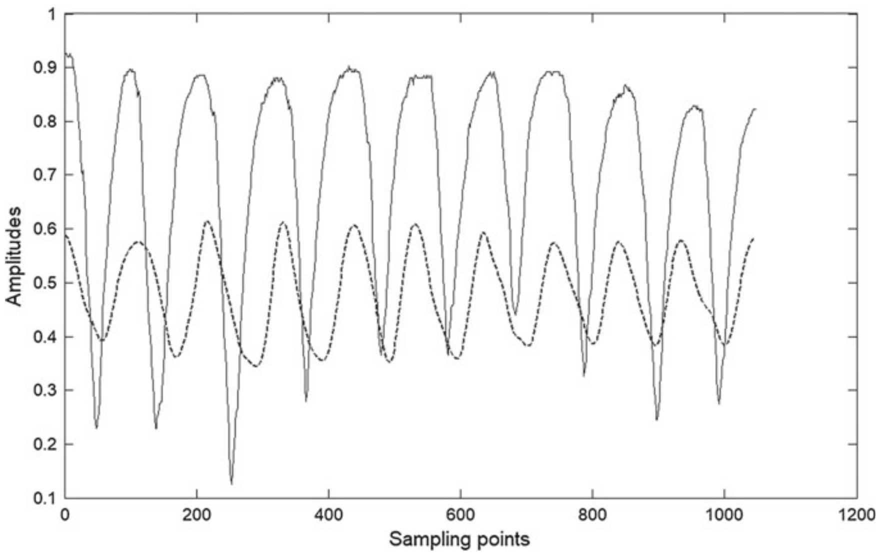

Fig. 2 RR measured with WWS (solid line) and extracted via EMD (dashed line)

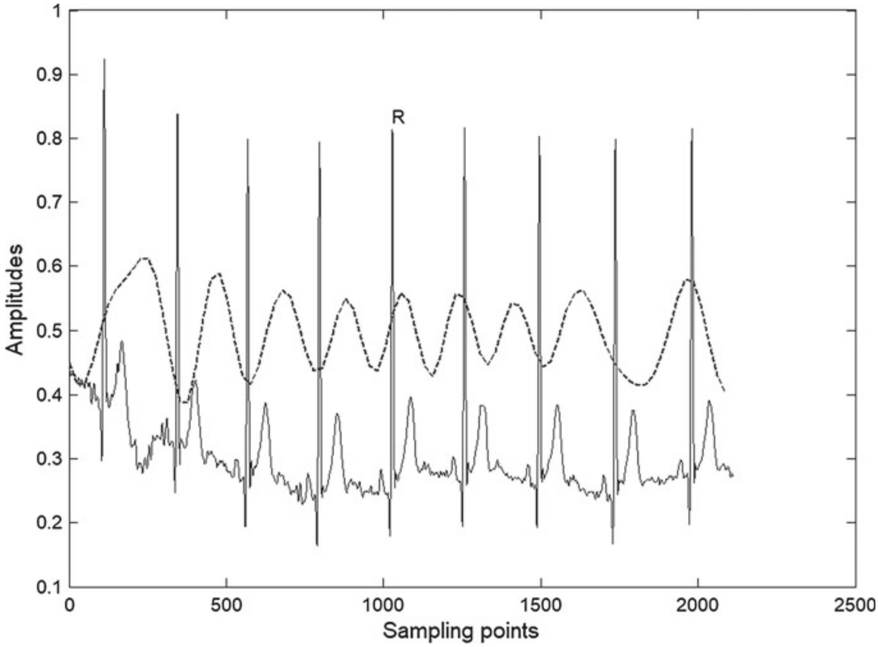

Fig. 3 HR measured with WWS (solid line) and extracted via EMD (dashed line). The 'R' wave is marked for reference

3.2.1 Micro-motion Analysis

As it is well known, the radar principle is based on the transmission of electromagnetic waves toward a target and the receiving of the returned waves reflected by the target. By comparing the transmitted and received signals, the radar station is able to determine position (range) and velocity of the target. In particular, the velocity of the moving target is obtained by exploiting the Doppler effect, on the basis of which the frequency of the received signal is shifted from the frequency of the transmitted one.

The Doppler frequency shift is proportional to the radial (i.e., in the direction of the line of sight) velocity of the target: it is positive if the target approaches the radar, and negative if the target moves away. Moreover, when the target is not a rigid body but has parts characterized by an oscillatory motion in addition to the main motion of the target (e.g., a walking human), such oscillation produces an additional Doppler frequency modulation called micro-Doppler effect [15]. Such micro-Doppler modulation can be regarded as a distinctive signature able to account for unique properties of a target. More specifically in this study, the micro-Doppler signature is exploited to detect and track human targets for monitoring of vital signs.

Normally, in the frequency domain, a signal is analyzed by using the Fourier transform technique which provides the frequency spectrum, i.e. magnitude and phase at different frequencies, of the signal during a certain time interval. Due to the micro-Doppler effect, the frequency spectrum deviates from the center frequency in a characteristic way, allowing to a certain extent to detect the presence of micro-motions. However, due to the lack of range information, the Fourier transform is not able to provide adequate information in presence of more complicated time-varying frequency modulations, but a high-resolution time-frequency transformation (i.e., able to characterize both the temporal as well as the spectral behavior of the signal) is needed instead. To this end, in this study, the short-time Fourier transform (STFT) was applied to the analytic form (i.e., computed via Hilbert transform) of the returned signal. In such a way, the micro-motion of one or more subjects can be effectively detection, as shown in Fig. 4 (left side).

At the purpose to reliably measure vital signs, also in presence of (moderated) subject's movements or a moving person nearby, the subject's micro-Doppler signatures need to be detected and eventually isolated from that of other subjects. Thus, the spectrogram (Fig. 4) was treated as a grayscale image and segmented in order to separate the foreground (i.e., one or more micro-Doppler signatures) from the background (i.e., noisy frequency components due to clutter reflections). Since the Doppler spectrogram is characterized by broad peaks corresponding to moving subjects, a simply adaptive thresholding technique was used.

After slightly smoothing the spectrogram (via averaging filter) to suppress noisy frequency components which can affect the segmentation process, the threshold was selected as equal to the standard deviation of the spectrogram. Once foreground

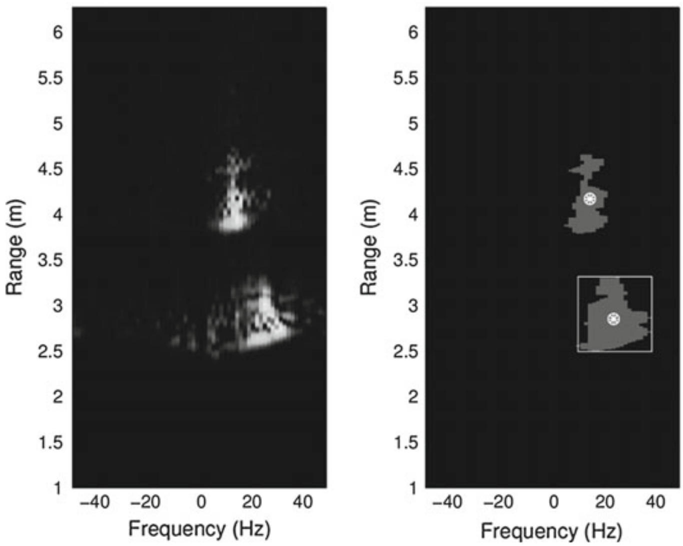

Fig. 4 Micro-Doppler spectrogram (left image) of two subjects moving in the same direction. The two related micro-Doppler signatures were segmented and the one closest to the radar sensor was selected (right image) for vital sign measurement

signatures were detected, the one closer to the radar sensor was considered for measurement of vital signs, as shown in Fig. 4 (right side).

3.2.2 Measurement of Vital Signs via EMD

Given a non-linear, non-stationary signal, such as a radar signal that conveys modulated RR and HR, the EMD is an effective time-frequency analysis technique, allowing to break down the signal into a set of IMFs among which RR and HR are included. The extraction process of IMFs is performed by the following steps: (1) computing of upper (joining maxima) and lower (joining minima) envelopes of the signal by using cubic splines; (2) estimation of the first component by subtracting the local mean of the two envelops from the original signal; (3) hence, the last computed component is treated as the original signal and the process is repeated until the envelopes become symmetric with respect to zero mean and no more components can be extracted.

3.3 Experimental Setup

The experimental setting was a laboratory room of 5.8 m $\times$ 3.8 m, shown in Figs. 5 and 6, in which two participants performed seven ADLs, namely cooking (CO), sleeping (SL), watching TV (WA), feeding (FE), dressing (DR), locomotion (LO), post fall (PF). The physical characteristics of the two participants are reported in Table 1. The radar sensor was placed in positions S1 and S2 at the two different heights from the floor of H1 = 1.4 m and H2 = 2.5 m. Note that the S2 position was beyond a drywall panel having thickness of about 8 cm. In addition, two time of-flight (TOF) cameras SwissRanger SR4000 [41] were placed on the wall at a height of 2.4 m (positions T1 and T2), in order to collect ground-truth data related to activities carried out by the participants.

The ADLs were performed at various distances with respect to the radar sensor. Referring to Fig. 5, firstly the positions marked on the X axis (equally spaced of 0.5 m) were tested for all ADLs. Secondly, the remaining positions were tested for only WA, LO and PF activities, since these last are more likely to happen in random positions.

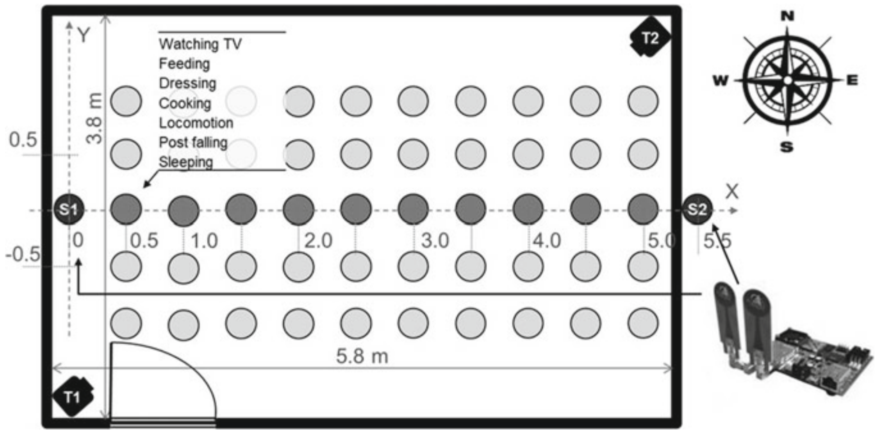

Fig. 5 Experimental setup: layout of the marked positions in which ADLs were performed, positions of the radar sensor inside (S1) and outside (S2) the room, and positions of TOF cameras (T1 and T2)

Each ADL was performed by the two participants orienting their face (or head for SL and PF activities) toward the four cardinal directions (North, East, South, West), starting from a static position and then progressively increasing the motion velocity until activity completion. Further details regarding assumed posture, involved movements and body's parts are summarized in Table 2. During the data collection, each participant was wearing a WWS (Wearable Wellness System) t-shirt [42] equipped with various sensors providing ground truth measurements for RR, ECG and body's movements (thanks to an embedded tri-axial accelerometer).

The TOF cameras, wall-mounted in position T1 and T2 (Fig. 5) at the height of 2.4 m from the floor, were used to efficiently annotate the starting and ending timestamps of each simulated action, i.e., change of body posture, as well as the occupancy level of the room, i.e., number and position of persons, as shown in Fig. 7. Firstly, the people present in the room were automatically detected and counted, by using a high-performing approach which does not need to track one person at a time (i.e., tracking-free approach), but on the contrary it is able to detect and track all persons' location at the same time on the basis of an agglomerative clustering method [43]. Secondly, starting and ending times of each performed action were automatically identified by decomposing (classification task) the action into a sequence of hierarchical postures [44] on the basis of high-discriminative features extracted from TOF range data [45].

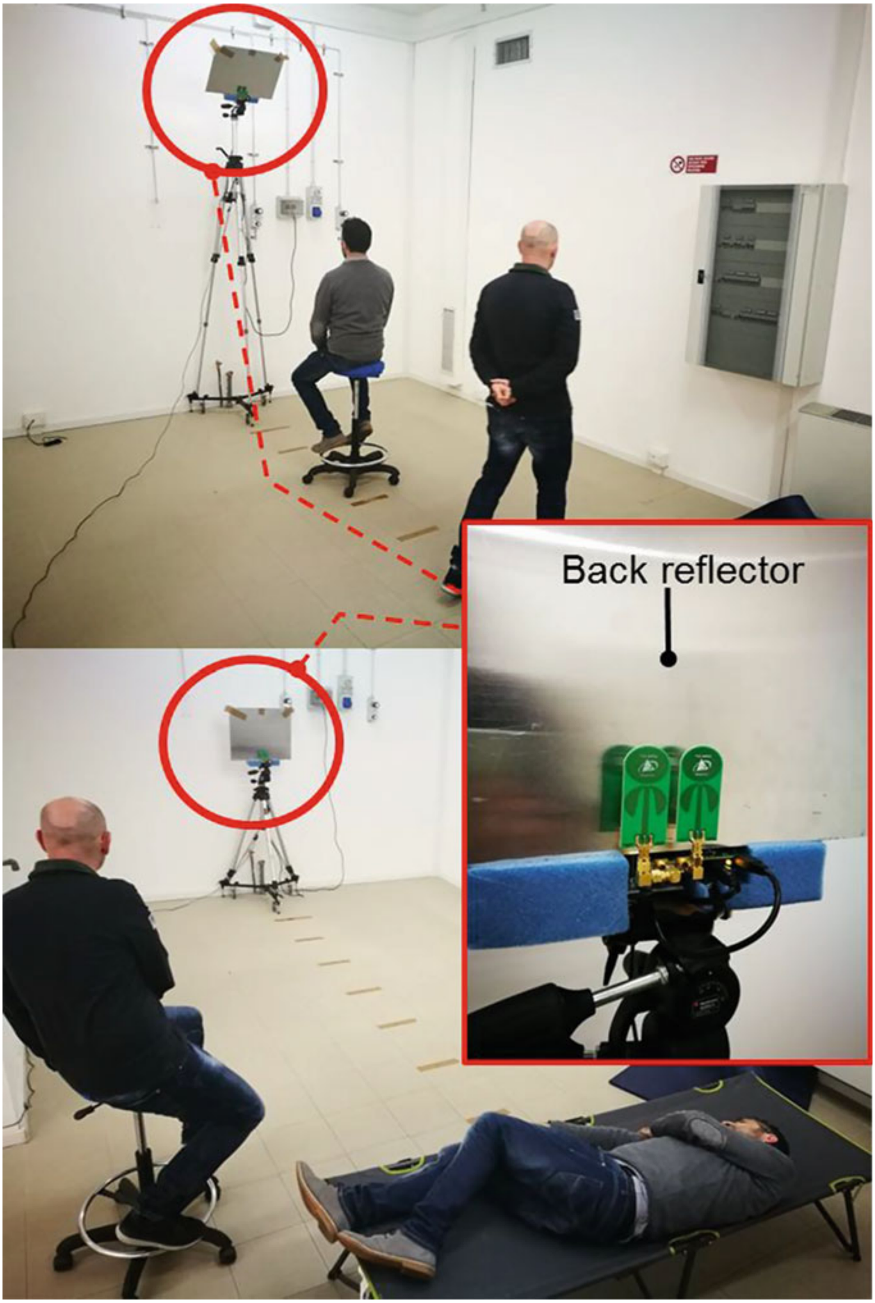

Fig. 6 Experimental setup. Pictures taken during data collection. It is also visible the radar sensor mounted at two different heights and its back reflector

Table 1 Participants' data

Gender	Age	Weight (kg)	Height (cm)	Chest circumference (cm)
Male	35	70	173	96
Male	45	84	184	104

Table 2 Further details of performed ADLs

ADL	Posture	Movement description	Body's parts
Cooking (CO)	Standing	Slightly moving hands mimicking the act of cooking	Superior limbs
Dressing (DR)	Sitting on the bed	Slightly moving arms, legs and torso mimicking the act of dressing	Whole body, but mainly superior limbs
Feeding (FE)	Sitting on the chair	Slightly moving hands/arms mimicking the act of eating/drinking	Superior limbs
Locomotion (LO)	Standing	Slightly walking	Whole body, with slight oscillation of superior limbs
Post fall (PF)	Lying down on the floor	Remaining motionless on the floor after a simulated fall	Mainly static position, with slight movement of the head
Sleeping (SL)	Lying down on the bed	Almost always motionless, sometimes turning to the opposite side	Whole body
Watching TV (WA)	Sitting on the chair	Almost always motionless, sometimes moving torso forward/backward or arms up/down	Torso, superior limbs

4 Results and Discussion

The detection performance was validated in terms of accuracy with respect to the ground truth. The validation was conducted in two phases, without and with a second moving person in addition to the monitored one within the radar FOV. The best coverage of the room was achieved with the radar sensor mounted at height H1, hence all reported results are referred to this height mounting.

Regarding the case with the only monitored subject present, the median accuracy of RR and HR detections are reported in Figs. 8 and 9, respectively. In general, the HR detection was more sensitive to movements than the RR one (especially to chest movements), resulting detectable only up to 2 m from the sensor. Beyond this limit, the movement compensation stage was not able to restore the SNR loss at the necessary level to separate the cardiac signal from the much stronger respiratory one.

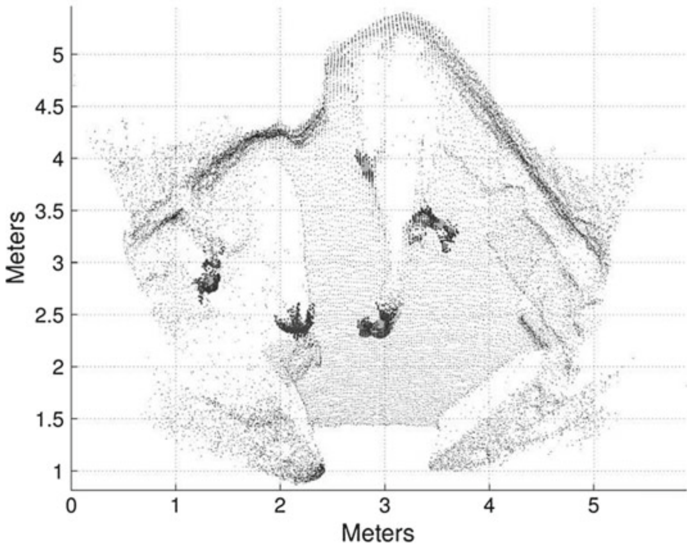

Fig. 7 TOF-based occupancy detection and posture recognition in a room with five people present

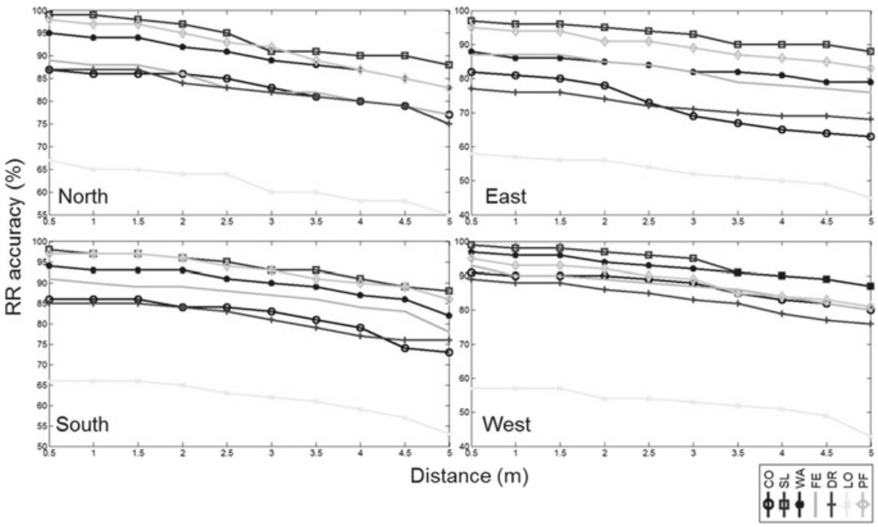

Fig. 8 Accuracy of RR detection at varying of distances and ADLs. The only monitored subject was present in the scene

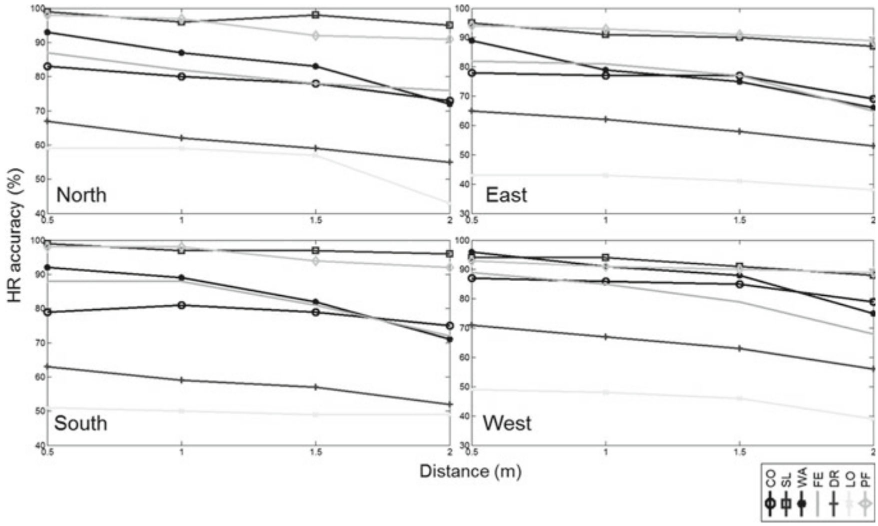

Fig. 9 Accuracy of HR detection at varying of distances and ADLs. The only monitored subject was present in the scene

Obviously, in both RR and HR cases, the best accuracy was achieved in correspondence of ADLs without too much movements, e.g., SL, PF and WA. This explains the poor performance observed during the LO activity in comparison to the other ADLs. The same applied, although at a lesser extent, in the case of the DR activity, due to the occurrence of chest oscillations.

Some differences were found also in dependence of the monitored subject's orientation. Especially in the case of HR, the most favorable orientation was toward the sensor, i.e., West and East for S1 and S2 sensor positions, respectively. The subject's position with respect to the sensor FOV (of about 100°) was also relevant, since the detection accuracy decreased as the subject moved away from the X axis (Fig. 5).

Regarding the second validation phase, with a second moving subject present in the radar FOV, the movement compensation stage was robust enough as long as the distance between the two subjects was greater than 1 m. The corresponding RR and HR accuracies are reported in Figs. 10 and 11, respectively. As one can appreciate by comparing the plots reported in Figs. 12 and 13, the overall detection performance was not significantly affected by the presence of a second moving person in the same environment. As previously mentioned, the validation has been also carried out by positioning the radar sensor in S2, i.e., outside the room, in order to investigate the TW sensing capability. In this circumstance, the clutter signal generated by the interposed wall was effectively suppressed by the clutter removal stage, and the RR resulted detectable, without loss in accuracy, within distances up to 4 m with respect to the sensor. Instead, regarding the HR, the maximum detection range dropped to about 1 m away from the sensor, without sensible accuracy loss.

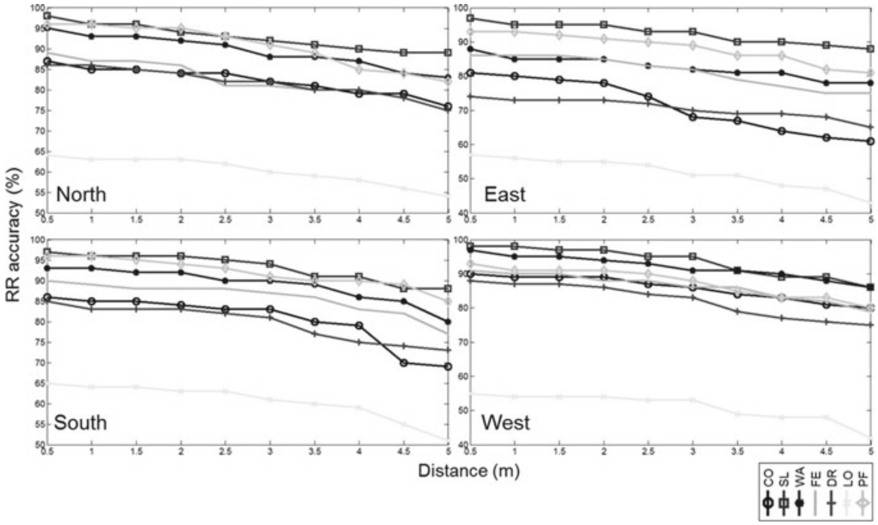

Fig. 10 Accuracy of RR detection at varying of distances and ADLs. Another person was present in the scene beside the monitored subject. The second person was walking/standing/sitting within a minimum distance of 1 m

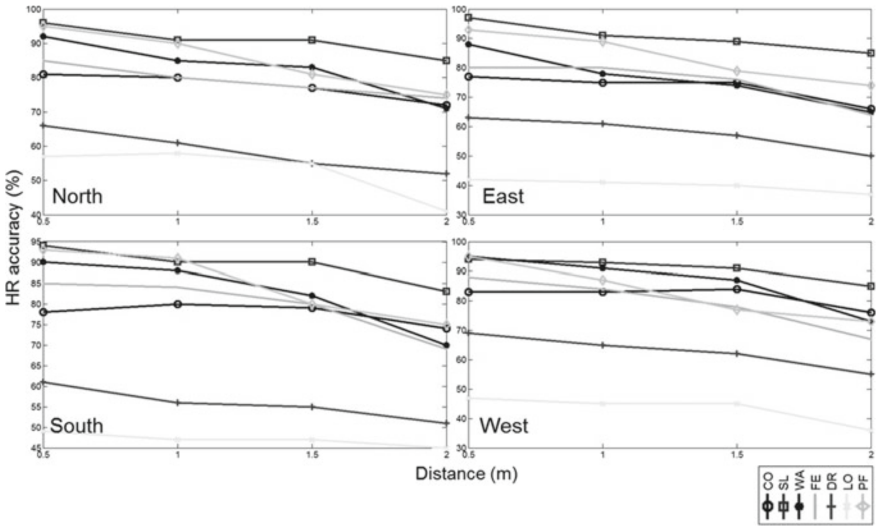

Fig. 11 Accuracy of HR detection at varying of distances and ADLs. Another person was present in the scene beside the monitored subject. The second person was walking/standing/sitting within a minimum distance of 1 m

The comparison of the present study with other similar ones is not straightforward. To the best of the authors' knowledge, no published study has been carried out previously aiming to validate the radar-based detection of vital signs in assisted

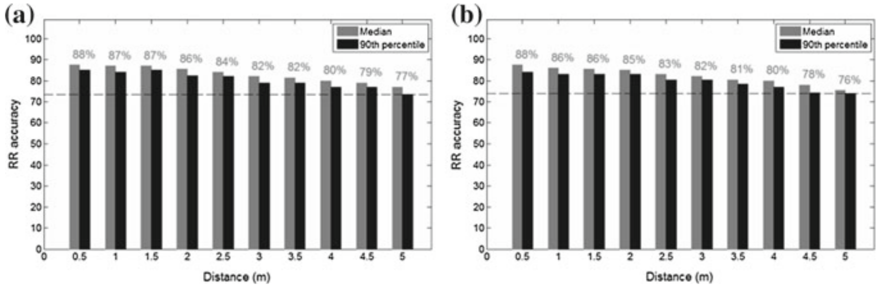

Fig. 12 Accuracy of RR detection in presence (a) and absence (b) of a second person

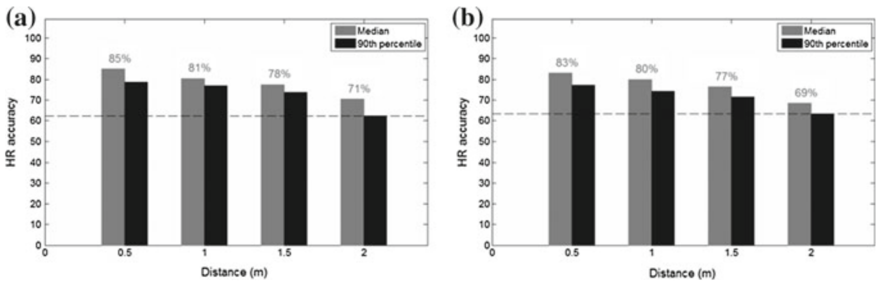

Fig. 13 Accuracy of HR detection in presence (a) and absence (b) of a second person

living scenarios under realistic conditions, i.e., performing ADLs. The only similar study is [31], in which however the suggested radar-based system was validated only for quasi-static activities, such as, typing on a laptop or using a cell phone.

Consequently, the high accuracy reported by that study cannot be considered as representative of real-life assisted living scenarios.

5 Conclusion

The aim of this study was to investigate the contactless detection of vital signs using an IR-UWB radar sensor in assisted living contexts. At this purpose, an algorithmic framework including a movement compensation stage was presented and the related experimental results reported. The presented framework was realistically evaluated by considering the detection of vital signs during the execution of various ADLs and also in presence of a second moving subject. Furthermore, the vital signs detection was evaluated at different distances, orientations and FOV positions with respect to two radar sensors, also in TW modality. The achieved results show that vital signs can be still detected also during ADLs, but with accuracy varying greatly depending on the level of movements and involved body's parts. Moreover, the radar returns caused by movements of the second subject were effectively compensated without significant loss of accuracy. In conclusion, the authors believe that this study provides a better understanding of opportunities and limits posed by radar technology for vital signs monitoring in assisted/smart living applications.

The ongoing work is focused on further investigating the movement compensation by using machine learning techniques (e.g., convolutional neural networks) and additional sensing modalities (e.g., inertial and vision) in conjunction with radars. The future work includes also the detection and tracking of vital signs (including heart rate variability) of multiple target subjects for assisted/smart living applications.

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Smart Monitoring of User and Home Environment: The Health@Home Acquisition Framework

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Abstract This work has been developed within the framework of the Italian smart city project "Health@Home (H@H)". The main goal is the development of a joint network (heterogeneous devices, both biomedical and home automation) to monitor the user's health conditions within the home environment, together with dedicated services from the measured quantities. In particular, H@H follows the context of the Active and Assisted Living environment to improve the well-being of elderly giving support to the users at home. In this paper, the authors describe the implemented final prototype software architecture implemented, the measuring protocol used in resting conditions and the implementation of three user services, providing real-time feedback about the user health status.

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1 Introduction

The World Health Organization (WHO) identified the demographic change as one of the biggest challenges for the society in the western countries [15]. Active Assisted Living (AAL) technology has widely become a dynamic area of research due to the increasing numbers of elderly citizens: the human caregivers may not be able to fully support the elderly in living independently in the future [1]. Therefore, there is a growing need for technological solutions that would support caregivers and relieve them from making frequent personal checks of their elderly charges [6]. Such systems should provide a continuous monitoring and notify in presence of gradual health changes or detectable anomalies [8, 10, 18]. Despite the importance of such goal, the level of technology readiness for smart homes and home health monitoring technologies is still low [9], also because of the low degree of interoperability among technologies. However, current research efforts show that assistive information and communication technologies can successfully contribute to all dimensions of elderly's quality of life [17]. As example, technologies can empower them to control their health problems, compensate functional disabilities and increase their safety [4]. This can be feasible through a unified "model" that includes patients and devices in a single virtual community, together with a smart processing of data coming from the sensors and the implementation of customized services [5]. In this framework, the Italian Smart Cities project "Health@Home: Smart Communities for citizens' wellness" (H@H) aims to play an important part. One of the main objectives is to develop and provide services (i.e. health care, social care) to assist the user within the home environment. This is achieved by the integration of heterogeneous devices, i.e. biomedical and home automation, into a unique acquisition framework and the use of Cloud Computing algorithms from the acquired quantities. An example of smart system, which integrates environmental and physiological sensors (i.e. heart rate) and allows to achieve a smart control of the indoor microclimate has been presented by authors in [14], while the concept of the prototype acquisition architecture and the cloud-based one has been discussed in [12, 16], respectively. In this paper, the authors will provide details about the final implemented architecture, which will be tested in the next months in a larger pilot. Then, the results coming from the application of the biomedical acquisition framework in two test cases, together with the description of a resting measuring protocol is discussed in Sect. 3. Finally, the implementation of three health-related "services", based on the processing of raw acquired quantities, is presented and discussed in Sect. 4. Some remarks conclude this paper.

2 Materials and Methods

The H@H software architecture allows to manage the processes of data acquisition, processing, storage and communication, with the minimum interaction required to the end user.

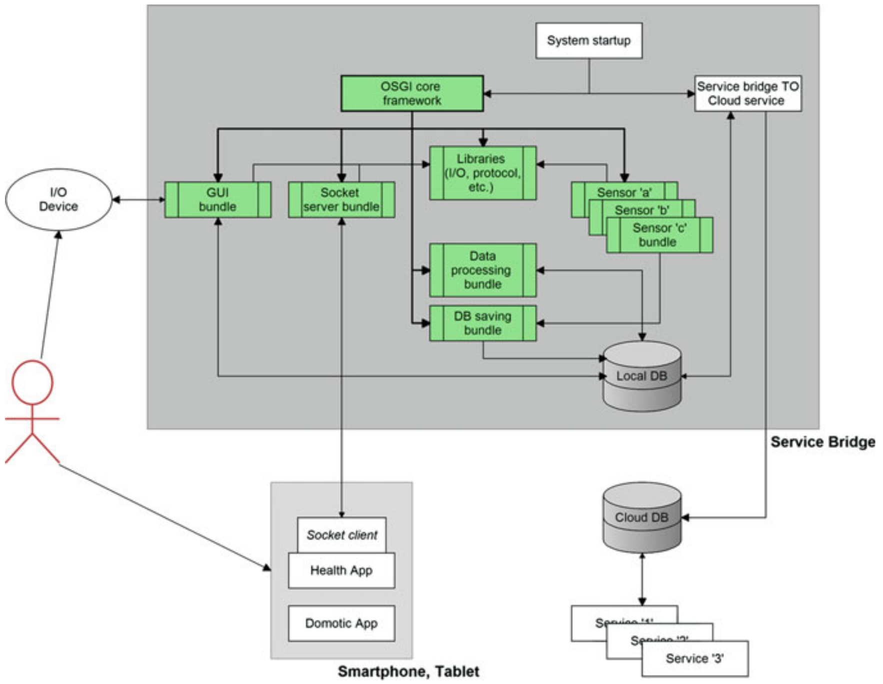

Fig. 1 The H@H implemented software architecture

The concept of the final framework is reported in Fig. 1. Once the device (e.g., the PC running the H@H software, referred as "Service Bridge") has finished the booting phase, two main processes are executed. The first is the OSGI framework, which contains all the developed bundles to deal with the previously cited steps. The second one is a porting service, which automatically sends data to the Cloud after they have been collected and stored locally in a database embedded in the device. In the next paragraphs, all these blocks are described in detail.

2.1 The Core Framework

OSGI (Open Services Gateway Initiative) is an open standards organization, which has provided a modular system and a service platform for the Java programming language, through a complete and dynamic component model. This means that each application or component developed, in the form of bundles, can be remotely installed, started, stopped, updated, and uninstalled. Following this kind of lifecycle, it is possible to add functionalities to the overall software architecture (e.g., a new sensor module, data processing, etc.), without affecting the ones already implemented. Moreover, the bundles work in an asynchronous way, without interfering with each other.

The framework is open source and is also available in form of standalone and executable runtime version. Once the bundles are correctly installed and the startup order is provided, this customized version of the OSGI framework can be launched without any additional action required to the user. Regarding the H@H architecture, the priority in the bundles startup has been given to both open source or third parties libraries which allow to deal with distinct aspects, such as data communication (e.g., Bluetooth, Wireless), graphic, database connector, etc. Then, all the other bundles are launched sequentially, without additional requirements.

2.1.1 Physiological Quantities Monitoring

The first aspect of the H@H architecture to point out is that it deals with heterogeneous devices (communication protocols, acquisition time, kind of data etc.). As for the biomedical and physical quantities to be measured within the project, six wireless devices (all available on the market) have been integrated in the acquisition framework:

- a multi-parametric belt, which provides both single quantities (e.g., Heart Rate, Breathing Rate, Acceleration) and streaming of data (i.e., ECG waveform)—Zephyr BioHarness 3.0;
- a pulse oximeter, for blood oxygen saturation and Pulse Rate—Onyx Nonin 9560;
- a blood pressure meter—Taidoc TD3128;
- a body weight scale—Taidoc TD2555;
- a glucometer—Taidoc TD4279;
- a body temperature device—Taidoc TD1261.

The first two devices are equipped with traditional Bluetooth module, which can be accessed through a SPP—Serial Profile Protocol, while the other are BLE (Bluetooth Low Energy profile), typical of the most recent devices and technologies.

A bundle has been implemented for each device, to decouple them to the overall architecture. Each one provides a public method to be called (e.g., by the bundle related to the GUI), so that the acquisition procedure can start. The authors adopted a proprietary BLE USB dongle from Bluegiga technologies to provide a communication system with the devices characterized from a Bluetooth LE protocols. Once the data have been correctly acquired, each module make a call to the one related to the storage on local database, to save the same in structured tables [16].

2.1.2 Home Data Monitoring

Differently from the biomedical measures, which are mostly instantaneous or with a fixed time, most of the environmental quantities requires a continuous monitoring. Moreover, some parameters (e.g., window opening/closing) are triggered events and so a different and dedicated procedure is needed to deal with them. Within H@H, a prototype Android App has been developed to deal with the monitoring and the control of the environment (i.e., Bticino standard equipment). Thermal comfort (temperature and humidity), visual comfort (light management) and occupancy have been monitored through such application. In addition, two OSGI bundles have been implemented to deal with:

- a smart fridge (Whirlpool), monitoring the opening/closing and refrigerator/freezer temperatures;
- a commercial product for monitoring of the air quality ("Snap" by Elica, http://snap.elica.com/it/), controlling and monitoring indoor air temperature, humidity and air quality.

2.2 Data Storage and Cloud

Two different levels of storage are provided to save data coming from the different sensors. The first is SQLite, which offers a self-contained, embeddable, zero-configuration SQL database engine. The local DB is organized in different tables, with the static ones referring to the different users, devices, features and indicators to be calculated. Then, all the raw quantities are stored in a single local table and the values are univocally identified by the combination of three ID numbers (user, device, and feature). In addition, a computing bundle has been implemented to process such raw data for fixed time span (i.e., daily, weekly or monthly) and provide the result of such computing (e.g., average, trend, maximum value, etc.) in a dedicated table. There is no sensible information of the users in the local database and these data are accessible only locally. Otherwise, data stored in Cloud (the second level of storage in the H@H architecture) are equipped with several layers of protection and only the registered user can access to his/her data. In addition to the OSGI framework, a runtime background service has been implemented to allow the porting of measured quantities from the Service Bridge to the Cloud. This process is synchronized with the local database and sends data once a new value is available.

2.3 User Interface

The user interaction with the acquisition framework is minimal. In fact, there is the only need of starting the acquisition bundle of a sensor and then the process is completely automatic. Also for this case, two practical solutions have been implemented. The first one makes use of the same Service Bridge, if equipped with a monitor and an I/O device (i.e., a mouse or a keyboard). A GUI (Graphical User Interface) bundle has been developed to allow the user to start the acquisition of a device, if he/she is enabled to do it (a button for each device he has acquired). A synthetic voice helps

Fig. 2 GUI implemented for Service Bridge for the biomedical and physical quantities acquisition

the user during the interaction with the GUI and some visual icons indicate if the acquisition procedure has succeeded or not. An example of this simplified GUI is reported in Fig. 2, while two measurements have been performed and one failed.

Since the H@H architecture can run in the Service Bridge without the need for user interaction, the second option is to make use of the same portable device (smartphone or tablet) that is running the domotic monitoring App. For this reason, an OSGI socket bundle has been implemented to let the system act also as a server and accept for connections. Then, a GUI for Android device has been developed to communicate with the Service Bridge (trigger the acquisitions, get data back, manage errors), via standard commands, passing through this socket.

3 Experimental Setup

The final architecture proposed will be tested within the project in several social houses in Treviso. Prior to this, the prototype system (Fig. 3) has been installed in two residential apartments. A total of 4 healthy adults (two males and two females, age >55 years) were asked to perform the following measurement protocol for a total of two weeks each:

- sitting and relaxing on a chair, breathing normally, wearing and turning on the multi-parametric belt (2 min);
- measuring with the saturimeter on the left index finger (15 s of acquisition);
- measuring the body temperature (i.e., ear temperature, single acquisition);

Fig. 3 The embedded micro PC for the test of the H@H architecture (left); user interacting with the GUI running on the Service Bridge (right)

- monitoring the vital signs from the belt (30 s) and then acquiring the ECG (Electrocardiogram, 30 s), while sitting and breathing normally;
- measuring the blood pressure (3 acquisitions while sitting and 3 while standing, one minute of delay between each acquisition);
- measuring the body weight, barefoot;
- removing and turning off the multi-parametric belt.

The users interacted with the GUI through a simple I/O device (e.g., a mouse) and they were asked to follow the instructions and launch the acquisition of each sensor.

During the tests, the Service Bridge (as shown in left image of Fig. 3), has been a micro PC Desktop from Hannspree (Intel Atom Quadcore 1.83 GHz, 2 GB RAM, 32 GB Memory, Windows 8.1 OS), connected to a TV through HDMI port.

Both WiFi and Bluetooth are available through the integrated antenna, while a BLED112 USB dongle has been attached on the PC to allow the use of BLE communication protocol. The list of devices used in the home environment, the measured parameters or signals and their technical specifications, are reported in Table 1.

The users have been instructed to perform the measuring protocol in the morning, before having breakfast, so that it could be possible to make comparison and analyze the acquired data.

3.1 Data Processing

One of the main objectives of H@H project is to provide services (e.g., health care, social care, etc.) to the users living in their homes. To achieve this goal, a smart processing of the data acquired is mandatory. The combination (i.e. data mining) of multiple quantities together would allow to get more refined and high-level information about the user well-being (e.g. the assessment of the kind of activity performed, as presented in [13]). In this paper, the author will discuss three services that the end user could benefit to assess his/her health status from the devices cited before. The

Table 1 Technical specifications of the biomedical devices adopted in the H@H architecture

Device	Parameter/signal	Accuracy	Resolution	Range
Multi parametric belt	HR (heart rate)	±1 bpm	1 bpm	25 ÷ 240 bpm
	BR (breathing rate)	±1 bpm	0.1 bpm	3 ÷ 70 bpm
	Acceleration	n.a.	0.012 g	−16 ÷ 16 g
	Trunk Posture	n.a.	1°	−180 ÷ 180°
	ECG waveform	n.a.	0.1 mV	0.25 ÷ 15 mV
Saturimeter	Blood saturation	±2%	1%	70 ÷ 100%
	HR	±3 bpm	1 bpm	20 ÷ 250 bpm
Temperature device	Body temperature	±0.2 °C	0.1 °C	32 ÷ 43 °C
Weight scale	Body weight	±0.5%	0.1 kg	4 ÷ 250 kg
Glucometer	Blood glycemia	±15%	1 mg/dL	100 ÷ 700 mg/dL
Blood pressure meter	HR	±4%	1 bpm	40 ÷ 199 bpm
	Systolic pressure	±2%	1 mmHg	60 ÷ 255 mmHg
	Diastolic pressure	±2%	1 mmHg	30 ÷ 195 mmHg

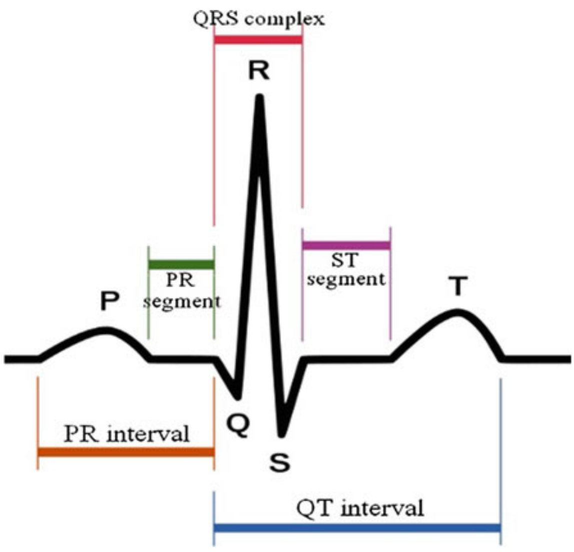

Fig. 4 ECG waves and time intervals

first one is related to the morphology of the ECG signal and deals with the automatic calculation of the time intervals (QR, QT, ST, PR), shown in Fig. 4. These quantities are some of the time intervals usually measured on the ECG waveform and used for diagnostic purposes.

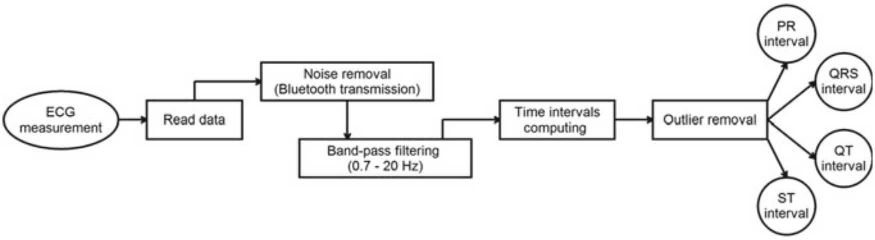

Fig. 5 Computation steps performed by the OSGI bundle for the time intervals computation

This aspect has been already discussed in a previous work of the authors [16] and the same algorithm described in [3] has been implemented in an OSGI bundle. The good measuring performance of the multi-parametric belt has been deeply investigated in these years and has also been evaluated by authors in a previous work [2]. The steps performed to allow the computation of the time intervals from the raw ECG signal acquired from BH3 are illustrated in Fig. 5. A detailed explanation of these steps is reported in [3].

A dedicated service has been implemented for both the caregiver and the user, which consists on the automatic computation of the ECG time intervals and the comparison with the physiological ranges provided in literature (30 < QR < 50 ms; QT < 420 ms; ST < 350 ms; 120 < PR < 200 ms). This allows to monitor the health status within the home environment and identify possible cases where a deeper investigation in required.

The second service is related to the blood pressure measurement. In fact, monitoring this parameter while sitting and then standing, following the protocol described in [11], is used to check if there is a dysfunction in the baroreceptive response. This consideration is of a physiological relevance, especially in older adults, e.g., in presence of pre-syncope or syncope symptoms. This analysis has been performed by comparing the average of the blood pressure measured while sitting to the one while the subject is standing. The deviation between these values should not exceed 20 mmHg for the systolic and 10 mmHg for the diastolic (i.e., orthostatic hypotension assessment) [7].

The last service is a measurement event handler, which occurs when the measure of one of the physiological quantity of the user exceeds his personal basal value. In presence of the same measuring protocol, the arousal of one parameter could provide a feedback to the user, or to the caregiver, with the need of performing a more detailed analysis consequently. Because of the singularity of each subject, the choice of the "basal" values should be user-centered. The authors suggest training the system and feeding it with data for a certain period (machine learning), to allow the calculation of the personal values. For example, the authors have investigated the data acquired in the two test cases (time span of two weeks) and the results are discussed in the next session.

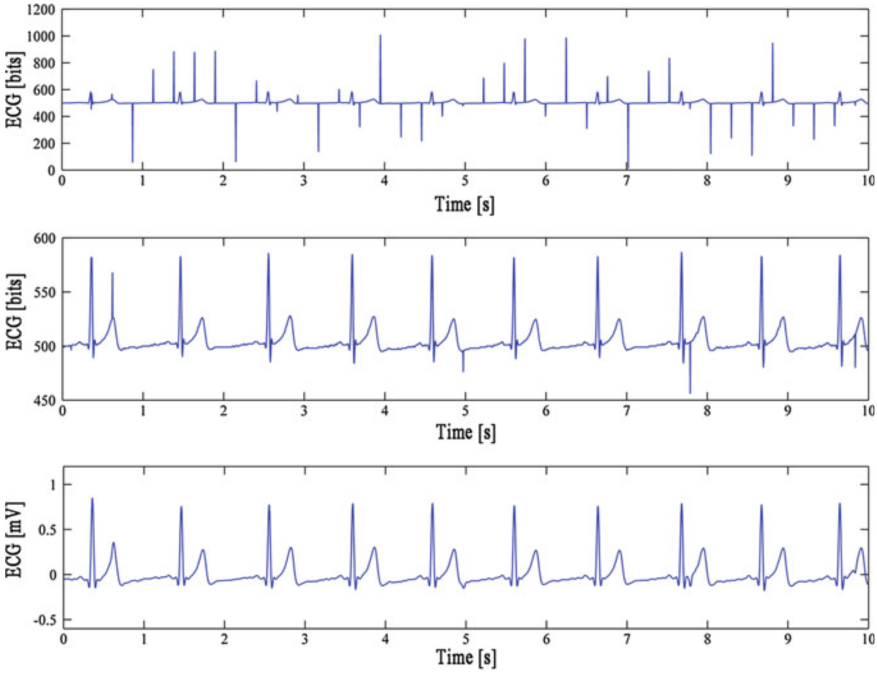

Fig. 6 ECG signal processing steps for the first 10 s of acquisition. Top: Raw data acquisition. Center: First step noise removal (Bluetooth transmission). Bottom: mV conversion, mean removal and band pass filtering (0.7–20 Hz)

4 Analysis of Results

In this section, some observations and results aroused from the preliminary tests are presented. First, the time interval identification service. Within the measuring protocol, the four subjects were asked to make a measurement of their ECG by means of the multi-parametric belt. This allows to get a raw ECG waveform, with a sampling frequency of 250 Hz. Figure 6 shows the processing steps conducted to get a smooth signal for the peak identification algorithm [3]. Then, the average value ± standard deviation has been calculated for all the time intervals and the result for the first case study is reported in Fig. 7.

In Fig. 7 we report the main parameters measured by the system; it is possible to observe that the values computed are all within the physiological ranges (the green area). In case one of the measured values fall out of these ranges, the software architecture reacts by notifying the user to make a new measurement with the same protocol (i.e., sitting and relaxing). If the same event occurs, an alert will be sent to the caregiver, to inform that the user would need a deeper clinical investigation.

The second example is related to the evaluation of orthostatic hypotension. Three pressure measures have been performed by the users, for both sitting and standing

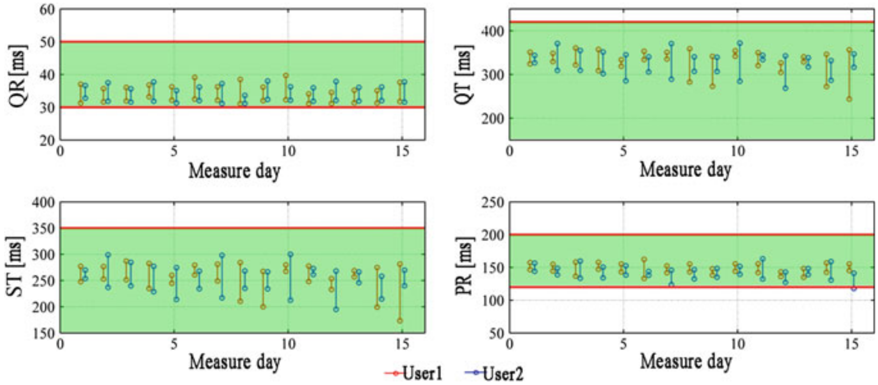

Fig. 7 ECG computed time intervals (average ± deviation) for the first two users

(with a time delay of 30 s between each new measurement and 1 min during the transition sitting-standing). Then, the mean value for the standing (P_{stand}) and sitting (P_{sit}) conditions and the pressure deviation ($P_{stand} - P_{sit}$) have been computed for each subject for all the days of acquisition. An example of such measurement for a single user, for both systolic and diastolic pressure, is reported in the upper section of Fig. 8. Then, the 95% confidence intervals have been obtained from the total deviations computed (Fig. 8, lower section). It can be observed that the blood pressure of user 1 is in average higher when standing with respect to the sitting condition, which appears to be contrasting with the other cases. This is a significant outcome, considering that it comes from an averaging of multiple acquisitions (with a consequent reduction in the mean values measurement uncertainty per square root of measures, i.e., from ±3 to ±0.4 mmHg).

The result is even more interesting, if considering the assumption of drugs of user 1 to control the blood pressure (i.e., against hypotension). Apart this, the other ones do not present statistically relevant differences between them and the deviation agrees with the acceptable physiological values (appropriate baroreceptive reflex). Even in this situation, the H@H architecture reacts to a higher deviation between the measurement of the two pressures (standing and sitting) by providing a warning to the user and an alert to the caregiver.

The final example is the management of the other physiological and physical data, in case there is a high deviation with respect to the basal value. Before this, it is necessary to identify clearly which is the basal value and what is the margin tolerance of deviation towards it. As a preliminary potential approach, the authors have computed a personal basal value, for each of the measured quantities, as the average of a two weeks of measures.

Table 2 shows the average and the standard deviations for seven physiological and physical quantities acquired during the tests for each user.

Finally, Fig. 9 shows the differences in the deviations computed for two quantities measured (i.e., HR and BR) and averaged in three different time ranges:

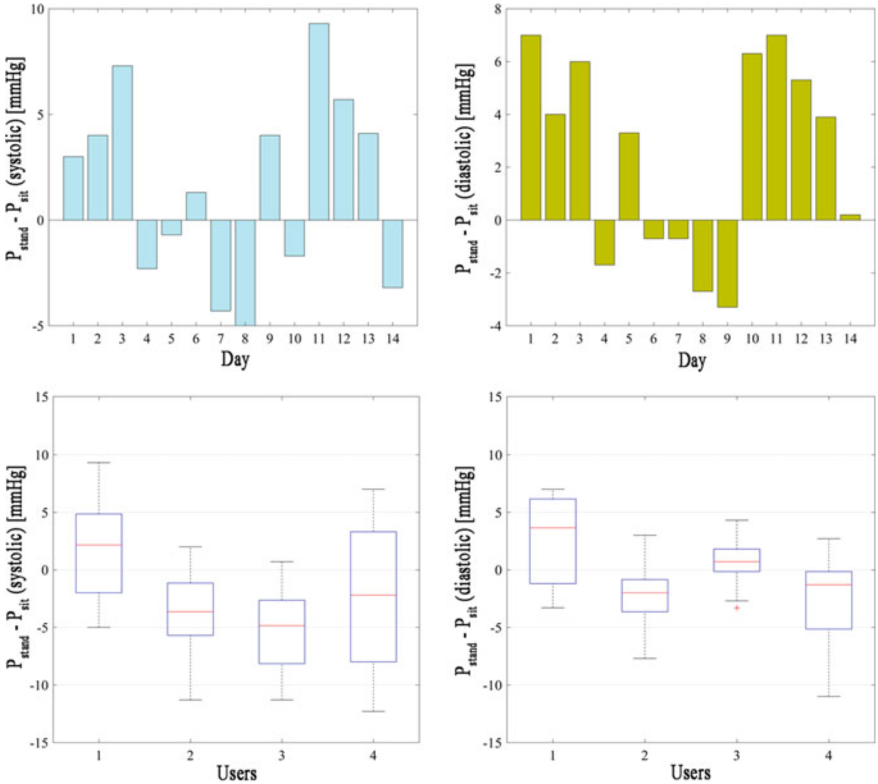

Fig. 8 Results coming from the blood pressure monitoring. Top: daily deviation between the systolic (left) and diastolic (right) from standing to sitting, for user 1. Bottom: Confidence intervals

- the first 4 days of acquisition;
- the first week of acquisition (from the beginning of the trials);
- the entire period of monitoring.

As expected a decreasing trend in the standard deviation computed for both HR and BR can be observed using more data (i.e., from 4 days to two weeks).

This suggests the importance of feeding the system to calculate user-centered baseline values and ranges. This aspect is particularly relevant for physiological quantities (i.e., HR and BR), which may vary widely, even if the subject is in resting conditions. Basing on this experience, a threshold limit (with respect to the personal baseline values already computed) of ±6 bpm and ±5 bpm has been identified for HR and BR, respectively. The same procedure has been applied for the other measured quantities. More than the traditional services that can be provided by the data coming from the sensors adopted (e.g., fever conditions, body weight periodical control, blood pressure assessment), the information provided by this personal warning

Table 2 Average value ± standard deviation computed for the quantities acquired at different time spans, for all users involved in the trials

Parameter	Average time	User1	User2	User3	User4
HR (bpm)	4 days	75.4 ± 3.5	74.9 ± 7.7	65.0 ± 3.2	67.2 ± 6.5
	1 week	76.1 ± 3.7	76.0 ± 6.0	66.1 ± 3.9	67.6 ± 5.0
	2 weeks	76.3 ± 3.1	76.2 ± 5.1	65.5 ± 4.4	68.9 ± 5.0
BR (bpm)	4 days	14.5 ± 4.8	11.7 ± 1.1	9.2 ± 1.5	10.0 ± 5.5
	1 week	14.9 ± 3.7	12.5 ± 1.7	9.7 ± 1.4	10.5 ± 4.3
	2 weeks	14.2 ± 3.4	12.5 ± 1.8	10.0 ± 2.4	10.5 ± 3.7
Systolic pressure (mmHg)	4 days	114.8 ± 4.1	103.8 ± 1.9	118.2 ± 2.5	119.5 ± 6.6
	1 week	117.8 ± 4.4	102.4 ± 2.9	117.6 ± 4.7	120.1 ± 6.9
	2 weeks	118.9 ± 5.3	102.3 ± 3.1	117.4 ± 4.0	119.2 ± 6.1
Diastolic pressure (mmHg)	4 days	84.6 ± 5.9	77.1 ± 2.6	69.9 ± 2.0	72.9 ± 4.8
	1 week	87.2 ± 4.8	75.1 ± 2.9	68.6 ± 4.7	73.8 ± 3.9
	2 weeks	87.2 ± 4.1	75.0 ± 2.7	69.0 ± 3.9	73.7 ± 3.2
SpO2 (%)	4 days	97.8 ± 0.5	97.2 ± 0.9	97.1 ± 0.4	97.3 ± 0.9
	1 week	97.5 ± 0.5	96.3 ± 1.9	97.0 ± 0.4	97.4 ± 1.0
	2 weeks	97.5 ± 0.5	95.9 ± 2.7	96.9 ± 0.7	97.0 ± 1.0
Weight (kg)	4 days	69.2 ± 0.4	59.4 ± 0.4	75.0 ± 0.5	67.6 ± 0.8
	1 week	69.5 ± 0.8	59.4 ± 0.7	75.4 ± 0.6	67.3 ± 0.7
	2 weeks	69.6 ± 0.7	59.6 ± 0.7	75.6 ± 0.6	67.1 ± 0.7
Temperature (°C)	4 days	36.0 ± 0.2	36.2 ± 0.1	35.3 ± 0.5	35.5 ± 0.6
	1 week	36.1 ± 0.3	36.0 ± 0.3	35.2 ± 0.5	35.7 ± 0.5
	2 weeks	35.9 ± 0.5	36.0 ± 0.3	35.1 ± 0.5	35.6 ± 0.4

service may help both the user and the caregiver in the evaluation and control of his well-being.

5 Conclusions

In this paper, the authors have presented the final version of the H@H system and the software architecture for the monitoring of user health status and the environment within their homes. The system is flexible, modular and easy to interact with. The monitoring of multiple quantities allows the implementation of multiple ad hoc services that both the user and the caregiver can benefit to better assess the health status and plan intervention, if necessary. In the paper, three simple services that have

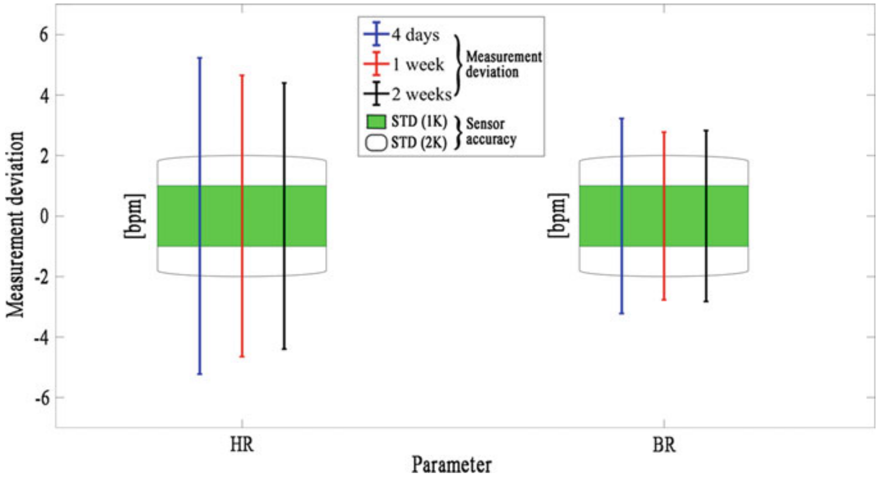

Fig. 9 Measurement deviations vs. sensor accuracies for the heart rate and breathing rate

been implemented in the system have been described. The first allows to identify the time intervals of ECG waveform in an automatic way and consequently provide feedback if they fall outside the physiological ranges. The second also is related to the health status of the user and evaluates the efficacy of the baroreceptor reflex, while measuring the blood pressure deviation (orthostatic hypotension evaluation). The last, on the contrary, is a feedback routine and lets the user be more engaged with his personal well-being, in an unobtrusive way. The overall solution will be tested in social houses in Treviso, Italy. A deeper monitoring campaign will help to improve both the acquisition performance and the services implemented, but will also give hints to the developers in implementing new functionalities, according to the feedback provided by the end-users.

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RESTOQUI: A Platform to Live at Home All Your Life

Silvia Pericu and Ami Licaj

Abstract Housing is an important part of life that has become increasingly important over the years. For as long as it is possible, most older people want to stay in their own homes, and to do this they must have freedom of movement in their own space. In this sense, adapting the living space of the elderly in terms of accessibility and security is a fundamental issue, because with age almost everyone experiences some loss of mobility and increasing difficulty bending, stretching and weight bearing. The medical realities of ageing—the physical, sensory and cognitive impairments that come to everyone eventually, must not to be ignored. However, we must recognize that many older people are disabled by the design of the environment around them, rather than intrinsically disabled. In this direction, some of these needs can be met by adapting existing homes, but when alteration is not feasible, design can provide products and services able to improve self-sufficiency and independence. There is potential for houses, furnishing and equipment to be much better fitted to the needs of an ageing population and, in addition, there is a wealth of design guidance and expertise available. On this basis *Restoqui* represents an opportunity to create a platform where customers can find a sort of catalogue of all the possible design solutions to adapt houses to their needs. The research is still at concept level but it deals with the needs of interior specialists, elderly users and their caregivers as well as geriatricians in order to create a virtual container that brings different skills together.

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1 Introduction

In order to guarantee a better quality of life for a higher percentage of the population even in old age, the domestic environment and suitable homes represent a core issue to support independent living. Housing is not the only issue: work, social engagement, health, as well as solidarity between generations, and maintaining one's autonomy are just some of the pivotal factors that together contribute to achieving the aim of ageing at home. It is a goal that can not be achieved through a single initiative, but requires a range of actions and approaches at individual and societal level that work together to achieve this outcome [1]. "However, we must recognize that many older people are disabled by the design of the environment around them, rather than intrinsically disabled. Designers have a responsibility to use all the advances in practice and technology available to them to reimagine products, settings, systems and services that will enhance the experience of later life" [2].

Nearly all older people live in standard housing in conventional neighbourhoods related to the place they come from, and in most countries the housing stock is not well adapted to older people because there are several mismatches between elderly needs and homes. Generally houses are traditionally designed for families and a large number of older people occupy houses designed for bigger households, even though they have problems managing them [3].

So what does adapting your living environment to the needs that may emerge over the years entail?

First of all, it must be said that there is some resistance from the elderly to the adaptation of their homes to the needs that can often arise very suddenly and that can appear not to be permanent. Disabilities are rarely perceived as evident unless they are strongly restrictive and have a high impact on quality of life. In Italy about 3.5 million seniors live alone, and according to European statistics, it is believed that about 45% of the population over state pension age is disabled in some way [4]. This goes along with a general refusal to recognize the needs that may arise due mainly to the difficulty of perceiving one's own condition of being elderly.

Likewise, the definition of guidelines to outline living environments suitable for the elderly population [5] is a strategy that is appropriate in relation to new constructions or building environments that are radically adaptable. A study of the UK building stock shows that in cases of a need for radical transformation, 16% of homes would need major structural alteration to become fully accessible, and in 28% of homes alteration is not be feasible [6]. Many projects in recent years have been developed with the aim of defining common good practice guidelines for the planning of older persons housing, both at European level and at national levels [7, 8].

The build-up of this kind of knowledge is especially important for building professionals, and usually not made to be easily understood by ordinary people.

In most cases, there is a need for small and very different adaptions because the ageing process varies from person to person and the plurality of needs makes cases extremely disparate. In this direction, some of these needs can be met by adapting existing homes, but also through the refurbishment or the availability of advanced products, that, thanks to new materials or recent improvements, can help to make environments more age-friendly.

It is therefore necessary to make accessible to the widest possible audience the indications on available products. The contribution of this paper illustrates how the concept of an accessible and comprehensible web platform was developed with design tools to start a dialogue with different types of users, doctors, professionals, care givers and the elderly themselves, on how to adapt one's home. A platform that is able to make people interacting with figures that are very different from each other: a need that is even more important when we consider that in the adaptation of houses certainly a key role is played by technologies that are able to facilitate the day-to-day tasks of the elderly user at all levels, by not requiring massive intervention on existing building structures but by easily enabling new functions.

When alteration is not feasible, design can provide products and services able to improve self-sufficiency and independence: from domotic and home automation that enables controlling the comfort and safety of the environment, to wearable devices, to fall prevention and monitoring systems, to telepresence and robot care. This key role will be even more important with the approach to later life in 2030 of generations who are already used to technologies. This trend, due to ageing of groups of increasingly educated people, will only strengthen in the coming years, resulting in a change in the relationship between older people and new technologies, as the increasing quota of silver surfers [9], using internet on a frequent basis, demonstrates.

2 The Concept

The paper illustrates the concept of a digital platform that displays possible solutions to everyday needs of elderly users who need to adapt their living environment to maintain independent life. Since 2015, when the first demo of the concept was delivered, we are witnessing a rapid spread of websites promoting elderly care products, that most of the time doesn't put in relation needs with spaces and with possible solutions, but just provides a range of specialist products to assist older and disabled people [10]. This paper highlights the importance of adopting a multitarget approach in the creation of a digital platform, able to put together languages coming from the medical with the ones of the building field and to make them accessible for everyone, both caregivers and independent elderly. In order to do this a user centered approach in the research methodology, as developed in the activities of the group of researchers from our Department, has helped to define the needs of the over 65 users, starting from a field research carried out in the last five years [11], and to link them to specific solutions able to increase independence in their day-to-day lives.

The availability of some of these technologies does not mean that this new generation of products or domestic appliances can currently be used by a wide range of consumers. The design of these products has to be studied, developed and tested with the final users before entering homes and there is a need for orientation in a market that is still immature and not perfectly aligned with the real needs of people. On this basis, *Restoqui* represents an opportunity to create a platform where customers can find a sort of catalogue of all the possible design solutions to adapt houses to their needs.

The home is a browsing space like the home page of a website, conceived as an accessible and implementable catalogue where products, devices, services and tips to be able to stay in one's own home can be found. Every action in the housing environment brings together a world of possible solutions to perform it. In order to help people to find the most appropriate solution to their needs *Restoqui* illustrates synthetic design and technical guidelines that can facilitate decisions.

Target

The platform is still at a concept level, but it was developed to meet the needs of the elderly and their caregivers as an easy tool with which to browse with clear guidelines for everyone. The needs of the over 65 were detected throughout a fieldwork, that has involved students of the degree course in Product Design, building empathic relationships with over-65 seniors in order to understand their real needs. This activity started in 2012 and brought to the construction of a repertoire of solutions for the needs detected in the survey. All this information represent the basis of the digital platform and must be communicated with different levels of readability depending on the target. One level of the platform is dedicated to interior specialists and professionals, because the need for more and better designed, age-appropriate housing in the private sector is evident and widespread. There is a wealth of design guidance and expertise available that must undertake the challenge of supporting health and well-being even in the presence of elderly diseases (i.e. sight or mobility loss or dementia). In order to achieve these results, the third area of expertise that has to be brought to the research is the medical point of view represented by geriatricians. Together with gerontological sciences, the research field of design is deeply committed to reaching the prime objective of active ageing, and the *Restoqui* website represents an opportunity to create a virtual container that brings together different skills. The medical field can define the influences on health in old age, but a design project can focus on human experience, on the differences characterising our perceptions, on communication tools for prevention, and on the creation of a more age-friendly environment. Design is about creating solutions to everyday problems and tackling people's needs with the aim of bringing their point of view into the design process.

What

The website brings together solutions to everyday problems for the elderly and these solutions can be products, objects, services, devices, wearable technologies or home appliances that can produce value and become solutions to support independent living and light and innovative housing. The research team selects and evaluates company products by defining the main requirements through a quality label for age-friendly products and services, but which is also able engage a modern and multigenerational customer base. The idea of a label that addresses lifelong housing design takes inspiration from the research entitled “Adaptive Environments for Enabling Senior Citizens” which proposes the label as a tool to assess factors such as the accessibility, adaptability and flexibility of a barrier-free house. This essay defined three levels of certification for a “Lifelong Housing Design” ecosystem composed of a group of guidelines and features (Green Label, Silver Label, Diamond Label) from which professionals and users could benefit, by creating and upgrading barrier-free, accessible houses for senior people [12].

Criteria

The products displayed i**n the website have been selected on the basis of some criteria that we have defined** during **the field research carried out in the** workshops **with the students.** They are as follows:

- products must follow the ten principles of **intergenerational design** that provide a blueprint for the design of all products, services, processes to engage and serve a modern, multigenerational customer base. These age-inclusive design principles (Fig. 1) were developed with an inclusive design approach and tested as part of “The age of no retirement project” [13]. This research’s main conclusion stated clearly that people of all ages are more alike than different and that values, needs and desires are unrelated to age. From this research we can make the significant inference that organisations are spending too much time and money on age-friendly activities that fundamentally limit their market scope and reach.
- the **contribution of medical science** in prioritising the issues connected with health and prevention in order to identify the problems to be solved and to deal with some of the serious health issues of modern society, such as obesity, heart disease, high-blood pressure, stroke, diabetes, some forms of cancer, and potential dementia;
- a **human-centred approach** involving people in the evaluation process by directly asking them to express their needs or by interpreting these needs with the help of designers, who immerse themselves in the user’s real world;
- and finally the **need for a conceptual transition** from a focus on products to people’s experience, trying to find where to simplify and make the interaction between user and product/service more efficient, with the aid of user-experience design and its tools.

Who

The evaluation process as well as the selection of products is up to the DAD research group, involved in finding new relations between user’s needs and services, objects, spaces and environments. The group is specialized in finding solutions and strategies to improve the quality of life for weak users even in the presence of cognitive impairment associated with ageing or Pervasive Developmental Disorders, and in defining the guidelines, concepts and projects with a User Centered Approach Design [14], merging different disciplinary skills such as design, architecture, psychology, sociology and cognitive ergonomics.

Fig. 1 The 10 Intergenerational Design Principles—In the research report from "The Age of No Retirement" that contains analysis and interpretation of data from the 28 business sectors that were performance-rated by the 2000 survey participants

"Is anyone going to complain about technology that is too intuitive, customer services that are too helpful, packaging that is too easy to open, financial products that are too comprehensible, transportation that is too safe and comfortable, clothes that are too flattering or homes that meet lifetime needs? Of course not: inclusivity across generation is key" [2].

3 Designing *Restoqui*

The complex aspect in designing the project was the mix between two elements: the multiplicity of the target/users and a big database of products, all based logically on the rules of accessibility and usability [15].

The project had the aim of creating a platform where different users can contribute to generating a mindful database of products to help elderly people to live at home for their whole lives in a safe environment.

Caregivers/elderly people, doctors/geriatricians and designers/interior professionals were the standard users of the website. The most difficult aspect of managing three different users is that all of them have three different backgrounds and attitudes. This implies that their needs and approaches during the navigation of a website are different.

Caregivers access the site to search for, to choose and to ask questions about one or more products for the home where their relative or cared for elderly person lives. They alone fully know the blind sides and the needs of the everyday life of an elderly person.

Doctors access the site to suggest to patients and their families how to improve the home for a better and safe lifestyle according to the patient's health report. They alone fully know and understand the health conditions of the elderly person.

Designers access the site to choose the most suitable products for the interior refitting project of the elderly person's home. They alone fully know the rules and standards of interior design and how to apply them in the home adaptation.

Design stages:

- Analysis and survey of what the web offers and good practices that are similar to the goals and functionality of the webpage that is going to be designed.
- Collection and creation of page content and structure of the information architecture.
- Definition of the user experience (UX) and user interface (UI) from the homepage to specific product information.

Benchmarking and Best Competitors

The first step of the project consisted in benchmarking and analysis of best competitors [16]. Benchmarking allowed us to understand how other websites manage a various number of users. Instead the analysis of best competitors enabled us to understand how other websites manage large quantities of data.

E-commerce websites were a very important inspiration model, because they represent large online catalogues of large amounts of products, which different people, and therefore different users, access to search and buy. An flawless user experience and a perfect user interface are extremely necessary to make the website self-explanatory and efficient for the e-commerce target, and to have a pleasant buying experience, without problems, doubts or difficulties.

Homepage

After the first survey stage the creation of the information architecture [17] follows in order to develop the user experience (UX). The information architecture was structured following a diagram that connects the different pages.

The research group focused at length on structuring and studied how to organize and make available all the product catalogue that the platform should contain, as this is the most important part of the entire UX of the webpage.

The catalogue was finally organized in alphabetical order to bring together different elements with the same initial letter: products, ambients and pathologies. This categorization was fundamental to allow three different users (caregivers, doctors, designers) to search according to their different needs. The efficacy of this choice lies in the fact that users know what they want but they do not know where to find it [18]. Another possibility is that they do not know what they want, but they have an idea about a similar topic to what they need.

For example caregivers know the pathologies of the elderly, but maybe they do not know which products are available and which ones are more suitable in specific cases. In this way filters are the best solution to manage the navigation of different profiles.

Another important aim of the website was the creation of a community where caregivers, doctors and designers are continuously connected. A community, where people who have questions or doubts or also suggestions, can express them and contribute to the creation of an active group.

The blog section was conceived in order to give the possibility, for example, to doctors to discover how families of elderly people use and experience specific products.

The most interesting aspect is that these two important elements—filters and blog—are always accessible during the navigation. So everyone can filter contents of the website or ask the community something whenever and wherever he wants during navigation.

Products/Spaces Page

The third stage was to design the user experience of the second part of the website, that appears after the selection of products or spaces in the homepage. This page is divided into two sections: the presentation of the space of the house with its products and the detailing of general rules and good examples for these spaces

For the presentation of the space, in order to simplify user experience, there are two ways to get to the same result, visually and textually. Both are useful to understand, navigate and arrive at the same part: the product page.

The visual part presents the image of the space with furniture—the aim is to show all furniture to help users to choose visually the product that they are looking for. All products are tagged with a little label that shows where to click and underline available products. The textual part presents a list of all furniture—the aim is to help users to choose those in a descriptive way. This is because people on the web usually only read short texts or do not read at all [19], and in all these conditions the website always has to guarantee a high level of accessibility.

A feature of these spaces/products pages is that they are always related to each other with a click. This is important because the user has to know in which space the product is located and moreover, he has to know which products are in the space. These continuous and obvious links between the various parts of the platform are crucial to avoid making users feel lost and to always let them know where they are located in the website, where they came from and where they can go after. All this navigation process creates a mental navigation model [20] from the first click on the homepage where the users learn the language of the website that will help them navigate correctly. In practice, as illustrated in the figure, you can see how the user, who has selected a mixer inside the bathroom section—B, will find the same initial letter of the bathroom space alongside his product—B—Mixer. This letter B, which refers to the previous section, is part of those elements that contribute to the creation of the mental navigation model (Figs. 2, 3, 4 and 5).

Final Step—The Choice of a Product

The final step of the navigation happens when a user is faced with a chosen product that they need. For the same specific illness or need there could be several products that differ in terms of budget, brand, and function. To help users to make the best choice, for every product a summary information sheet is available in which the product is well described. For every product three are always three groups of information: brand information—name of the product, name of company, link to the company website #—a short description of the main function of the product #—i.e. mixer that automatically balances temperature—and finally, its specificity—i.e. reduces risks of burning hands or accidental cold showers. If users finally find the perfect product for their needs and the search experience was simple, clear, accessible and friendly, the aim of the website has been achieved.

Graphic Design

For the graphic interface of the website a specific turquoise-green gradation was chosen to suggest the concept of a 'good solution'—in contrast to a bad solution or an error that is generally represented with a red colour.

This gradation of turquoise-green is also a reference to the medical field, because products on the website are for elderly people with illnesses, and this colour may have a positive and comforting feeling.

Figs. 2–5 From 2 to 4 the web site progression from the homepage to the chosen product page and in Fig. 5 the product summary information scheme

Fonts were selected on the basis of accessibility rules for the web. From the dimensions to the weight, all possible solutions were considered to make the best choice in order to give a clear and simple user experience. Also the employment of specific graphic elements during the navigation and experience, such as icons, was aimed at making the experience more comprehensive and self-explanatory [21].

4 Discussion

Restoqui is for the time being at concept level. Results and feedbacks about real use of the system are not presented in this paper, but some considerations can be discussed interpreting outputs and comparing them with the aims of the design.

It will be necessary evaluating the project with a test. The basis of the web design is the users centered approach, that brought to explore needs of the over 65 in real life. According to this also the accessibility of the system must be proven with real users.

At European level interest and research funding will grow in the sectors of silver economy as an engine of growth, active ageing as a challenge to the social area and not only in health, domotics and innovative housing solutions, health and social inclusion, development of age friendly environments, personal health management. This means that there is a general need of expertise, in particular in the private sector, that can spark development in the offer of solutions, from enabling technologies, to social benefits of supplying products/services tailored for the user's fragility.

In this direction universities and academic researchers, as well as impartial consumers' associations, can play an active role in defining a sort of quality assessment for products and in helping users to identify their needs and to find the most suitable solutions. It is therefore a priority to define the criteria that must oversee this type of assessment in order to help the choice of products suitable for the housing stock's existing situation and for the social context. To achieve this goal, an interdisciplinary approach is required, with regard in particular to medical sciences, through the development of a common language, accessible to all.

5 Conclusion

In this paper, the authors have presented the concept of a platform, *Restoqui*, where customers can find a sort of catalogue of all the possible design solutions to adapt houses to the needs of the ageing population, in order to guarantee older people the possibility of staying in their own home with freedom of movement in their own spaces. The platform contains a database of products and has currently been developed as a prototype. It has been structured to target three different users: caregivers, doctors, designers; and according to the needs of the various users, the database has been divided into three types of possible filters: pathologies, spaces, products.

In this research, the academic partner should have the role of certification body, which guarantees and verifies certain standards necessary to be part of the product catalogue, and therefore on the platform.

In a consumer/product system companies can play a key role. Creating a network and a bridge between companies and universities would not only enable the development of the platform itself, but also an improvement in the products on offer.

Within this ever-transforming society, in which everything is becoming more and more immaterial and ephemeral, design and what it refers to are changing. From products to services, everything passes through or is born in a digital context. *Restoqui* could have many future developments in this regard and could become a container, not just of products, but also of services dedicated to older people, in order to change not only the digital user experience but also the experience of people in real life by tackling the needs of everyday life inside the home and outside.

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Contributions to the paper were made by Silvia Pericu (Abstract, 1. Introduction, 2. The concept, 4. Discussion) and Ami Licaj (3. Designing *Restoqui*, 5. Conclusion).

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Heterogeneous Non Obtrusive Platform to Monitor, Assist and Provide Recommendations to Elders at Home: The MoveCare Platform

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Abstract MoveCare develops and field tests an innovative multi-actor platform that supports the independent living of the elder at home by monitoring, assist and promoting activities to counteract decline and social exclusion. It is being developed under H2020 framework and it comprises 3 hierarchical layers: (1) A service

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layer provides monitoring and intervention. It endows objects of everyday use with advanced processing capabilities and integrates them in a distributed pervasive monitoring system to derive degradation indexes linked to decline. (2) A context-aware Virtual Caregiver, embodied into a service robot, is the core layer. It uses artificial intelligence and machine learning to propose to the elder a personalized mix of physical/cognitive/social activities as exer-games. It evaluates the elder status, detects risky conditions, sends alerts and assists in critical tasks, in therapy and diet adherence. (3) The users' community strongly promotes socialization acting as a bridge towards the elders' ecosystem: other elders, clinicians, caregivers and family. Gamification glues together monitoring, lifestyle, activities and assistance inside a motivating and rewarding experience. More information can be found at http://www.movecare-project.eu.

1 Introduction

According to Eurostat [1], the old age dependency ratio, i.e., the ratio of older dependents (older than 64) to the working-age population (15–64 years) of European countries will approximately double between 2015 and 2080 from 25 to 50%. Another more important indicator is the economic dependency ratio [2, 3]. The economic dependency ratio is defined as the ratio between those typically not in the labor force (the dependent part) and those typically in the labor force (the productive part). In the next years there will be more persons not in the labor force rather than labor force. These reposts stress that governments must ensure policies that enable older people to continue participating in society and that avoid reinforcing the inequities that often underpin poor health in older age. Contributions far outweigh any investments that might be needed to provide the health services long-term care and social security that older populations require are needed. Elders with physical and cognitive problems are recovered in nursery homes too early: too little is done to let them stay at home longer. This view can be changed, if adequate monitoring, assistance and recommendations for a healthy lifestyle are provided to elders, especially when in a pre-frailty state.

This theme has been addressed by several research projects funded by the EC under FP7/H2020 and AAL frameworks. Several of these projects focus on having

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a singular interacting robot with an assistive environment, like for instance CompanionAble [4], Robo [5], Domeo [6] and the ExCITE projects [7]. As seldom a robot alone could provide a full range of functionalities, varying levels of complexity of the system may be present, for example, in GiraffPlus [8] a full sensor network and simpler mobile robot telepresence robot was used. An alternative solution exploits low-cost technology to support elders at home: for instance, Oldes [9] offers stimulation and remote overview to improve elders quality of life and WeCare [10] explores social aspects in building a community to support elders living alone. Similarly, projects like ReAAL [11] and Saapho [12] explore domotics to monitor elder lifestyle at home. Smart objects have been specifically built in H_CAD [13] and CareToy [14] projects to stimulate and provide exercising to children at home.

Based on the results of these works we have developed a novel platform named MoveCare (Multiple-Actors Virtual Empathic Caregiver for the Elder) [15]. This platform focuses on providing a comprehensive solution at home to ensure an independent, safety and healthy life to elders. It is a hierarchical platform that integrates a virtual caregiver, endowed with artificial intelligence, a community of users, an activity center, a network of domotic sensors and smart objects and a service robot, and not least, technologies for social interaction between a virtual community of users, to provide monitoring, recommend and provide activities and assist the elder. An overview of the platform is provided in Sect. 2.

2 MoveCare Platform Overview

Movecare platform is targeted to pre-frail elders, who are those people who have an independent life but are keen to get into frailty state [16–18]. Enabling them to live at home for a longer time requires three main functionalities: (a) monitoring to detect early physical and cognitive decline; (b) providing instruments to counteract decline by means of proposing a mix of personalized cognitive, physical, and social activities tailored to the elder needs and habits; (c) assisting the elder in everyday tasks such as looking for lost objects, supporting diet, and therapy compliance (Fig. 1).

Such intervention should be totally unobtrusive as possible as elders should be able to continue their normal life without any form of constraint or conditioning. This is a key factor for such platform to be possibly accepted and adopted widely by elder population.

Key elements of the platform are a Service Robot, a Virtual Community of Users, an Activity Center, a constellation of monitoring objects and a Virtual Caregiver endowed with Artificial Intelligence, that analyzes all the data, makes personalized recommendations and communicates with the elder's caregiver. The robot chosen is Giraff [19] that was explicitly developed to serve the elders and it was awarded "Most Promising Innovation" of 2011 by the AAL organization. It has an open architecture that allows to extend it easily and it mounts at least one RGB-D camera.

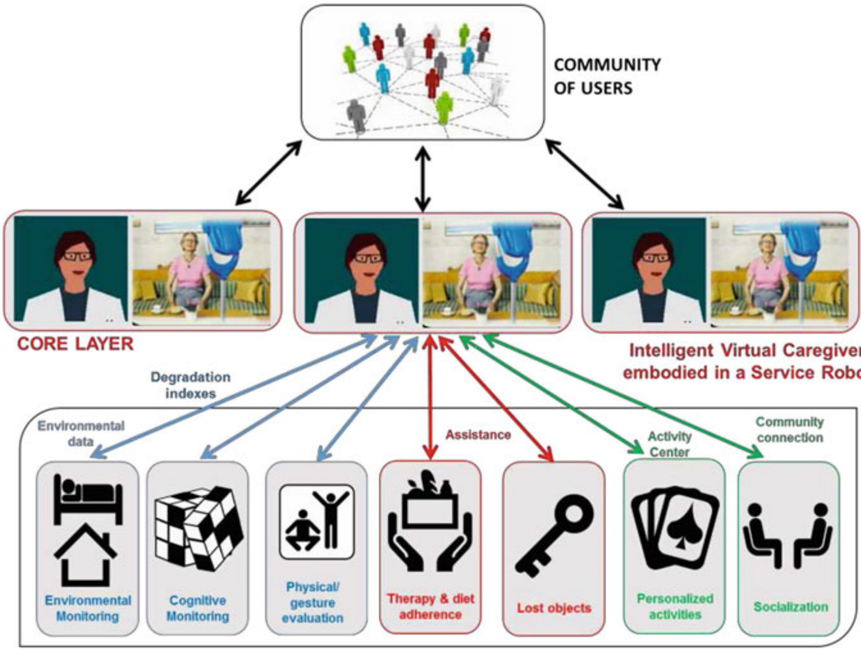

Fig. 1 The hierarchical structure of the MoveCare platform. Core layer is constituted of a Virtual Caregiver embodied in a service robot; Service layer is a modular layer that operates at user home and provides monitoring, assistance and intervention. Elders, caregivers and peers are kept into the loop through a Virtual Community of users

3 The Service Layer: Monitoring, Assistance and Activities

3.1 Activity Center

Physical and cognitive activities are provided through a Community Based Activity Center (CBAC). This enables users to do activities with peers, each living remotely in his/her home through a Virtual Community hosted by PartecipaMI portal [20].

The CBAC is the user's main access point to the system (Fig. 2). It leverages web technologies to provide a simplified GUI that can be displayed on multiple media devices (e.g., a tablet, the home TV or Giraff's display). The user can access his/her personal area, start activities, and send/receive invitations to/from peers. A central window is reserved to the activity while on the side of the screen small windows display a real-time audio-video of the peers who are playing with the user. This allows an audio-video interaction while doing activities increasing the extrinsic motivation to use the platform.

Cognitive activities developed are playing cards and Pictionary game. Cards are played over a green deck displayed in the central window of the screen. Each user, in turn, can make his/her move, that is visible to all other users, using drag and drop over a tablet or using a remote control that allows pointing over the TV screen. While playing the user can chat and discuss with his/her peers. Additional peers can join just to watch the game.

Users can be invited among the users who have already logged into the Virtual Community. Users are profiled also in terms of preferences, so that the Virtual Caregiver can provide personalized suggestions of activities. Moreover, the profile and the past history of people with whom the elder has played, are processed to suggest possible peers for the actual game, and suggest possible new peers who can be liked by the elder. This enables the elder to possible make new acquaintances through the system.

During gaming, user's moves and reaction time are recorded. These data are collected to provide indicators on the proficiency in that activity. These indicators are sent to the Virtual Caregiver for evaluating them along with the data from monitoring systems.

Physical activities will also be carried out with peers with a 24 h service. A server will provide to the user a streaming video showed in the central window of the CBAC. The video shows a sequence of exercises specifically designed to improve balance of elder population, interpreted by an elder himself. Each user can follow the exercises and his/her video displayed on the side windows.

A set of specific exercises will also be developed to be carried out with the user's avatar under the guidance of exer-games, inspired to the IGER system [21] recently developed for autonomous rehabilitation at home.

Some of these activities can also be played with instrumented objects, for instance an anti-stress ball and used to measure physical indexes like the maximum pressure that can be exerted for monitoring purpose. Integration with sensors widens monitoring and control of activities, which become engaging contexts where to operate transparent monitoring (in Sect. 4, we outline a concrete example).

Peers are suggested starting from the profiles registered on the Virtual Community of users. Through pattern matching techniques applied on elders profile forums, groups and individuals to which the elder may connect are suggested, increasing their engagement in MoveCare. The analysis of the social ties network of users provides clusters of users with similar interests and attitude. Through conversation in the community, socialization and externalization of knowledge will take place.

To improve attractiveness, besides the social dimension, gamification is explored to boost extrinsic motivation.

3.2 Monitoring and Environmental Data

Monitoring in Movecare is achieved in a transparent way, that is nothing is required to be worn by elders nor it is required that they change their habits.

Main physical problem encountered by elders are falls that may easily induce fractures that in turns provide a speed-up in the aging process [22]. To avoid this

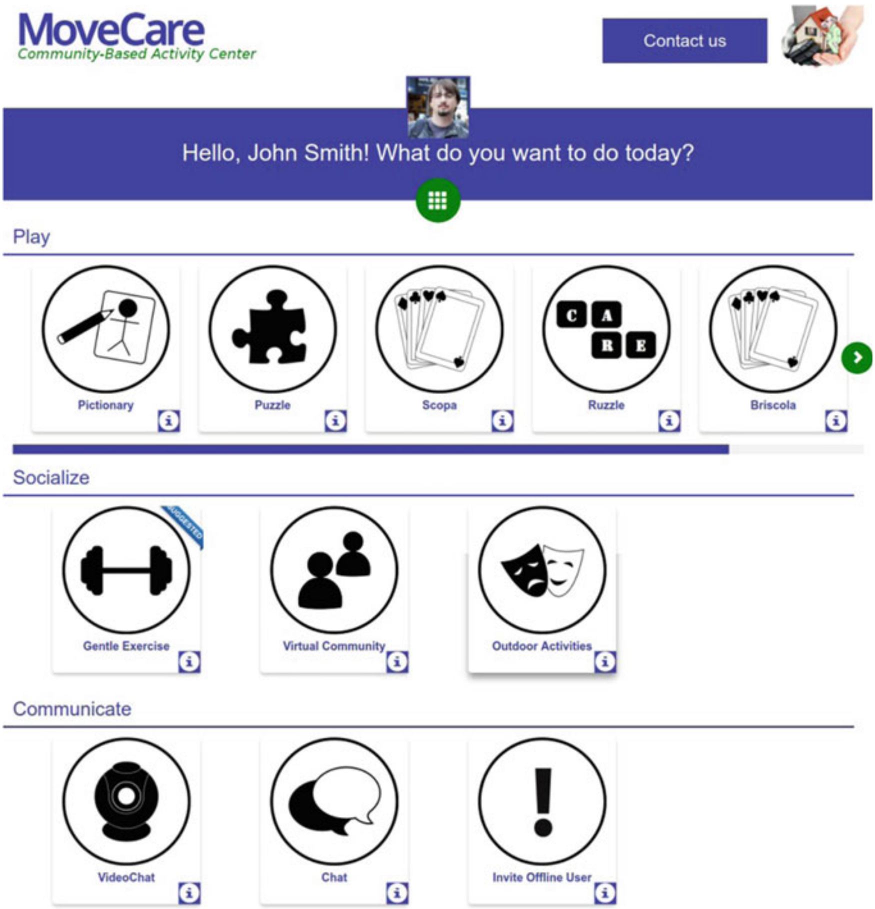

Fig. 2 Main interface of the CBAC from which activities can be easily accessed

postural stability has to be monitored. Several approaches have been developed to this purpose, mainly based on wearable sensors [23–29].

A different approach that is based on instrumenting insoles [30–32] or a walking cane [33] has been recently proposed. We will further develop this approach developing a modular micro-architecture that senses pressure and movement and transmits in real-time wireless the data to a host. Such micro-architecture can be embedded into different objects like cane, trolley handles, insoles, pens, cups and so forth and can transmit continuously the data to a host. These objects will provide several types of data.

Data on cane, trolley handles, insoles are logged and will allow following over time postural stability in common and frequent activities of daily living (walking, shopping …). Postural stability will be evaluated indoor and outdoor. From these measures, the weight borne by the walker and the symmetry of elder's posture can be determined along with gait features.

To derive a better understanding of the elder physical state, when the elder is at robot sight we compute the skeleton through the RGB-D camera on the Giraff robot.

The measurement of force exerted in the interaction with objects of common use, like cups, pens, handles and so forth inside which the developed sensing micro-architecture has been inserted is also measured. The analysis of these data all together provide a robust indexes of possible physical degradation.

Changes over time can indicate if the elder's gait is becoming slower, unsteady or needs walking-aid assistance. Reduction of the force exerted on objects during the interaction can be a clear sign also of physical degradation.

Similarly, we monitor cognitive decline with multiple functionalities. Indexes of de cline can be computed from degradation of performances in cognitive activities administered by the activity center. Moreover, we implement a digitized version of two of the most used clinical tests: the Trail Making Test and the Bells Test: the first is used to evaluate planning ability [34] and the second was introduced to detect hemineglect and it is commonly used as an attention test [35]. Both provide good indexes of cognitive decline.

We study and develop a novel approach to early detect cognitive decline through the analysis of voice, obtained for instance, from phone conversation, to determine pitch, jitter, shimmer and pace. To this aim, cepstrum analysis or Short Time Fourier Transform [36] of audio signal with vocal folds opening and closing rates is considered. Stress is detected using the innovative Dypsa algorithm [37]. We identify, with the help of clinicians, a set of features associated to emotional state of the elder while speaking and track it over time to detect meaningful changes that can be linked to cognitive decline [38–43].

3.3 Assistance

To increase motivation in using the system, trust is a key element [44]. To increase this, several functionalities of common use by the elder have been identified.

One element that can help creating this bond is solving problems, even small, in everyday life. Loosing objects is common and enabling Giraff to locate them for the elder can promote trustiness in the relationship.

We explore the integration of semantic vision and RF-ID to find lost objects inside the house, to which an RF-ID tag has been attached. The concept at the basis of the method is the acquisition and the processing of the RSSI (radio signal strength indicator) emitted by the tagged objects as soon as the robot, wearing the RF-ID reader, approaches them. UHF radio frequency allows to get information starting from 1.5 meters of distance from the object and the RSSI value is growing up as soon as the object is becoming nearer and nearer. This solution is complementary to the vision that can supply an indication of the position of the object when it is in the field of view of the robot camera. UHF tags are very cheap and widely available in different sizes and shapes making easy the selection of the best one for each type of object and also the tagging of multiple objects for any purpose.

With this solution there is no need to artificially introduce changes within the user's house. Still, there exist situations in which object location fails when tackled only through a vision-based approach (e.g. objects inside drawers, pockets, etc.). Hence, the use of small RFID tags attached to some everyday objects is also addressed to extend Giraff's location capabilities to those objects that may be hidden to the view.

Safety is another key point to promote trust. A novel system based on distributed microphones with DSP processing capabilities will allow the elder to call Giraff, also when in a different room, realizing a distributed voice command system always available to the elder. In case of an alarm (a fall, dizziness, and so forth), the elder can shout "help" and Giraff will approach and send a video to the caregiver who can assess elder situation, communicate or intervene.

Moreover, MoveCare guides the elder in taking prescribed drug at the correct time intervals thus supporting therapy compliance. We aim here at designing an effective and simple solution to promote therapy adherence. Current solutions are just slightly more than text reminders or they are based on smart containers. It is based on a multimedia reminder of novel generation that can be most informative and intuitive. It will provide an alarm at the right time through video/animation/graphical instructions with voice explanation through smart-phone. We aim to display a picture of the drug box with the posology and the number of pills remaining, that is downloaded from elder profile.

Assistance with diet is also provided through the virtual community. Cooking suggestions are provided with animations on how to prepare particular dishes. Uploading/downloading cooking recipes from the community is enabled, thus increasing collective knowledge on diet and on cooking too. Possible connections with established website on recipes can be made. Recipes can also be filtered according to elder profile.

4 The Elements of the MoveCare Platform

Starting from these observations, we have identified the following components.

4.1 Virtual Caregiver

The different functionalities are coordinated by a Virtual Caregiver that analyzes the input collectively provided by monitoring systems, the activity center and the Virtual Community and suggests activities, provides recommendations at the point of need and raises possible warning for the elder's caregivers.

Activities, assistance, recommendations and monitoring are managed by a service robot through an embodied Virtual Caregiver, context aware endowed with artificial intelligence. Thus it closes the loop from monitoring to recommendations and to the actual elders caregivers.

Interfacing modalities with the Virtual Caregiver is fully inspired to Natural Users Interfaces (NUI interfacing modality through voice and gesture). These modalities are carefully designed and implemented to favor the establishment of stable and positive bonds [45].

Particular care is put in the design of the virtual caregiver avatar, such that it does not fall in the so called “uncanny valley” [46]. Its aspect will be stylized so as the subject clearly understands that the avatar is a humanoid being, but does not really pretend to be a human being. We design and provide several avatars so that the elder can choose the preferred one. Avatars are endowed with a repertoire of movements and simple facial animation with approximated lip synch among which the most suitable animation congruent with the current speech produced by it. We also explore real-time text to speech synthesis. We exploit emotional content in feedback messages provided by the Virtual Caregiver to patients: humor, references to mutual knowledge, politeness and trust will be mixed through time.

The Virtual Caregiver is implemented through a novel mix of sub-symbolic and symbolic reasoning on the huge amount of heterogeneous data coming from sensors, community and activity center to evaluate elder’s state, to launch warnings and alarms to the proper actors, to adapt activities and recommendations and to continuously refine the single elder profile (Fig. 3).

In particular it employs a context recognition engine that uses a temporal constraint-based-propagation approach. This approach employs temporal reasoning techniques to perform on-line recognition of temporal patterns of sensory events. This task introduces a key novelty in temporal constraint-based context recognition, namely the ability to take temporal uncertainty in the sensor readings into account. This capability is an important enabler for continuous robust recognition, as this allows us to interpret the output in time of sensors in ways that fit high-level, user-defined models of behavior, and possesses the necessary good performance to be used on-line. The symbolic models underlying the inference are grounded on a constraint-based representation. The key advantage of doing so lies in the widely recognized capability of this paradigm to support search and incremental constraint solving capabilities, and the relative efficiency of the resulting applications. The user-supplied rules used by the inference module define how sensor readings correlate to context that can be inferred and be used to provide decision support for multiple actors of the system. These correlations are expressed as temporal constraints in Allen’s Interval Algebra with metric bounds [47]. However, the overall architecture supports the more expressive INDU algebra [48] which adds constraints on the relative duration of intervals. Activities, events, and alarms are inferred by performing temporal constraint propagation on the domains of intervals generated by the preprocessing module and the output is a domain of intervals that are admissible with respect to the rules activated. In this task, effort is placed on implementation of these algorithms, and on adding flexibility in the terms used for the rules. To evaluate the reasoner, we will also implement hance data analysis of signals by leveraging from context

Fig. 3 Giraff robot head with the Virtual Caregiver displayed

information. Answer Set Programming (ASP). This particular task starts early to be useful for monitoring data which have a strong temporal dimension and are difficult to inter.

Short-term behavior classification pertains to the daily habits and it is carried out on user activities and monitoring logged by the MoveCare platform inside the cloud. We implement an evaluation system, based on fuzzy systems, to transform user's behaviors into scores, according to their adherence to recommendations defined for that user and inserted in his/her profile in way similar to that described in [19]. This score represents daily habits in the range from healthy to unhealthy and provides a risk indicator. Short-term analysis is implemented in five stages: data gathering, data preparation, extraction of indicators, reasoning and events detection, and notifications. The system continually updates the current score associated to lifestyle, the daily goals negotiated with the carers and the percentage of completion. If it is the case, the time when the users reach their goal. At the same time, data are constantly mined to detect significant events (e.g. large decrease in physical activity) to elicit counteracting mechanisms. To this aim, notifications are sent to carers.

Integration of different indexes over time by the Virtual Caregiver to provide a robust evaluation of possible cognitive decline. To this aim, long-term trend of elder behavior is assessed. To this aim changes of scores computed on short term behavior are evaluated against statistically not meaningful fluctuations. Goal of long term is detecting the risk of the elder to enter in pre-frailty state develop risk behaviors that may be difficult to detect just with the short-term analysis. A bad habit can be the result of an exception from the short-term point of view, but if that is repeated over time with a certain and increasing scoring detection, that may result as a long-term indicator of the risk of adoption of a bad habit by the elder. Machine learning techniques are also applied to iteratively learn from the behavioral data stored trends in a robust way. Novel fast multi-scale algorithms based on neural networks [49] and kernel regression [50], are considered here.

To come up with decisions, the Virtual Caregiver integrates a combination of Artificial Intelligence and Machine Learning techniques with context reasoning to infer gap of data in the system. This task will be crucial to create a robust system where the lack of information coming from the monitoring site may affect at the results of the monitoring and interaction with the user. This allows for instance asking Giraff to helping collecting new data or the Virtual Caregiver to propose specific activities. Context reasoning is used before the short and long-term analysis to provide more consistency to the data applied to the algorithms that will end up triggering the required notifications and alerts and visualizing the long-term risk behaviour trends of the user. Our aim is to use Machine Learning techniques to determine which trends are present, where these trends emerge from context reasoning. Then, we reason upon these trends in order to provide plausible explanations. Ultimately, the aim is to create a synergy between symbolic approaches for handling data and the connectionist ones, leveraging from the strengths of both approaches. For this task, Answer Set Programming (ASP) [51] is investigated to derive better interpretation and reasoning about learned trends. The motivation for choosing ASP resides in handling the uncertainty in the sensor data and the need to maintain an open-world assumption. This task requires intensive research to understand how the quality, heterogeneity and different types of data gathered can affect the performance of the combination of different output

Data collected daily Correlation between trends identified and changes in clinical parameters allow identifying most significant prognostic indexes. Obtained models are tested against the data obtained from the pilot and data provided in the literature.

4.2 A Service Robot

Movecare uses a novel powerful vision system as the main sensor to provide an unobtrusive solution for robot navigation that is based on IniniTAM approach [52]. To make robust it uses multiple RGB-D cameras to survey the environment and navigate it. Environment reconstruction through vision is merged with planar models reconstructed through a laser scanner that constitute the initialization for navigation [53].

Giraff will navigate inside the elder's house through remote guidance to derive a map of the house. This map will be semi-automatically annotated using the approach described in [54] such that main obstacles will be present in the navigation map. This will allow also a robust localization of Giraff inside the elder's house. Movecare adopts the Giraff platform, teleoperated when needed, but that can also be guided by that Virtual Caregiver to become an active "companion". Key novelties in Movecare is to have a robot proactive in assisting the elder by monitoring his/her psyho-physical state, helping him/her searching for objects, providing suggestions and feed-backs and guiding him/her through adequate activities that can be administered by itself or through other actors (e.g. phone, TV, community).

User-robot interaction is accomplished through both gesture and voice recognition, providing a natural mean for the elder to interact with the robotic system. Moreover, communication referred to shared knowledge, putting particular emphasis on enhancing the robot's non-verbal communication skills, is developed so that human-robot interaction becomes natural and fluid.

Similarly, as the Virtual Caregiver in MoveCare is going to be a close partner to the elder, the need for a natural and effective communication is a fundamental issue to promote trust. Therefore, another important aspect is to develop an interface modality that can be tailored so that naive users can adopt behavioral cues and voice explanation to form an understanding of the beliefs, intentions, goals and abilities of the robot and the Virtual Caregiver. The challenge is to make the robot's thought processes external and thus observable.

Another key feature for effective Human Robot Interfacing is the integration of the user's explicit and implicit feedback. As in any assistive, cooperative, or interaction-based tasks, user feedback is critical to task performance. The most commonly used form of explicit feedback for interactive service robots consists of providing information to the user directly in the form of language, possibly with accompanying visual information. As for implicit feedback, Breazeal et al. [55] demonstrated that the use of implicit communication by a robot could improve task performance and robustness to errors. Implicit feedback can be based on motion and gestures. This will be indeed the *modality* adopted in MoveCare: interaction is mediated by the Virtual Caregiver avatar endowed with simple gestures and facial animation and by simple animation of the Virtual Caregiver avatar.

4.3 The Community of MoveCare Users

Social networks play an important role in enforcing the relationship between elders and between an elder and his/her carers. Some remarkable examples have been studied. SparkPeople [56], a community of people wanting to lose weight, DLife [57] targeted to diabetes patients, stupid cancer [58], a community of people aged below 40 with cancer. MoveCare capitalizes on this to provide a Virtual Community to users. This is created starting from "Partecipami (participate)" [20] that serves the Milan metropolitan area that enjoys presently >7000 registered members, of which

≈3500 are active and 15% are over 65 years. The community provides (1) Social support in order to put the elder in contact with relatives and friends, to avoid isolation, to allow social activities like multiplayer gaming, also to increase the opportunity of a reciprocal monitoring; (2) Gamification feed-back to support cooperation and competition with pairs and increase motivation. (3) Provide recommendations on diet using animation, graphical instructions and videos.

The community is extended to point to the home page of MoveCare services. It is also the entry point for registering to the MoveCare platform. Lastly it provides specific functionalities targeted to sharing information. A multi-media repository is hosted that allows elders to upload multi-media information on past memories thus enabling collective memories. Support to diet is also provided with the possibility of sharing not only recipes but also comments and observations. Lastly it fully support audio-video chat realized inside the Activity Center.

4.4 The Monitoring Systems

One of the characteristics of the MoveCare platform is that elder has not to wear anything. For this reason a host of monitoring systems are deployed. A set of sensors belong to domotics: presence sensors, pressure sensors under the mattress or the sofa, TV switched on and so forth are all connected through an IoT concentrator that provides to send the data to the cloud server using novel Bluetooth LE protocol [59].

A different set of sensors is those that can be inserted inside objects used to walk. These can be insoles that can be put inside the shoes [60], or a microarchitecture, designed ad hoc, that can be inserted inside a walking stick or a trolley. Such a microarchitecture can be built starting from the sensing board made available by several producers, integrated with specific sensors. These will be integrated inside a specific case designed and realized through 3D printing [60].

Monitoring is based only on the results from the activity guided by the activity center. All the monitoring data are analyzed by the Virtual Caregiver to provide recommendations and launch possibly warning to the caregivers.

5 Evaluation

Movecare is a heterogenous platform that integrates robots, artificial intelligence, webservices and domotics. Managing such a system poses a great challenge.

The variegate functional needs of elders call for a new definition of "service" and "service level" against which MoveCare is evaluated. One of the key challenges of MoveCare system is to make simple the use of such a complex system by the different actors. This requires both a design and technological effort aimed to provide the most smooth, simple and effective functional interaction with the elder and with the other actors. Effective indicators to assess service level gains will be identified and collected in the pilot against real use by elders at home. From the technological point of view, novel metrics will be defined aimed to continuously monitor the dependability of the whole system starting from continuous monitoring the single actors in terms of accuracy, reliability and availability. This allows to continuously tune the intervention changing the weight and the combination of the actors involved in the high level functions.

To evaluate all these aspects in a real setting, a pilot study will be carried out during which 30 independently living elders, 16 in Extremadura region and 14 in Lombardia region will use the system for three months.

To derive a common framework to characterize and evaluate such multi-actor system (and multi-actor systems in general) abstract measures of dependability, accuracy, reliability, resolution will be defined along as usability metrics that will be adapted to single user. Processes to update the framework to the actual condition is also developed.

At design level, the challenge of MoveCare is to integrate in a single approach the perspectives of two completely different domains: on one side the user centered design, aimed at the full inclusion of the human actor, and needed to make the final product accepted by the end users, and on the other a robust design approach necessary to assure a suitable reliability of the complex system as a whole. This particular nature of MoveCare impacts also on the selection of metrics to be applied to test the system and assess its overall functionality. On one side it is necessary to trace usability and technological acceptance, with the due emphasis on user-product interaction; on the other it is needed to identify and assess noise factors (including the end user him/herself) impacting on the complex system overall functions. A hybrid approach based both on deterministic methods for the assessment of product performance [61] and on heuristic ones for evaluating more subjective aspects will be implemented [62, 63]. The identified metrics will be collected. A step forward is to derive from this application related set of metrics, suitable indicators of service level gain in terms of impact of the complex system on the quality of the human performance [64].

6 Conclusion

The large development in the technology offers the possibility of creating a full variegate system that can make safer for elders living alone at home. To obtain this several scientific and technological challenges have to be tackled to provide a reliable and dependable system that can be safely deployed at elders home.

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Virtual Modeling of the Elderly to Improve Health and Wellbeing Status: Experiences in the Active Ageing at Home Project

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Abstract Ageing of the population will result in significant social changes in the years to come. A way to cope with social impacts produced by growing seniority is to design and provide services for elderly people to improve their quality of life by means of ICT solutions, both fixed and mobile (wearable and not), pervasive and with low invasiveness according to Ambient Intelligence (AmI) paradigms. The Active Ageing At Home project strived to realize a Personal Guidance System to guide people's behavior and habits for their benefit, their well-being and to stimulate preventive actions. The goal is to allow individuals to have an active role in managing their own health and in maintaining good health conditions by showing them their "virtual model", which reflects their specific characteristics in terms of personal profile, risk factors, tastes and personal preferences, eating habits, level of physical activity, sleep/wake rhythm and as such improves their self-awareness in the direction of healthy and wellbeing-favorable behaviors.

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1 Introduction

The constant increase of life expectancy and the consequent aging phenomenon in the next 20 years will inevitably produce deep social changes that lead to the need of innovative services for elderly people, focused to maintain independence, autonomy and, in general, improve their wellbeing. The Active Ageing At Home project (AA@H) meant to realize an innovative and integrated system to help improve the quality of life of the elderly, fostering their autonomy to live in their homes, and to provide and manage for themselves in order to keep good health.

The project was developed in the context of Ambient Assisted Living (AAL) that promotes the use of innovative technologies to allow older people to keep living in their own houses, rather than hospices or nursing homes. For this purpose, AAL specifically designs intervention on homes to adapt them to different situations (health or disease), enhancing older people's autonomy, easing daily activities and guaranteeing safety conditions.

Care of the elderly and promotion of technology in gerontology environments requires a deep knowledge of older people's need and expectations. AA@H realizes personalized services built upon a comprehensive ICT platform, which can guide people to carry out a healthy life style and to maintain their level of autonomy in different dimensions (security, mobility, memory, and sociality). The goal is to allow individuals to have an active role in managing their own health and in maintaining good health conditions.

The technologies proposed in AA@H are largely based on heterogeneous, distributed and connected smart-sensors, smart-actuators and smart-devices integrated into a scalable technological platform, which is context-aware and enables services to assist and monitor users in their own life environment. The platform is meant as an extension of other domotic solutions inside the home environment and is integrable with open platforms in AAL realm, such as the ones promoted by the UniversAAL project, and by the coordinated European Union EIP-AHA (European Innovation Partnership on Active and Healthy Ageing) action.

ICT solutions with a high technological impact were developed with the concept in mind to extend the time in which elderly people can live independently in their homes. AA@H promoted the porting of Ambient Intelligence (AmI) technologies to the new sector of the "Silver economy", helping make the involved technologies pervasive to seniors by means of the identification and the removal of the technology barriers that typically prevent them to benefit from ICT tools [1]. The AmI ICT platform designed for AA@H infers knowledge by integrating automatic tools for reasoning, knowledge discovery, ontologies acting also as a decisions support system in the contexts of monitoring, security, assistance and inclusion. The ICT platform upon which AA@H builds its services, is based on a cloud infrastructure in order to organize the collected data in a remote system assuring reliability, scalability, security, performance and independence from the device or application used to access to the data. Special attention is devoted to managing privacy and sensitive information.

The proposed solutions are not aimed at substituting the capabilities and experience of the caregivers, but on the contrary, they provide technological support that allows reducing the cognitive load and stressing on the people, leading to a reduction of the general cost of the assistance and an increase of the quality of service. The collected data are processed by means of modules that are capable to extract key information required by different stakeholders (relatives, caregivers, service providers) identifying automatically critical situations and allowing an efficient monitoring of the well-being level of the user. The solutions and services were also designed using a user centered methodology allowing to realize innovative products according to the specificity and habits of the users [2]:

a. solutions aiming at increasing the sense of safety and self-reliance at home: intrusion detection systems, monitoring and indoor localization using active and passive radiofrequency vision systems;
b. multi-sensing solutions for the prevention/detection of critical or potentially interesting events related both to the person (falls, unconsciousness, difficulty in walking, …) and the environment (flooding, presence of gas and smoke, temperature, …);
c. multi-sensing solutions for primary and secondary prevention of cognitive and affective deterioration by means of the analysis of behavioral patterns targeted to "Activities of Daily Living" (ADL), levels of sedentary, social life, habits. The proposed technologies contribute to keep the elderly autonomous and confident but also prevent degradation of mental, physical and cognitive conditions, detecting potential risk situations at their early stages [3];
d. systems for the evaluation of correct eating behaviors in case pathologies are present and the maintenance of a balanced diet is required;
e. solutions of Personal Fitness for the execution of regular physical exercises with gesture recognition and adaptation to the user's profile;
f. solutions enabling the socialization using ad hoc social networks developed specifically for the interests and possibilities of elderly people. Such network provide edutainment service as for example: reading books, newspaper or magazines related to the interests of the user; joining discussion groups on specific arguments; sharing images and stories; keeping in contact with family and friends; participate to and organize events by inviting also other people; play online games alone or within a group;
g. solutions of Interaction Design specifically realized for elderly people designed with a user-centered perspective which enhances familiarity, pleasantness and positive impact on everyday life.

The main outcome of AA@H was the development of a Personal Guidance System to orient people's behavior and habits towards their benefit and their well-being. To this extent, AA@H delivers a *Virtual Model* system of the individual. The Virtual Model (VM) analyzes behavioral data and detects patterns through fixed and wearable intelligent microsystems, employed and interconnected among them, and through inference logic. The VM also allows the evolution of the monitoring model, from a static profile to individual specificity, taking the overall individual's wellbeing into account, including psychological and relational aspects, not only physical. Through interaction with users, the system fosters their awareness and participation in managing their own well-being, stimulating change in unhealthy habits in favor of a better life style that can help keep them healthier and prevent or minimize risks of disease. In this way individuals play an active role in managing their own health and in maintaining good health conditions.

2 Virtual Model

The VM is the main contribution and the qualifying element of AA@H. It reflects important characteristics that are specific of each person (e.g. personal profile, risk factors, heart functionality assessment, harmful behaviors, tastes and personal preferences, eating habits, level of physical activity, sleep/wake rhythm, etc.) and can provide personalized indications by interacting with the individuals to make them more conscious of unhealthy behaviors. An intelligent environment was devised to:

a. monitor indicators for health status, physical and intellectual well-being of the individual;
b. act as personal guidance, evaluate the individual's evolution in time and promote correct life styles and behaviors;
c. prevent and detect critical situations or risk (e.g. smoke in the room or fall), avoiding false alarms but promptly intervening in case of need;
d. promote adequate physical activity;
e. promote active socialization and participation in community life.

eResult delivered its OMNIACARE platform in the AA@H Project, mainly to build the software part of the VM. OMNIACARE is a software product endowed with very broad characteristics of configurability, scalability and robustness. The Virtual Model module is realized extending the PHRS (Personal Health Record System) functionalities in OMNIACARE with behavioral analysis functions. The model is built to be self-adaptive and self-calibrating to adapt to variations in time. The system also analyzes a huge quantity of structured and non-structured data to infer high-level information as posture, behavioral patterns and their interaction with the VM itself.

Given the complexity of the problem, a structured approach is adopted to build the Virtual Model, through a hierarchy of properly coordinated software modules. Among these, a part of activities specifically concerns the development of virtual sensors, based on the techniques of analysis of the raw data of the lowest level, and addressed to the recognition of behavioral changes. These data, mainly coming from the environment in which the person lives, are more difficult to fit directly into a virtual individual model, and must first be processed by a module based on inference techniques, fusion and analysis of large amounts of heterogeneous data, which provides summary information, plus more expressive indexes, consistent with the individual model. The identified areas, for which the collected information is computed and made available for the creation of the VM, are:

1. Food
2. Water
3. Weight
4. Stress
5. Mobility
6. Socialization
7. Sleep/wake cycle
8. Posture
9. Heart and breath parameters.

The VM allows the definition of the user's standard, i.e. profiles the user in such a way that ranges are defined in each area within which he/she must be maintained in order to preserve a conservative situation (e.g., keep the current weight). The user, based on the default profile, is then stimulated to improve his vital and wellness figures by setting objectives. The information made available by the data management module, allows to define encouragements, which are shown as notifications (e.g.: "You only walked only 1 km today, you should move a little more"). To this purpose, an objective definition module is provided. This module is intended as an extension of the incentive functionality, since it provides different targets compared to the previously mentioned standard. The module allows the definition of consistent objectives with possible pathologies in the user, or with other particular conditions. The configuration of the objectives can take place by a tutor or physician.

The architecture of the VM is made of a main DB which also hosts the application layer of OMNIACARE, and of different elements all around it. The end user works with a mobile device (smartphone or tablet) from where to use the AA@H applications. In addition, the mobile device in some cases acts as a gateway for associated sensors (e.g. the Pulse), or at least as an input system for certain parameters (food, water, etc.). All of this information is sent to the central server through a layer of services (RESTful web services) and feeds the main DB (Fig. 1).

A middleware software layer is realized which creates a common interface for all data sources, and thereby allows:

– data collection
– data encoding/synthesis
– data provision.

In this way, it is possible to show the measured data in a comprehensive manner and make it available to the physician or caregiver. Similarly, information (or a subset) is accessible to the user, on the OMNIACARE web platform or by an application for mobile devices. Two separate software modules, the Data Aggregator and Statistical Analysis, take care to make the information accessible from the OMNIACARE platform.

The task of the Data Aggregator module is to create an aggregation of data on which to perform the research, collection and synthesis of data in the form of synthetic

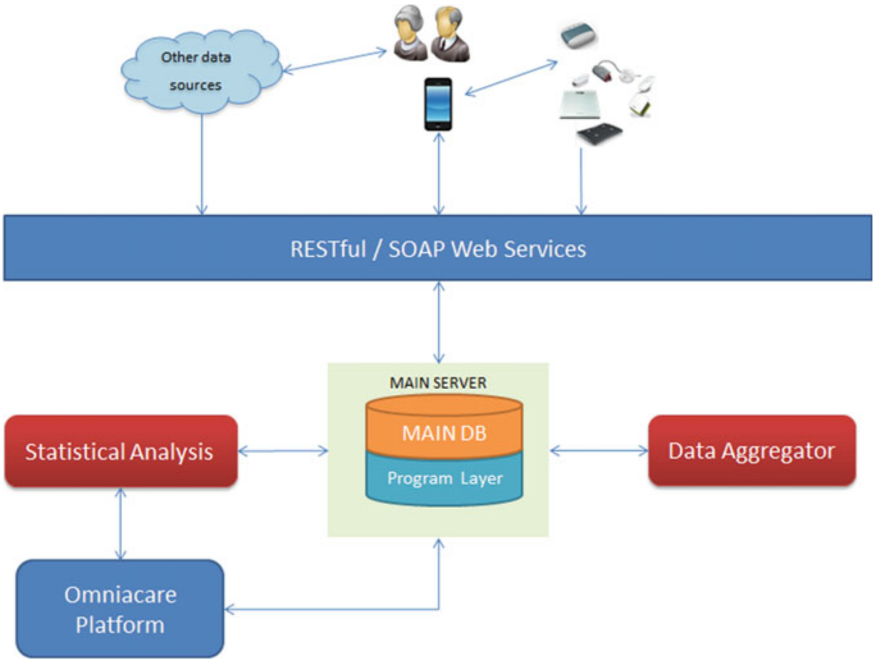

Fig. 1 Virtual model architecture

information, in order to achieve the specific business intelligence solution that shows the user summary information and significant state. The Data Aggregator works on a large number of samples, numerical or otherwise, from heterogeneous sources (applications, services, sensors), and its task is to produce the valuation indexes in the defined areas (sleep/wake, food, water, etc.), which are numeric. Exploiting the numerical representation of the parameters, it is possible to dynamically add other indicators within the system. The Data Aggregator works on the central database, from where it draws the raw data on which to apply the algorithms defined therein. Then it inserts into specific tables the results of calculations that represent the summary information. The identified procedures for the execution of the process are:

1. Data aggregation operations are triggered by appropriate insertions of measurements, or blocks of received data. (Observer–Observable logic);
2. Operations are automatically executed with predetermined frequency: data is processed periodically, generating the corresponding synthetic data.

Depending on the collected information, one of the two modalities or both can be applied.

The task of the Statistical Analysis module is to analyze aggregate data acquired from the outside and correlate it with the user profile, i.e. it works on aggregated data generated by the Data Aggregation module to perform a statistical analysis, comparing the available information generated by the Data Aggregator module with

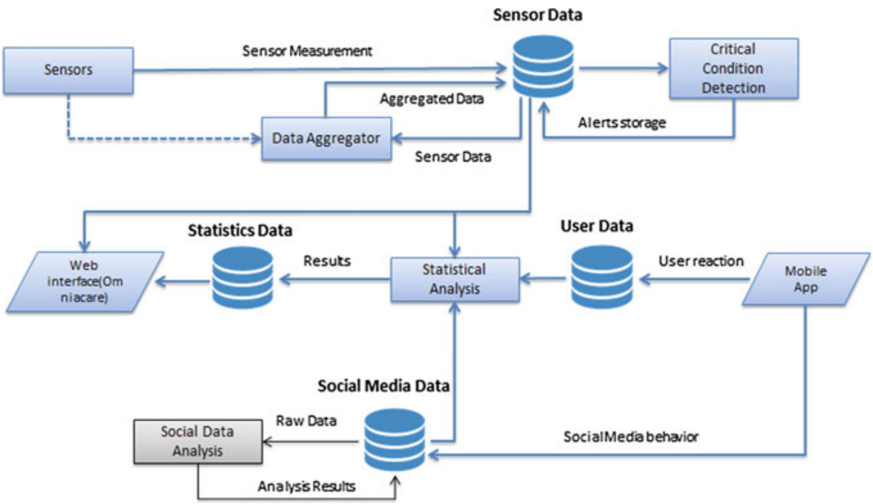

Fig. 2 Virtual model control flow

profile information of the user. The Statistical Analysis module provides all information to be displayed directly in the OMNIACARE web platform user interface (UI). It is invoked whenever it is necessary to refresh the UI, or when the client system (for example, a smartphone) needs to receive summary information representing the user's status. A caching mechanism is used to reduce the number of computations of the Statistical Analysis module, triggering them only in the cases where it is necessary to refresh the UI; in particular when the inner algorithms cannot be quickly executed.

Figure 2 that illustrates the Virtual Model control flow is shown.

The dashed arrow between the Sensors block and the Data Aggregator block shows the ability to pass data directly to the Data Aggregator module, performing a sort of pre-processing of the information, in the cases when this operation is feasible a priori. This is possible whenever the specific aggregation operation is independent from other data and thus computation can be made starting from the single sample received, or from the block of samples received. If the collected data need to be correlated with other information, sensor data will be stored in the database first. All information gathered, both in terms of raw data and aggregate data, are processed by an additional module ("Critical Condition Detection") that takes care of detecting a series of pre-configured critical conditions. Starting from the aggregated data, the information is processed in a subsequent step by the Statistical Analysis module, which relates the aggregated information with the information that constitutes the user's profile. The results thus obtained are shown in appropriate interfaces for an easy display of the user's progress. As can be seen from the diagram, the social media information are handled by a separate Social Data Analysis module, that pre-filters the information acquired by the social section, then provides them to the Statistic Analysis module to be processed by the algorithms defined therein.

In order to support the incentive functionality, substantially it is necessary to evaluate the deviations between the information synthesized by the Statistical Analysis module, and the numerical information relating to the levels defined in the user profile. This mechanism is integrated in the Statistical Analysis module. Notifications depend on the standards defined for the patient. If a threshold is exceeded, a notification is generated and forwarded to the user (client app). Some limitations exists, to make sure that notifications are not repeated or too frequent, thus disturbing the user. It is possible to configure the type of notification for each parameter observed. One-time notifications are available, meaning they will be sent only once to the client. Also, recurring notifications are implemented, dependent from the user reaction (e.g. "every 2 h, until the user responds", where the answer is also generally indicative of a behavior of the user). This model also determines the priority level. For example, the exceeding of a threshold of a vital parameter is considered as a high priority. At the same time, tolerances are defined for the various types of synthetic observed parameters, expressed in percentage terms. The notification algorithm considers these percentages, avoiding trigger notifications in case there is not a significant deviation with respect to the defined standard.

As concerns the user interface, the visual representation is configurable. For each synthetic parameter it is possible to specify the appropriate indicator from a set of possible widgets available. Among such widgets are:

1. Progress bar/gauge: a horizontal or semi-circular bar that shows the parameter progress in percentage;
2. Pie chart: data is distributed in slices, proportional to the percentage;
3. Histogram: vertical rectangles relating to a specific parameter progress;
4. Semaphore: three light indicator for multiple states evaluation (Fig. 3).

Widgets combined together give form to configurable dashboards, adapted to the user or caregivers' needs, which constitute the visual output of the VM.

3 An Example of Virtual Model Usage

In the AA@H project context, the two partners eResult and STMicroelectronics worked alongside to develop important parts of the overall system.

One of the contributions to the project by STMicroelectronics was directed to health parameter monitoring in the individual. The effort was to detect a comprehensive set of information in a non-intrusive way that could result acceptable to the senior. For this purpose, a wearable device was employed. The vital parameter detection device used was MR&D's Pulse Sensor, based on STMicroelectronics BodyGateway's technology™ chipset, CE certified. It is a wearable, battery operated device intended for use as a part of a multiparameter analysis system. It uses a sensorized component adhesive (plaster), placed on the body of the assisted person.

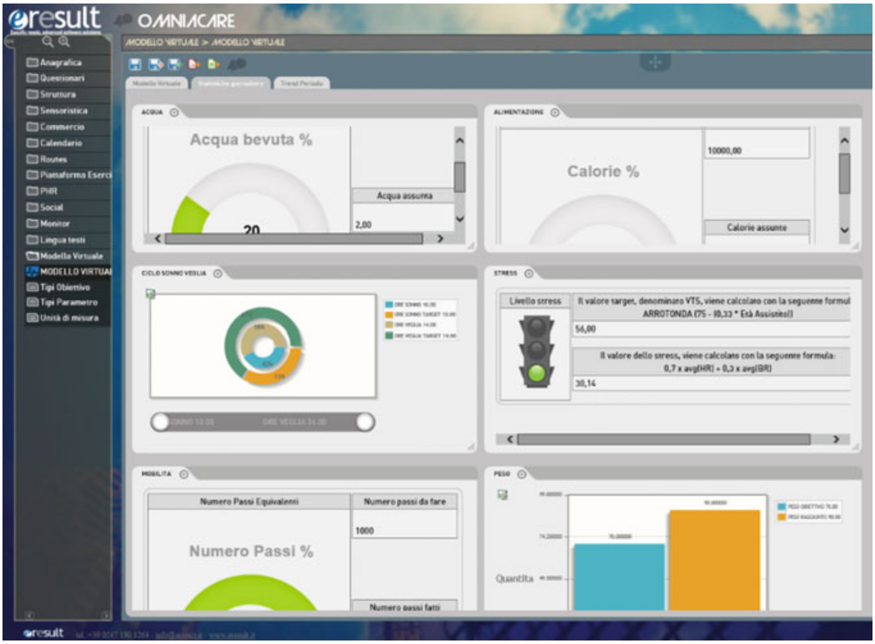

Fig. 3 Virtual model dashboard widget example

It can record symptomatic and asymptomatic events and is suitable for ambulatory monitoring of non-lethal cardiac arrhythmias. The Pulse Sensor is under the form of a plastic container, round-shaped, measuring 59 mm × 50 mm × 16 mm, with four electrodes on the back, three indicator LEDs and an operation button on the front.

The device permits to record heart rate, respiratory rate and, through an accelerometer, the level of activity of the person, providing the management system of continuous or periodic messages of information to/from the server according to specific settings defined by the medical staff. The raw data acquired and recorded by the Pulse sensor are combined with a number of embedded algorithms, allowing to obtain more information and more reliable, respect to the single signal. The algorithms can also be adapted to the single patient, adjusting the relevant parameters. When the physiological data exceed the limits set in the system, a notification is sent out, and the recipient receives the raw signals for that specific event.

Several types of records are gathered from the device:

– 5-min lasting ECG curve once every hour;
– 5 min lasting R–R Interval measurement once every hour;
– breath frequency during the day;
– heart rate during the day;
– activity level during the day.

Fig. 4 VM heart parameter plotting widget

Data is collected from the device and sent to eResult's OMNIACARE cloud for computing and displaying in the VM dashboard. OMNIACARE computes data from the Pulse using a norming algorithm and shows ECG curves in standard mm-chart diagrams and all of the other non-ECG parameters as punctual graphs or trend diagrams (Fig. 4).

OMNIACARE offers a comprehensive list of comparative charts, including ECG curves on equivalent grid graph paper, where the x axis is scaled on 1 mm = 40 ms (25 mm/s). The VM dashboard is accessible via any Internet connection, using the most common browsers (Internet Explorer, Mozilla Firefox, Google Chrome, Opera). The physician, with appropriate credentials and permissions, can access information about his patients anywhere and prepare comparative analyses, based on the curves of recorded parameters. This allows the evaluation of chronic disease evolution, with particular regard to the patient's response to drug therapy, in order to adapt the type and dosage of medication to the situation of the individual patient, based on objective factors and thus improving the quality of care.

The Pulse Sensor proves extremely reliable in the vital parameters detection. Results of the experimentation demonstrates that the device, coupled with OMNIACARE and VM, permits not only to monitor the normal parameters (ECG, respiratory rate or activity level) but also to assess the daily behavior of the neurovegetative cardiovascular pattern related to activity level and respiratory rate [4, 5].

The overall system permits to monitor not only the normal parameters (ECG, respiratory rate or activity level) but also to have a daily behavior assessment of the neurovegetative cardiovascular pattern related to activity level and respiratory rate. The Heart widget implemented on the VM can help the physician and the caregiver in the control of particular patients. In fact, data are processed online to determine several physiological indexes (Heart Rate/HR and Heart Rate Variability/HRV, Res-

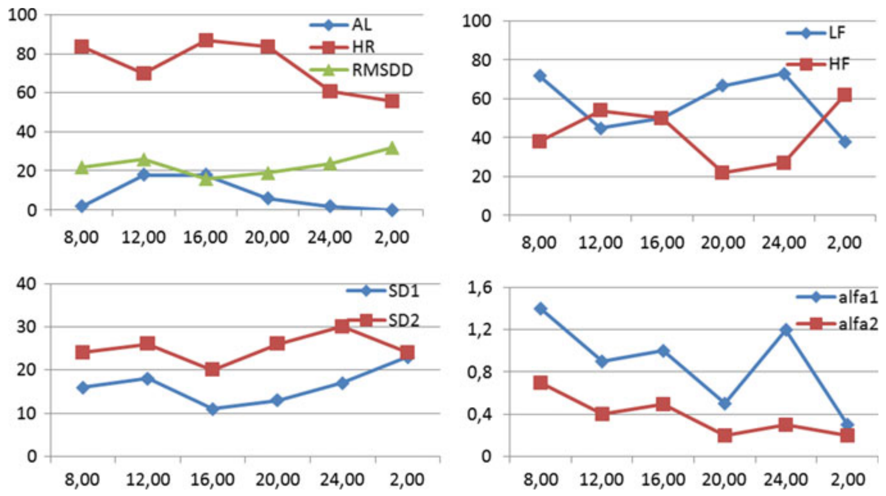

Fig. 5 Graphs of a patient with pseudo normal neurovegetative assessment

piration Rate, Activity Level and Body Posture). From the VM it is possible for medical staff to measure the ECG parameters, especially the impulse formation and conduction, very important in patients under therapy with particular drugs. As an example the pictures below, drawn from the system, show a patient who represent various neurovegetative behaviors in daily routine, plotting the activity level, the HR and the behavior of the principal indexes of HRV, expression of the sympathetic and parasympathetic activity during a day, analyzed by means of linear and non linear analysis in different patients (Fig. 5).

The device's wireless connection and the VM reachability from any Internet browser allow various device application and several monitoring arrangements ranging from real-time monitoring to long-term recording of biological signals. Implementation of this virtual model capability may facilitate both accessibility and availability of personalized monitor and therapy. Further studies would validate it in the clinical and healthcare environment.

4 Discussion

Among the other objectives, the AA@H project proposal meant to demonstrate the considerable potential of smart sensor nodes networks in devices based on low power and low cost, which allows performance and new features such as intelligent vision or the sensing of human physiological parameters, compared to current systems made of bulky and high cost sensors. This project, therefore, acted as a forerunner of a possible market offer for monitoring devices and systems, and for systems endowed with algorithms specially developed for the extraction of the information of interest from the data supplied by the sensors.

STMicroelectronics made a platform with advanced features and that provides ability to aggregate complex functions. The dedicated hardware and firmware by STMicroelectronics and the software components designed and realized by eResult, allowed the possibility to implement the functionality required by the application scenarios defined for the project.

The project developed new knowledge about architectures of sensor networks and the development of sensing hardware/software capabilities. The network architecture used in AA@H hides the heterogeneity of the underlying technologies of communication and is robust enough to optimally manage a large number of connected devices even in case of failure of individual nodes.

From a system perspective, it is expected that the technological trend will result in the development of new devices in the field of assistive technologies and further advancements in the next years, such as:

– the availability of Internet in each device (Internet of Things), that will allow the integration of system for the internal and external support to the person (at home and outside);
– the concept of web services and web of the objects, that will guarantee the integration of systems and service with an added value, creating new opportunities for a higher number of support services;
– the realization of technologies and RFID devices, that will evolve into a Wireless Sensor Network;
– the development of nanotechnologies and sensors systems, that will allow their integration in common materials, as well as the opportunity of wearing them;
– the increase in networking capacity, that will favor the development of new services devoted to video and multimedia communication within the home and outside;
– a particular attention for context–aware data, services and application. Assistive technologies in the future will privilege the user's perception of the presence, location, devices, date, time;
– the growing potential of robotics, that will favor the development of advanced systems, able to move automatically for giving cures and assistance;
– the improvement in automated analysis of the user health and cognitive state;
– the establishment of new methods for the integration of system devoted to entertainment and communication, that will develop new contexts for improving the relationships among older people.

Those advancements will require proper integration and communication, for which the AA@H project paved the way for the participating partners to keep working with, and gain a competitive advantage.

5 Conclusions

From a software integration perspective, the developed Virtual Model by which elderly can keep the pace with a wellness and behavioral improvement program set by coaches and physicians helps to raise the age until which the elderly person can live independently in their own homes. This helps reduce the rise in social costs due to rise in the average age of the population.

On such basis, it can be affirmed that the AA@H project promoted a gradual and acceptable approach to the technologies for the older people, in order to win over their natural mistrust and indifference in face of something new, complex and potentially invasive such as new devices. The elderly were in fact directly involved in identifying appropriate mechanisms of interaction with simple and intuitive IT tools, in the perspective of maintaining autonomy and enrichment of their lives.

From a market perspective, the current situation in home automation is gradually coming to social optimum conditions: the expectations of potential customers is rising, because knowledge of the possibilities offered by this type of technology is high and the use of technical aids to overcome the disability is common and accepted practice. On the supply side, the market now offers solutions that properly meet requests with requirements. With such premises, and for consequences arising from the extension of life span, it is believed that the elderly sector will account for more and more importance in the overall market for home automation. Indeed, it will be one of the most solid pillars, because linked to basic and unavoidable needs of the person and not to the general economy.

The project activities and experience can therefore seen as a collective effort on one side to produce tools and advancements in technologies for the environments of life, on the other to allow the development of new expertise and market possibilities.

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How to Increase Older Adults' Accessibility to Mobile Technology? The New ECOMODE Camera

Nadia Mana, Ornella Mich and Michela Ferron

Abstract Designing and developing mobile technology that is able to meet the needs of older adults is fundamental to improve their independent living and expand their social inclusion. However, although mobile technology is nowadays widely present in our every-day activities, older adults continue to lag in its adoption. While exploring what hinders older adults in adopting mobile technology and questioning about how to increase their accessibility to it, the paper presents the ECOMODE project, whose technology based on the Event-Driven Compressive (EDC) paradigm is a possible answer. First, to contextualize our study, the paper describes the ECOMODE technology based on multimodal interaction, i.e. mid-air gestures combined with voice commands. Then, it details the process followed to design the interaction based on the ECOMODE technology, which aims to increase accessibility and usability of mobile devices for older adults.

Keywords Mobile technology · Multimodal interaction
Speech-based interaction · Mid- air gesture-based interaction · Interaction design
Older adults

1 Older Adults and Mobile Technology

With the advance of medical treatments and better life conditions, humans are now living longer and therefore the ageing population is increasingly growing. Currently, Europe has the highest proportion of population in the world aged 65 or more (18.9%).

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For example, Spain has approximately 10 million people over 65 years old [1], while France and Italy count approximately 12 [2] and 13 million [3], respectively. What's more, these numbers are likely to rise: in Europe it is estimated that 1500 million people will be over 65 years old by 2050 [4]. In this context, people tend not only to live longer, but also to remain more active during their old age [5]. For this reason, older adults represent a major target for ICT-related research [6].

Mobile technology can enrich the lives of older adults and support their wellbeing by helping them to expand their personal social networks, develop their relationships and, in general, by positively influencing their social inclusion [7]. However, although mobile technology is nowadays widely present in our everyday activities, older adults continue to lag in its adoption. For example, only 77% of Americans aged 65 or older have a cell phone versus the 91% of all adults, and only 59% of seniors report to surf the Internet versus 86% of all adults [8]. Older adults also differ from the general population in their habits about mobile device ownership: in 2015, only 18% of American seniors had a smartphone, whereas more than half of all Americans had one [8]. Similarly, the "Adults' Media Use and Attitudes Report" by Ofcom [9] states that in 2015 in UK the people from 65 to 74 years old using smartphones and tablets were 21 and 26% respectively, whereas in case of users over 75 years old these numbers drop to around 6 and 14%.

Several factors come into play to explain the non-usage of mobile technologies by older adults. Attitudinal, cognitive and age-related changes hinder older adults in adopting digital technologies [10, 11]. For example, a significant majority of them affirms that they have difficulty in learning new technologies and say that they need assistance when using new digital devices [8]. Furthermore, seniors have to face physical challenges to use technologies. For example, the reduced visual acuity and constrained visual field, largely affecting older adults, makes it difficult for them to recognize fine details of icons or pointers used in graphical user interfaces (GUI) [12]. Moreover, difficulties with input devices may relate to muscle strength and power [13], as well as to reduced range and slower motion or greater difficulty in performing fine motor tasks [14].

Touch-based interaction has improved the usability of technology for older adults. For instance, Findlater et al. [15] showed that, although older adults were significantly slower than younger adults in tasks such as pointing, dragging, crossing and steering, the touchscreen reduced this performance gap, compared to the desktop and mouse. In particular, the touchscreen resulted in a significant reduction errors and movement latency of 35% over the mouse for older participants, compared to only 16% for younger adults. However, touchscreen interaction cannot overcome the aforementioned perceptual and motor challenges brought by ageing, such as the difficulty in distinguishing fine details or in selecting small buttons. Moreover, unlike resistive screens, which use mechanical pressure to detect touch, capacitive touchscreen panels exploit the electrical conduction of the human body, and therefore anything that limits the hands conductivity is a potential pitfall. Gloves, thick calluses on the fingers, or dry skin are all factors that can prevent electricity to flow to the touchscreen panel. In particular, calluses are areas of thick and dry skin that can appear on the fingers of older adults who have done manual jobs for several years (i.e., carpenters), while dry skin, or xerosis, is a common skin problem in older adults, due to different factors, such as changes in keratinization and lipid content [16].

Multimodal interaction, leveraging and combining multiple interaction modalities such as speech, touch, vision, and gesture, is a possible solution to increase the accessibility to mobile technology for older adults. Since its inception, multimodal human-computer interaction has sought to provide not only more powerful and compelling interactive experiences [17], but also more accessible interfaces to mobile devices [18–20]. Potential advantages of multimodal interaction include major flexibility, greater robustness and precision over unimodal input [19]. Moreover, multimodal interaction can improve accessibility to technology for diverse users and usage contexts [18]. As Oviatt states [17, 21, pg. 405]: "The advent of multimodal interfaces based on recognition of human speech, gaze, gesture, and other natural behavior represents only the beginning of a progression toward computational interfaces capable of relatively human-like sensory perception." For this reason multimodal interfaces can accommodate individual differences and have the potential to better support users with special needs and capabilities, including older adults [17, 21]. Indeed, for seniors the continued use of one single modality could result in discomfort and tiredness, especially considering their physical characteristics. Surely, the flexibility of multimodal interaction reduces physical fatigue. As demonstrated by several research studies [19, 22–26], multimodality makes human-computer interaction easier and more natural.

Nevertheless, there are still some limitations to overcome to make multimodal interaction with mobile devices completely feasible for older adults. Indeed, although the advantages of devices based on multimodal interaction are widely recognized [27], further work is needed to improve interaction accuracy and to make technologies more accessible to people with disabilities or age-related minor impairments. In particular, even if touch screens are better than other input devices because they promote directness and good hand-eye coordination [14], further development should be done to make them suitable for extensive data entry and to accommodate visual and motor control capabilities of older adults. Concepts such as pinching, swiping and double clicking may be both alien and physically challenging for seniors [28]. Similarly, the devices with speech-based input need improvement to reduce the technical difficulties in processing the speech of older adults [29], because the algorithms for Automatic Speech Recognition (ASR) are usually trained on generic speech corpora and not specifically on older adults' voices. The performance of such ASR systems significantly decreases (of around 9–12%) when used by older adults [21]. This is mainly due to substantial changes in the speech when ageing, and specifically to the alteration of the vocal cords, the vocal cavities and the lungs, which cause modifications in the speech production mechanism [30].

Another issue related to the touch screen and speech-based interaction with mobile devices is that these types of devices are mostly used outdoor, where people often have to move around in a complex environment. Outdoor scenarios are challenging because applications based on touch interaction are penalized by adverse light conditions, while those based on voice control usually show low performance due to high background noise levels [31].

From the point of view of interaction, mid-air gestural interfaces [32] are considered a worthy alternative as a way for interacting with mobile technology because for the ageing population they can be natural, fun and enjoyable to use [33]. Furthermore, mid-air gestural interaction require less fine motor skills than touch interaction, can effectively reduce the learning curve [34, 35], and present advantages over other interaction paradigms as people usually express themselves through gestures in their everyday social interactions. For these reasons, mid-air gestural interfaces could foster technology adoption in those user groups, such as older adults, who find traditional technology difficult to use.

From the point of view of the design of the interaction, for years mobile technology addressed to older adults has been designed according to the "*rhetoric of compassion*" [36], which moves from the assumption that, to compensate for some kind of "*lack*" of these target users, often portrayed as "*in need of help*", technology for seniors has to be simplified. For this reason, the market offers many examples of mobile phones especially designed for seniors (e.g., BRONDI Amico Semplice, AEG VOXTEL SM250 and NGM Facile CIAO), which have reduced functionality and only basic accessibility (Fig. 1).

Now, HCI prospective is gradually moving toward a new paradigm [37] that can be described as a "rhetoric of engagement" [38], which fosters users' empowerment through technology, i.e. technology enabling users to become better equipped to the point where they can innovate for themselves.

By embracing this novel HCI paradigm, the ECOMODE project aims to provide a technological answer based on multimodal interaction, i.e. mid-air gestures combined with voice commands, to overcome the main limitations of the multimodal interaction and make it feasible also for older adults.

Fig. 1 Examples of mobile phones especially designed for seniors

2 The ECOMODE Technology

The ECOMODE (Event-Driven Compressive Vision for Multimodal Interaction with Mobile Devices) project,[1] funded by the EU H2020 ICT22 call for "Multimodal and Computer Interaction", aims to realize a new generation of low-power multimodal human-computer interfaces for mobile devices, combining voice and gesture commands. The combination of vocal commands and mid-air one-hand gestures can be especially suitable for older people as it can improve accessibility and technology adoption, offering an interaction modality that is more accessible, intuitive and natural than traditional ones [33].

The project exploits the Event-Driven Compressive (EDC) paradigm [39], a bio-inspired, event-based, asynchronous information sensing and processing approach with disruptive characteristics. EDC devices combine ultra-high temporal resolution and continuous-time operation, compressive sensing based on redundancy suppression, and wide dynamic range at the sensing stage, with fast, extremely efficient, data-driven processing—yielding compact, low-power, high-performance sensing and computing devices.

In the domain of computer vision, traditional techniques use cameras to capture sequences of images at a certain "frame rate", and computational algorithms process visual information frame-by-frame. This is computationally expensive and includes the latencies of sensing, transmitting and processing each single frame, which causes a severe limitation of the temporal resolution of the system. In contrast, EDC technology exploits the biological metaphor and is frame-free. Indeed, EDC vision sensors transmit information as soon as a change occurs in their visual field, by achieving very high temporal resolution, coupled with extremely low data rate and automatic segmentation of significant events.

The ECOMODE technology is based on two main pillars: (1) a mid-air gesture control set, and (2) a vision-assisted speech recognition set. On the one hand, EDC vision sensor technology applies low and high level EDC visual processing for hand and finger gesture recognition and the execution of interaction commands. On the other hand, EDC vision sensors with auditory sensor input acquire temporal dynamics that are combined with visual clues from lip and chin motions to gain robustness and back-ground noise immunity of spoken command recognition and speech-to-text input.

The goal of the proposed research is the exploitation of highly dynamical information from ED vision sensors for robust speech detection and processing. The temporal information provided by EDC sensors will allow to experiment with new audio-visual techniques for voice activity detection and new models of speech temporal dynamics based on events as opposed to the typical fixed-length segments (i.e. frames).

Thanks to these innovative characteristics, and in contrast to practically all existing technologies, EDC is able to support device operation under uncontrolled conditions. Poor lighting, particularly in outdoor scenarios, and high background noise, where

[1] http://www.ecomode-project.eu/.

usually other structured infrared light-based gesture detection devices fail, are no obstacles anymore for gesture and speech recognition. In these challenging conditions, traditional video-based devices cannot cope with the high intra-scene dynamic range given by the high levels of infrared background from natural (sun) light, and conventional speech recognition becomes unreliable due to high levels of background noise. Furthermore, the sparse nature of information encoding makes EDC excelling conventional approaches in energy efficiency, yielding an ideal solution for mobile, battery-powered devices.

3 The ECOMODE Interaction Design

As described in the previous section, the ECOMODE project aims to develop an innovative technology, able to effectively recognize vocal and gestural commands for interacting with mobile devices. In this section, we will describe the design process followed to find out how the ECOMODE technology can be used to create a usable and accessible interaction with mobile devices for older adults.

To design the ECOMODE technology, a user-centered (UCD) approach [40] was followed. UCD, an iterative design process that aims to develop an understanding of user needs, is based on the use of a mixture of investigative and generative methods and tools, such as surveys, interviews, focus groups). We started the design process by investigating users' characteristics and requirements through a literature review. This took us in identifying the following main dimensions to explore:

Profile of the users—age range; gender; geographical origin; income; level of autonomy; level of frailty; living arrangements and family situation; physical function; mobility; health; cognitive ability; hobbies; travel habits; users' activities in the aggregation centres for older adults; stories about social involvement and entertainment; social aspects and group dynamics.

Technology familiarity—general attitude towards technology, computers, tablets, smartphones; frequency of use of technology; main purposes in the use of technology; preferred setting—indoor or outdoor—in the use of technology.

Usability and accessibility issues—problems and difficulties with the hardware, such as cables, buttons, screen dimensions; problems and difficulties interacting with technology, such as perception and comprehension aspects, icon dimension and intuitiveness; positive and negative aspects in dealing with mobile technology.

Dexterity issues—problems and difficulties interacting with technology, e.g., gestures and other input modalities; use of the touchscreen keyboard and related possible problems; interaction with other elements in the user interface, e.g., links, icons, text fields.

Desiderata on user services—main problems and needs of older adults; preferences and contextual aspects characterizing older adults' everyday life.

According to co-design approaches [41], such dimensions can be investigated by directly involving the target users and the relevant stakeholders. At the early stage of the ECOMODE project, we conducted a preliminary study with older adults using a Wizard-of-Oz technique [42] and two interviews with experts.

3.1 A Study with Older Adults

Ten volunteers (5 females and 5 males), recruited among members of a local seniors' association, were involved in a preliminary study to explore the aforementioned dimensions and how older adults perform multimodal interaction with a tablet device (Fig. 2) while taking pictures by using a set of predefined mid-air gestures and vocal commands.

Fig. 2 Participant interacting with the tablet device using multimodal interaction (one-hand gesture and speech input)

The average age for the participant group was 68.9 years (SD = 3.62), the youngest participant was 62 years old and the oldest 75 years old. All participants were mobile phone users: four had mobile phones with a physical number pad, while six had touchscreen-based mobile devices. All participants but one reported to use their phones every day, mostly for making calls, but some also for sending text messages and taking pictures. Three participants owned a tablet device, but only one of them used it on a daily basis for taking photos, surfing the Internet and writing emails. The majority (seven out of ten) said that they owned a computer but only three of them used it more than three times a week (for checking emails, writing documents and spreadsheets). None of them had experience in interacting with technology using mid- air gestures (e.g., Wii or Kinect) or voice commands (e.g., personal voice assistants). All but one reported to be familiar with touch-based screen interfaces (e.g., smartphones and ATMs).

Self-reported satisfaction ratings for taking photos with the tablet device using a multimodal interaction were on average high: on a scale from 1 to 5, participants reported a mean value of 4.4 (SD = 0.48). Four participants stated they would use this device during a trip outdoor, five people were positive about using the device but they had concerns on using vocal commands in public (mainly regarding issues about privacy or disturbing people around). On average, holding the tablet with one hand was not perceived as an obstacle (M = 4.10, SD = 0.99) and making gestures using the tablet was considered quite comfortable ("How would you rate the comfort of holding the tablet on one hand and making gestures with the other hand?", M = 3.75, SD = 1.03).

When asked about their preferred style of interaction among (a) touch, (b) gesture, (c) voice and (d) the combination of gestures and voice commands, 3 participants stated that they preferred the multimodal interaction, 4 the voice commands and 3 the touch interaction. The participants who preferred the multimodal interaction found the combination of gesture and voice commands a good compromise for using the tablet outdoor and indoor. They liked the immediacy of voice commands but considered also the benefit of using gestures in situations when speaking aloud could not be preferable.

By observing the participants while using the multimodal interaction, we noted that the participants hold the tablet device at about 30–40 cm from the face but they performed the mid-air gestures at different distances from the tablet device. As shown in Fig. 3, most of them (8 out of 10) performed the gestures very close (6–15 cm).

3.2 Expert Interviews

As well as involving our target users in our design process, we deemed important to also involve some stakeholders to explore and discuss different aspects regarding the characteristics and lifestyle of older adults, their relationship with technology, the major problems and difficulties they encounter when dealing with technological products (tablet pc, in particular), their needs and desiderata, from the experts' point

Fig. 3 Examples of mid-air gestures performed at different distances, but quite close to the tablet device

of view. To this end, we conducted two interviews with two experts working with older adults in different contexts. The first expert was a volunteer at a voluntary association for the protection of older adults' rights based in Trento (ADA, Associazione per i Diritti degli Anziani), who had been working with senior citizens for three years. The second expert was a researcher at Fondazione Bruno Kessler (Trento) who had been working as community coordinator in different research projects involving older adults.

We found that older adults are portrayed as a very heterogeneous group regarding different aspects, such as mobility, frailty levels, income as well as technology familiarity, in accordance with the existing relevant literature [6, 43, 44]. One of the main reasons for older adults to approach aggregation centers is the need for social contact, for overcoming loneliness: older adults meet new people at the center and make new friends, finding someone who listens to them. Family also emerged as an important dimension in which technology can play a role, for example to maintain contacts between family members who live apart. Older adults sometimes ask to learn to use technology, such as the computer and the Internet, to satisfy practical needs, such as accessing their online bank account. The older adults referred to the experts were overall active and self-sufficient. However, heterogeneity emerged also with regard to self-sufficiency and mobility capabilities. Older adults can also suffer from age-related diseases, and this reflected in the interviews. Health aspects seem also to be very central in older adults' life. Older adults were portrayed as physically active, socially committed people, who like to travel and to take care of their grandchildren. That is consistent with several studies that have shown that older adults tend not only to live longer, but also to stay more active during old age [5, 6, 45]. Privacy also emerged as a crucial dimension to consider when designing technology with and for older adults because they are very sensitive to this aspect.

Globally, the interviews confirmed the findings from previous literature studies, according to which elderly people are not always reluctant toward technology [6, 18, 44, 46, 47]. Indeed, our experts confirmed that, in their experience, older adults are initially interested in learning to use novel technology, even if later it becomes difficult for them to fully interact with it. According to the experts' experience, older adults are usually not familiar with tablet technology, but they attend the classes because they received it as a present or driven by curiosity. Not being familiar with tablet technology may also influence older adults' attitudes towards it. Experts report that elderly people are often afraid of breaking it, and they tend to use it mainly indoor. Older adults also tended to regard the tablet as a means for entertainment and fun. The experts confirmed Wilkowska's findings [26] according to which previous computer experience and expertise is related to perceived ease of use of technology. The interviews also confirmed previous studies' findings according to which perceived usefulness is one of the most important factors affecting technology acceptance (e.g., [18, 26, 48]).

With regard to usability and accessibility aspects, two categories of interesting aspects can be observed: interaction with the hardware and interaction with the software. With regard to the hardware, experts observed that some components of the tablet might be uncomfortable, because they are too little or fragile for senior users. They also noticed that many older adults are not familiar with the gestures required to interact with the tablet, such as pressing a button for a few seconds in order to start it. However, there are also some positive aspects related to the dimensions and the weight of the tablet, which seems to be a portable and intuitive technology for older adults. With regard to the user interface interaction, experts noticed several aspects that can pose some difficulties for older adults. Dexterity issues can pose problems interacting with the fingers, and to this end experts found the pen to be helpful. Interface elements, such as applications' icons, should be big, simple, and few. Unnecessary elements should be removed, and labels should be written in seniors' native language. Furthermore, according to the experts, some older adults seem to be uncomfortable with notifications, and would prefer a simpler technology. Finally, gestures and fine movements can pose problems for older adults interacting with the user interface.

4 Conclusions

In this paper we started from the fact, widely known and accepted, that the society is getting older: Europe has currently the highest proportion of 65+ people, and the number is going to rise in the next years.

Mobile technology has the potential to improve the lives of older adults in several respects concerning their psychological, social and physical wellbeing, but it is not yet in widespread use among the elderly population. The reasons for the low exploitation of this potential can be traced to several factors, such as attitudes, technological familiarity and self-confidence, but also cognitive and physical age-related functional decline. Research has shown that, although older adults are frequently portrayed as resistant to technology [49], they do not always conform to the ageist stereotype. On the contrary, they are willing to use technology, if this meets their needs, desires and expectations [50, 51]. Nevertheless, age-related physical challenges still hinder the use of mobile technology by the elderly population.

Whereas touchscreen interaction cannot overcome the aforementioned perceptual and motor challenges brought by ageing (e.g. difficulty in distinguishing fine details or in selecting small buttons), mid-air and speech multimodal interaction, leveraging and combining multiple interaction modalities (e.g. speech, touch, vision, and gesture), is a possible solution to increase the accessibility to mobile technology for older adults.

While questioning about how to increase older adults' accessibility to mobile technology in order to improve their independent living and expand their social inclusion, the paper introduced the ECOMODE technology, based on the EDC paradigm and multimodal interaction (i.e. mid-air gestures combined with voice commands), as a possible answer.

After having explored possible reasons of the hindrances met by the older adults in adopting mobile technology and presented multimodal interaction as a possible solution to overcome such hindrances, the paper described the ECOMODE technology by highlighting its advantages in contrast to other existing technology in the domain of computer vision. Then, the initial steps toward the design of the interaction with the ECOMODE device have been detailed by presenting (a) the dimensions explored to investigate the older adults' characteristics and requirements in order to develop a more usable and accessible multimodal interaction, (b) a preliminary study with ten older adults and (c) two expert interviews.

In conclusion, by leaving the "*rhetoric of compassion*" [36] and embracing the new HCI paradigm [37] described as "*rhetoric of engagement*" [38], the ECOMODE project aims to make the interaction with mobile devices efficient and effective also for older adults. An efficient and effective interaction could increase older adults' access to mobile technology and bring benefits for them in term of independence and social inclusion.

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Part II
Assistive Robotics

Degrees of Empathy: Humans' Empathy Toward Humans, Animals, Robots and Objects

Alan D. A. Mattiassi, Mauro Sarrica, Filippo Cavallo and Leopoldina Fortunati

Abstract The aim of this paper is to present an experiment in which we compare the degree of empathy that a convenience sample of students expressed with humans, animals, robots and objects. The present study broadens the spectrum of the elements eliciting empathy that previous research has so far explored separately. Our research questions are: does the continuum represented by this set of elements elicit empathy? Is it possible to observe a linear decrease of empathy according to different features of the selected elements? More broadly, does empathy, as a construct, resist in front of the diversification of the element eliciting it? Results show that participants expressed empathy differently when exposed to three clusters of social actors being mistreated: they felt more sad, sorry, aroused and out of control for animals than for humans, but showed little to no empathy for objects. Interestingly, robots that looked more human-like evoked emotions similar to those evoked by humans, while robots that looked more animal-like evoked emotions half-way between those evoked by humans and objects. Implications are discussed.

Keywords Empathy · Robots · Social robotics · Social distance
Human-object continuum · Living-nonliving continuum

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1 Introduction

The aim of this study is to present an experiment in which we compare the degree of empathy that a convenience sample of students expressed with humans, animals, several typologies of robots and objects. We decided to include in our research various elements that previous research have so far explored separately or combined in a different way. The reason to build this complex setting of observation was to have the possibility to measure and compare the empathy with a set of selected elements belonging to the three natural realms: humanity, animals and inanimate objects. Now the third realm has become diversified because it contains objects that move autonomously (robots) and objects that continue to be inanimate.

Previous research that inspired the present study was conducted by Gray et al. [1] with the aim of describing the main dimensions that characterize different living and nonliving beings and the perception we have of their minds. In their study, Gray et al. found two main dimensions able to differentiate elements: their perceived capacity of feeling and of agency. In our study, we looked at this issue from a different perspective—that is, the empathy elicited by a human, an animal, a robot or an object being mistreated—and we introduced more nuanced differentiations regarding robots. In particular, the stimuli we used included a human, a cat, an anthropomorphic robot with the bipedal human structure ("Atlas", Boston Dynamics), a four-legged robot resembling the structure of a mammal ("Spot", Boston Dynamics), a robot half-way between the Roomba and the Mars Rover, a smartphone and a Rubik cube.

We selected the following research questions. Does the continuum represented by this set of elements elicit empathy? Is it possible to observe a linear decrease of empathy according to different features of the selected elements? More broadly, does empathy as a construct resist in front of the diversification of the element eliciting it?

In this research, we drew on the research carried out by Riek et al. [2] by adapting it to extend the study of empathy with robots outside the human-mechanical axis. This allowed us to explore whether social distance (i.e., the difference between the empathizer and the one empathized with) plays a role in inferring mental states and sharing affective states.

This study is organized as follows: in the next section, we address the main issues of the debate regarding empathy. In the following section, we articulate the debate on empathy according to the various elements with whom it develops. We then illustrate our methods. The next section is devoted to a description of our results, while the final section presents a discussion of the results as well as the limits of this research.

2 Empathy

Empathy is the ability to understand and feel what social partners feel, to perceive their feelings and emotions and to understand others' points of view, mental states, beliefs and thoughts. As such, empathy is an important emotional competence and a crucial social skill. Empathy is a skill that fosters socialization, solidarity and social cohesion in human society. It represents one of the prerequisites for a successful and rewarding interpersonal understanding and interaction. In interpersonal relationships, empathy is one of the main gateways to the moods and in general to the world of others. Thanks to empathy, the individual can grasp not only the meaning of what the other party is saying, but also can capture his/her emotional, innermost phenomenological messages, which are expressed generally by nonverbal language. A detailed, historical reconstruction of the concept of empathy is given by Pinotti [3], who helps us to understand that empathy is at the basis of many important mechanisms that shape the social life. For example, Pinotti reports that Plato and Aristotle were perfectly aware that the identification of the public in the bards who recited their poems or in the theatrical actors was based on empathy. For his part, Freud [4] states that empathy is necessary to come to know the existence of a psychic life different from ours. Simmel [5] and Dilthey [6] suggest that empathy is necessary to the historical reconstruction of events and protagonists of the past. However, many scholars have stressed the limits of the empathy construct. Geertz [7], for example, highlights the intercultural limits of empathy; he states that empathy will never be able to make one understand what being a "person" or "individual " means for a Balinese, a Javanese, or a Moroccan. In contrast, Hoffman [8] points out that the strong interspecies empathy with animals seems to be characterized by fewer problems.

At the neurobiological level, a particular class of neurons called mirror neurons, discovered recently by Rizzolatti et al. [9], enables us to understand the mind and the lived experiences of other individuals. Participating as witnesses to actions, feelings and emotions of other individuals activates the same brain areas that are involved in performing the same actions in first person and in perceiving the same feelings and emotions in first person. Gallese [10], one of the italian scientist who discovered mirror neurons, argues that at the base of empathy is an 'embodied simulation process'. This process, which is ancient in terms of human evolution, is a motor mechanism characterized by neurons that would act immediately before any cognitive processing. According to Gallese et al. [11], perceiving and understanding the meaning of an action require its *internal simulation*. In other words, the observer understands the meaning of the other expression not necessarily or exclusively by analogy, but through a simulation mechanism. This mechanism is a modeling process characterized by a non-conscious, automatic and pre-linguistic mechanism of motor simulation. It is precisely this simulation that produces the sharing of the same state body between observers and observed and allows this direct form of understanding.

While empathy has been studied on a number of different levels and fields, leading to many different and only partially overlapping definitions, a broad agreement is reached on the following main components of empathy:

(a) a cognitive facet, entailing the understanding and mentalization of another person's point of view and perspective
(b) an affective facet, entailing the affective experience of the other person's emotional state

(c) the ability to distinguishthe feelings of the self fromthose (inferred) of the other person [12].

As such, empathy encompasses both a non-affective perspective-taking ability and an affective sharing component.

This discourse reveals clearly that the genuine definition of empathy addresses human beings. However, in the last half century, although social sciences have continued to consider society and social relationships as the core of investigations, they have begun to encompass the attitudes and behaviors of humans toward objects. For example, Barthes in 1957 [13] argued that to understand society it is necessary to focus on the myths and symbology attached to the objects of everyday life. Douglas and Isherwood [14] pointed out that objects serve to build social alliances or alienation. For Appadurai [15], objects have social lives, are socialized things, and have also a particular social potential. Latour [16] stated that it is impossible to build the social only with the social, as sociologists must recognize the role of objects as mediators of the social interaction. Finally, Cetina [17] observed, in modern societies, an "increased orientation toward objects as sources of the self, of relational intimacy, of shared subjectivity and social integration". In conclusion, objects, and particularly technologies, have been increasingly recognized as unintentional mediators of social relationships.

At the same time, non-human social actors are expanding their presence and impact as social companions, even in respect to popular sensitivity. In the past, non-human social actors meant animals only, but today they include more and more robots. While animals' and robots' mental and affective states remain mostly a philosophical issue, empathy with them in past decades has attracted the increasing attention of scholars. In particular, empathy with animals has been widely recognized and studied—one example is in [18]—whereas empathy with robots has only recently been touched upon [2]. Fundamentally, research in social robotics has focused, among other topics, on the emotions that the appearance of robots elicits in humans. An intriguing question, however, is how we humans infer robots' mental states, and how we affectively react to them, since both affective and cognitive empathy require our acceptance of the mental state of the entity we empathize with. Of the few studies on this subject, Riek et al. [2] explored whether the degree of anthropomorphism of the robots' appearance affected empathy with them. They showed that people are more empathetic with human-like robots than with robots that were more mechanical in appearance. On a neurological level, Rosenthal-Von Der Pütten et al. [19] showed that neuronal patterns of activation in human observers of videoclips of social interaction between humans and other humans versus humans with robots did not differ when the interaction was affectionate, but did differ when it was violent and abusive. This result suggested that we may differentiate between humans and robots in some interactions but not in others.

3 Empathy Toward Robots, Technologies and Objects

The construct of empathy in reality is challenged significantly if we change the object of the empathy. Let us try to see what happens to this construct in the various cases we considered. Rather than the simple simulation mechanisms we found between humans, the empathy of humans toward robots, animals and objects is based on a double mechanism of simulation, in the sense that we have to simulate also that the other entity has something in common with humans, a sort of humanization process.

Empathy toward robots. The key point from which to start is the simulation. The Simulation Theory is a well-established theory in psychology that states that we understand others' minds through simulating [20]. What happens, however, when we are led to simulate a simulator such as with the case of the robot? Traditionally, the automata embodied the attempt to pose a robot as a human being. This was the main reason for the hostility expressed toward robots by the Catholic Church, which was attributed to "the magic halo that surrounded them and that derived from the delay with which the public understood the truth of the artifact" [21]. This simulation increases considerably in the case of androids or gynoids and in general with anthropomorphic robots. However, it reaches its apex with the Turing test used to evaluate if an artificial intelligence is effectively able to posit itself as a human being [22]. What is the acceptable measure of the simulation of a simulator? The theory of the uncanny valley [23–25]. Suggests that the more a robot is human-like, the more we become familiar with it, until its similarity reaches too high a degree, at which we feel a sense of unease. From this, we expect to derive the conclusion that for humans it is easier to simulate the simulator's actions or feelings when the quality of the simulation generated by the simulator is sufficiently poor that it enables us to understand immediately that the simulator simulates its actions or feelings. This topic is precisely what the present study is about.

Empathy toward animals. O'Connell [26] puts it simply that empathy is "the capacity to experience the feelings of another person or an animal, cognitively or emotionally". However, if we posit that the construct of empathy requires the understanding and simulation of the feelings of the others, even only imagining the feelings of animals appears very difficult. Perhaps this is the reason for which, as Angantyr et al. [27] point out, a substantial body of research exists on inter-human empathy and inter-animal empathy, but a shortage of research exists on the comparison between the empathic reactions of humans to humans and that of humans to animals. For example, Paul's [28] survey (N = 514 adults) on measuring empathy with humans and with animals revealed that these two forms of empathy were modestly correlated, indicating that they are unlikely to tap a single, unitary construct. Animal-oriented empathy was associated to the current ownership of pets and to their ownership during childhood, while human-oriented empathy was related to having a child or children at home.

Angantyr et al. [27] conducted their own experiments on this issue, and obtained the following results: in experiment (1) women showed significantly more empathy with animals than with humans, whereas men expressed the opposite. In experiment

(2) adult women expressed the same degree of empathy with a child as with a puppy, and in experiment (3) adult men and women expressed the same degree of empathy with a baby as with a puppy. These experiments are interesting because they not only reveal gender differences regarding empathy toward humans and animals (although the literature shows contradictory results in this concern) but they also introduce in the setting a puppy which elicits the same degree of empathy as a baby.

Empathy toward technologies and objects. In addition to the above mentioned research, Misselhorn [29] addressed directly the topic of empathy with inanimate objects and concluded that with objects we feel a form of empathy involving a kind of imaginative perception. Crozier and Greenhalgh [30] proposed a model which draws upon the principle of empathy to explain properly the complexity of the aesthetic experience. It might be surprising to discover that the word "empathy" was first used by Titchner [31] to indicate the process of "humanizing objects, reading or feeling ourselves into them". This process is related to the irrepressible human need to reduce the distance between individuals and the world that surrounds them, to reduce uncertainty. We can say, Phillipps [32] argues, that the empathic theory was developed "with nineteenth century German aesthetes, who believed that humans can derive feelings from objects, particularly architectural or natural for which they used the word *Einfühlung,* or 'feeling into'".

4 Methods

4.1 Paticipants

We recruited participants by presenting the experiment during lectures at the University of Udine (Italy). A total of 163 students participated in this study: 95 of them were male, 67 were female, and 1 did not specify the gender. Their mean ± standard deviation age was 20.09 ± 2.28 years old, and they came from three different study courses: Laboratory of Social Robotics in the graduate program in Multimedia Communication and Technologies of Information, Economic Sociology in the undergraduate program of Social work, and Psychology of Communication in the undergraduate program on Web and Multimedia Technologies.

4.2 Stimuli

We prepared seven short (2 s long) videoclips in which a human pushed, thrust or threw a "passive" social actor (PSA). While all the interactions were only slightly violent, all of them were obviously negative. Our rationale was to show different PSAs being victims of a negative interaction in order to make participants feel empathic with them. By varying the nature of the PSA, we manipulated our main independent variable (i.e., the social distance between the human observers and the social actors with which they had to empathize). The PSAs and the interactions of which they were victims were a human being pushed; an anthropomorphic robot with the bipedal human structure ("Atlas", Boston Dynamics) being pushed with a pole; a cat being pushed with a foot; a four-legged robot resembling the structure of a mammal ("Spot", Boston Dynamics) being pushed with a foot; a robot half-way between the Roomba and the Mars Rover being pushed with a foot; a Rubik cube being thrust with a foot; and a smart phone being thrown by a hand on a bed. The humans performing the actions were fully visible only in the human and anthropomorphic robot video clips, while in the other videoclips only the interesting body part was shown.

We hypothesized two axes of social distance: the first is the living-nonliving: humans and cat on one pole, the Rubik cube on the other, and robots somewhere in the middle. The second axis is the human-animal (humans on one pole, cat on the other, and the remaining objects positioned in-between).

4.3 Procedure

To assess the participants' basic levels of empathy, each participant was first required to complete the Empathy Quotient scale (EQ [33]). Participants were then exposed to the seven videoclips. The videoclips were present ed sequentially in three university classrooms, projected on a screen. The presentation order of the videoclips was randomized and resulted in three different orders.[1] After each videoclip, the participants were requested to complete two self-evaluation tasks.

The first task aimed to evaluate how much participants felt sorry for the PSA ("How sorry do you feel for the object or person that was a victim of the action?") on a six-point Likert scale. The second task aimed at self-assessment of emotions felt by the participants ("While watching this videoclip I feel:") and attributed to the PSA ("While watching this videoclip I imagine that the object or person feels:"). We used the Self-Assessment Manikin (SEM [34]), which is a nine-point visual scale for measuring emotional valence (from unhappy to happy), arousal (from relaxed to activated) and dominance (from lack of control to fully in control).

In addition to basic socio-demographic variables (sex and age) and the type of program in which students were enrolled, the questionnaire contained items investigating the ownership of a smartphone or a cat; being familiar with several types of "robots" such as Siri, Cortana, etc.; and having tried to solve a Rubik cube. The questionnaire also investigated the use of the smartphone and several robots such as Roomba, Bimby, a robotic arm and a robotic mower. Finally, a free association exercise was given on the smartphone, and a question investigated on a five-point

[1] The first sequence of videoclips had the following order: mammal robot, Rubik cube, anthropomorphic robot, mechanical robot, cat, smartphone, and human. The second sequence of videoclips had this order: anthropomorphic robot, mammal robot, mechanical robot, Rubik cube, human, smartphone, and cat. The third sequence had the following order: mechanical robot, anthropomorphic robot, human, smartphone, cat, Rubik cube, and mammal robot.

scale the emotional attachment to the smartphone and the Rubik cube. For space reasons, data pertaining to this last section of the questionnaire and to the feelings attributed to the PSA are not reported in this paper.

4.4 Data Handling

Among the EQ scores, only the "cognitive empathy" subscale (items 1, 19, 22, 25, 26, 36, 41, 43, 44,52, 54, 55, 58 and 60) turned out to be reliable (alpha > 0.70). The subjects with a score inferior to the median (< 16) were classified as having a low empathy level, while those with a score equal or superior to it ($\geq$ 16) were classified as having a high empathy level.

The values of valence, arousal and dominance of emotions (i.e., the SEM scales) were entered as dependent variables into a $7 \times 3 \times 2$ repeated-measures ANOVA. PSA (human vs. anthropomorphic robot vs. animal vs. mammal robot vs. mechanical robot vs. Rubik cube vs. smartphone) were variables within subjects; videoclip order (order 1 vs. order 2 vs. order 3) and empathy level (high vs. low) were variables between subjects.

Data were analyzed using the StatSoft Statistica10 package (Statistica, 2300 East 14th Street, Tulsa, Oklahoma, 74,104). Post hoc multiple, pair-wise comparisons were performed using the Bonferroni test. A significance threshold of $p < 0.05$ was set for all statistical analyses.

5 Results

Feeling sorry

Analysis of the answers to the "How sorry do you feel for the object or person that was a victim of the action?" question revealed both a main effect of the PSA (F(6936) = 79.88, $p < 0.001$) and its interaction with the videoclip order (F(12,936) = 2.65, $p = 0.002$). Post hoc comparisons identified (all ps < 0.01) a first cluster composed of non-living elements—mechanical robot (1.37 $\pm$ 0.08), the Rubik cube (1.42 $\pm$ 0.12) and the smartphone (1.38 $\pm$ 0.09)—which elicited lower levels of empathy than a second cluster including humans, anthropomorphic and zoomorphic elements—the human (2.67 $\pm$ 0.13), anthropomorphic robot (2.26 $\pm$ 0.14) and the mammal robot (2.42 $\pm$ 0.14). Within each cluster, the levels of empathy elicited by the PSAs did not differentiate. The videoclip with the cat yielded the highest result (4.12 $\pm$ 0.17; all comparisons' $p < 0.001$). Figure 1a shows the responses to the "How sorry do you feel for the object or person that was a victim of the action?" question for each PSA.

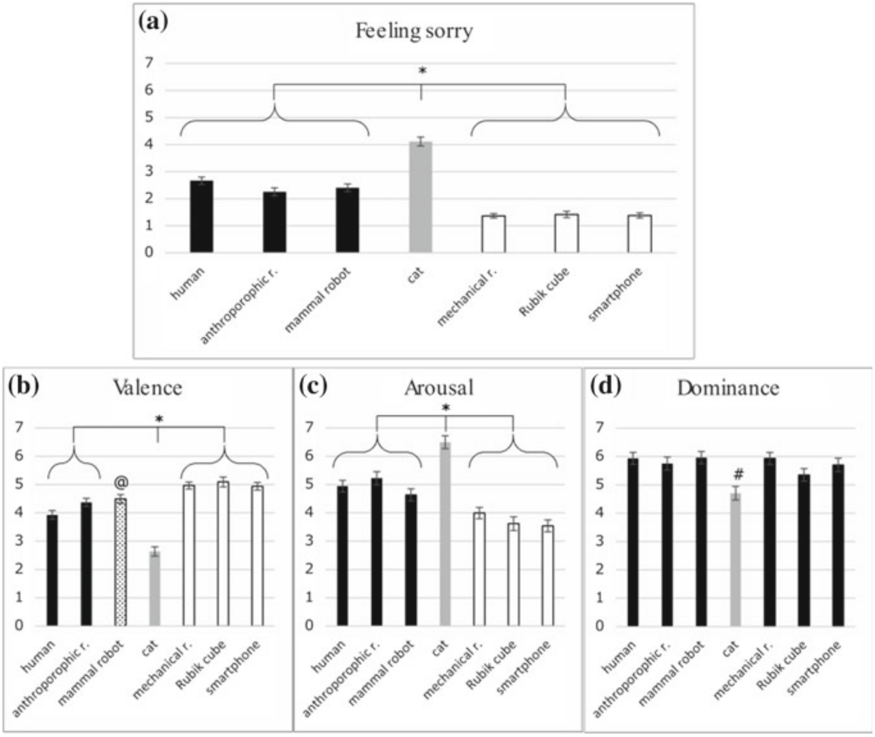

Fig. 1 All comparisons marked with * are significant with $p < 0.05$. **a** "Feeling sorry" responses for all PSAs. Bars of the same color denote nonsignificant differences. **b**, **c**, **d** SEM scale responses for all PSAs. Bars of the same color denote nonsignificant differences within each graph. @: The mammal robot videoclip only differs from the cat ($p < 0.001$) and the Rubik cube videoclip ($p < 0.01$) in valence. #: The cat videoclip differs from all other videoclips ($p < 0.001$). In dominance

The videoclip order did not affect the general pattern. A slightly higher variance in reactions was observed only for the group that used the third order, which started from the mechanical robot, and which shows a significant difference only for the evaluation of the cat videoclip.

Self assessment of emotions—subjective feelings

Analysis of the SEM evaluations to the "While watching this videoclip I feel:" question was performed over 160 subjects after case-deleting for missing data. The ANOVA revealed a simple effect of both between-subjects variables: i.e., empathy level ($F(1154) = 5.51, p = 0.02$) and videoclip order ($F(1154) = 11.83, p < 0.001$). The main effect of empathy level showed an answering pattern with generally higher values (5.03 ± 0.09) for participants with low empathy levels than for participants with high empathy levels (4.71 ± 0.1; $p = 0.008$). The interaction between empathy level and other variables did not reach significance (all ps > 0.472). In other terms, the more participants are empathic, the more they feel sad and out of control when looking at the videoclips. Despite the between-group differences due to videoclip order (see the section regarding the limits of this study), the ANOVA showed a full within-subjects significant interaction between PSAs and SEM scale ($F(12,1848) = 38.208$, $p < 0.001$).

Looking at the valence (from sad to happy), post hoc comparisons showed again that the feelings activated by PSA can be grouped in three clusters. The cat videoclip yielded the lowest scores (2.63 ± 0.16; all *p*s < 0.001), meaning that our participants felt extremely sad when looking at the cat being mistreated. A second cluster groups the valence scores of the human (3.93 ± 0.15) and anthropomorphic robot videoclips (4.37 ± 0.15), which are just below the neutral point of the scale and activated a moderate level of sadness. The third cluster groups the valence scores of the smartphone (4.94 ± 0.14), mechanical robot (4.97 ± 0.12), and Rubik cube videoclips (5.09 ± 0.17), which suggests a lack of negative feelings activated by these videoclips. Finally, the mammal robot (4.49 ± 0.16) is positioned between the second and the third cluster; the valence of emotions activated by this videoclip was significantly different only from the cat videoclip ($p < 0.001$) and the Rubik cube videoclip ($p < 0.01$).

A similar pattern emerged from the analysis of the arousal (from relaxed to activated) scale. The cat videoclip (6.5 ± 0.23) significantly differed from the other PSAs (all *p*s < 0.001), having yielded higher arousal than other videoclips. The human videoclip (4.94 ± 0.21), anthropomorphic robot videoclip (5.22 ± 0.23) and mammal robot videoclip (4.64 ± 0.22) constitute a second cluster. They activated relatively high levels of arousal. Again, the smartphone (3.54 ± 0.21), Rubik cube (3.62 ± 0.24) and mechanical robot (3.99 ± 0.2) are grouped into a third cluster, which is an object-like group. These videoclips activated lower levels of arousal.

The Post hoc comparisons for the dominance scale (from lack of control to fully in control) only showed lower scores for the cat videoclip (4.7 ± 0.24) compared to all the other videoclips (all *p*s < 0.001).

Figure 1b, c and d show the responses to each SEM scale for all PSAs. Table 1 shows means and standard deviations for each SEM scale for all PSAs.

Table 1 SEM values for each videoclip

	Valence		Arousal		Dominance	
	Mean	s.d.	Mean	s.d.	Mean	s.d.
Human	3.93	0.15	4.94	0.21	5.93	0.21
Anthropomorphic robot	4.37	0.15	5.22	0.23	5.75	0.23
Mammal robot	4.49	0.16	4.64	0.22	5.96	0.22
Cat	2.63	0.16	6.50	0.23	4.70	0.24
Mechanical robot	4.97	0.12	3.99	0.20	5.93	0.21
Rubik cube	5.09	0.17	3.62	0.24	5.35	0.22
Smartphone	4.94	0.14	3.54	0.21	5.70	0.24

6 Discussion and Final Remarks

In our study we showed different social actors, including human, cat, an anthropomorphic robot with bipedal human structure ("Atlas", Boston Dynamics), a four legged robot resembling the structure of a mammal, a robot half-way between the Roomba and the Mars Rover, a smartphone and a Rubik cube, being mistreated and measured the evoked emotions in human observers by means of a self-report questionnaire. It must be considered that our study was set beyond the uncanny valley [22–24]—that is, the area in which robots resemble humans so much that they might be confused with them. Studies have shown that likeability of android robots in this area does not follow a linear trend, but drops. Indeed, we only used stimuli that are obviously non-human. As such, this choice is particularly interesting when seen in light of the "threat to distinctiveness hypothesis" [35], which states that robots are more likely to be accepted if the distinctiveness between them and humans is preserved.

The results showed that participants clustered the selected social actors on the basis of their similarity with living things (i.e., their perceived social distance). This study confirms the work of Riek et al. [2] which showed that empathy is modulated by perceived social distance in androids, and extends the results further to non-android robots and objects. Our results also preliminarily question the findings by Gray et al. [1], who found a neat distance between robots, on the one hand, and humans and pets, on the other, on the dimension of experience (that is, the capacity of feeling pain, rage, hunger, etc.). Indeed, we found that participants empathized more (i.e. more negative valence, more arousal, less dominance, more feeling sorry for) with mistreated humanoids than with mistreated object-like actors. Moreover, we found that participants felt more empathy with the cat than with all the other actors, even more than humans.

By looking at appearance alone, the mammal robot was included among the stimuli to explore perceived social distance for both axes, human-animal and living nonliving. If the axes were completely orthogonal, our results would have suggested that the mammal robot would be positioned in the middle of living-nonliving axis, and on the animal side of the human-animal axis, but in terms of empathy it scored lower than both poles of this second axis. As such, we might infer that empathy is modulated only by social distance on the living-nonliving axis. However, this interpretation presents some problems: if we used another animal, let's say a rat, hippo, hyena or triceratops, would the results be the same? Maybe the perceived social distance was not modulated by cats, because they are perceived more like pets than animals in general, but this speculation needs to be tested. This result, however, is in line with other studies showing at least as much empathy with animals than with humans; an example is [26]. An interpretation of this particularly intense empathy with animals needs to be proposed here. We suggest consideration of at least two elements: the first is that people are aware that animals are more vulnerable than humans; the second is that animals are able of an unconditional love for humans or, as Philipps [32] posits, "the possibility of reciprocal altruism cannot be dismissed". If this was correct, another layer of analysis would be needed: indeed, in no videoclip did we show a reason for being responsible for mistreatment for any "passive" social actor (PSA), but the cat videoclip elicited completely different responses than other videoclips, nonetheless. Such interpretation requires us accepting a mental state of the animals (shown also in our study) that may add to the "responsibility" layer, both of which may interact with social distance. As such, further studies on this topic are required.

This study has other limits. First, the experiment was run during university classes, whereby the videoclip order was the same for large groups of participants. In fact, we notice answering patterns depending upon the videoclip order (interacting separately with the PSA and SEM scale variables), impacting both the general way in which participants responded to each videoclip and how they "set the standard" for each SEM scale. These results have no clear meaning to us and require further analysis. However, even if we used the strictest post hoc correction (Bonferroni), a number of within-subject results still survive the correction. Thus, a null hypothesis is difficult to accept. A follow-up study would need to use single-participant presentation and a fully randomized videoclip order to overcome this problem that renders the interpretation of the results slightly more difficult. Second, further studies could use longer videoclips in order to elicit a proper empathic answer from the participants. Moreover, the videoclips were balanced on a number of dimensions (number of actors per videoclip, duration, etc.), but the depicted action was not totally balanced; perhaps this was the source of some of the variance we found. Finally, an additional control condition for animals instead of, or in addition to, the cat videoclip would have prevented the interpretation problems experienced with the animal/pet dilemma.

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Human-Robot Cooperation via Brain Computer Interface in Assistive Scenario

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Abstract In the last years, the development of robots for assisting and collaborating with people has experienced a large growth. Applications for assistive robots include hospital service robots, factory intelligent assistants and personal homecare robots. Working in shared environments with human beings, these robots require effective ways to achieve an increasing human-robot cooperation. This work presents a possible approach for performing human-robot cooperation, namely recognition of a user selected object by means of Brain Computer Interface (BCI), followed by pick and place via a robotic arm. The object selection is achieved introducing a BCI that allows the user, after a training phase, to choose one among six different objects of common diffusion. The selection is achieved by interpreting the P300 signals generated in the brain, when the image of the object, desidered by the user, appears on a computer screen as a visual stimulus. The robot then recognizes, through a classifier, the selected object among others within its workspace, and inscribes it in a rectangle shape. Finally, the robot arm is moved in correspondence to the object position,

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the gripper is rotated according to the object orientation and the object grasped and moved into a different position on a desk in front of the robot. This system could support people with limited motor skills or paralysis, playing an important role in structured assistive environments in a near future.

1 Introduction

Ambient Assisted Living (AAL) is typically classified according to the targeted functional domain, and might include home and building automation systems [1], monitoring platforms [2], medical devices [3], assistive robots [4] and many other solutions [5, 6]. Among them, there is a great interest in developing robotic assistants to help and support disabled people performing different tasks [7] and allowing them to extend the permanence at home, without the help of a caregiver or moving to health care centers. Several previous robotic systems demonstrate that patients may carry out useful tasks using a robotic assistant. Robotic assistance for disabled users, and even for elderly people, is an application scenario with a great potential: from the simple interaction, through the achievement of a goal as taking an object [8, 9], to a more complex collaboration realizing a task together [10] or deciding to participate in a motor task on the basis of the successful possibilities [11].

In the literature, different works have investigated the human-robot cooperation in order to realize simple motor tasks. In [8], the goal of handing an object has been raised by cooperating with the Domo robot, realizing a contact detection with the object and a control of the hand velocity by implementing a Support Vector Regression (SVR) with a Gaussian Radial Basis Function (RBF) kernel; stiffness adaptation also contributed to improve the grasping power, and it was possible to estimate the dimensions of the object from the joint angles of the robot hand fingers. In [9], a human-robot cooperation method is developed between the human control and the robot autonomy. The human achieves the task of directing the robot arm to nearby objects on a table and the robot detects the objects, adjusts the position of the gripper and grasp them. In [10], the authors investigated the goal-directed cooperative object swinging through an energy based control concept, which permitted a robot to cooperate with a human in a goal-directed swing-up task. The robot played the role of a leader or an acting contributing follower. The presented control concept is also shown to enable a following robot to actively contribute to the task even without knowing the human's desired energy level. In [11], the dynamic collaboration between a human and a robot was realised, introducing the confidence of the task as a criterion for robots intervention during an arrangement object task. The humanoid robot Hiro participated in the task when the confidence level was high. This information was obtained using a Multiple Time-scales Recurrent Neural Network (MTRNN).

Another important aspect for the human-robot interaction is related to how these two actors communicate between themselves. This usually can happen through commands based on speech (e.g., voice) [12], gesture recognition [13] or a combination of them [14]. Depending on the severity of the user's disability, different modes of interaction and control of the robot can be considered, for instance, via a joystick, via head- or eye-tracking, or via Brain Computer Interface (BCI) [15]. Some works as in [16, 17] introduce hybrid solutions to control robot arms or medical robotics in which BCIs are supported by other kind of recorded signals or technologies in order to perform motor tasks. In particular, BCIs are devices which translate the brain activity of the user into specific signals, which may be used for communicating or controlling external devices [18, 19] without the use of peripheral nerves and muscles. BCIs represent an interesting option for people affected by neuromuscolar disorders, but whose brain activity is normal, such as in patients affected by Amyotrophic Lateral Sclerosis (ALS). In [20], a human-robot interaction based on ElectroEncephaloGraphy (EEG)-BCI for patients affected by locked-in syndromes caused by ALS has been investigated. The brain signals (P300) are processed to extract features used as input to control the NAO robot in order to perform actions as recognise, locate and return an object to the user. Accordingly and with the same goal, authors in [21] present a study to navigate a humanoid robot towards the user in order to physically interact with her/him. In [22], a similar approach was investigated by authors. A computer screen contains all the feedback information for the subject to operate the robot. The BCI system records and analises the EEG signals and recognises the command which the subject expected. The command is then sent to the NAO robot to execute the corresponding movement.

In the literature three different types of stimuli are commonly adopted to drive a BCI: visual stimuli, tactile stimuli and auditory stimuli. For this, where the BCI is connected to a robot, it is possible to realize different applications. In [23], authors investigated a BCI framework, based on a low cost EEG device, the Emotiv EPOC headset, driven completely by four thoughts patterns tested on a problem of controlling a wheeled robot. In [24], the application of EEG-measured Error-related Potentials (ErrPs) has been studied to closed-loop robotic control. These potentials are particularly useful for robotics tasks because they are naturally occurring within the brain in response to an unexpected error. The ErrP signals from a human operator were decoded in real time for controlling a Rethink Robotic Baxter robot during a binary object selection task. In [25], a human-robot cooperative approach to reliable planning and execution is presented. This system consists of three components: human user, wheelchair robot and the noninvasive brain-computer interface which can represent limit types of user's intention patterns based on EEG signals. A BCI controlled autonomous robotic assistant for liquid intake has been described in [7]. The system includes autonomous online detection both of the cup and of the mouth. A technique for online estimation of the location of the user's mouth, even under partial vision occlusion has been investigated in order to respect the constraints that the cup stays upright while moving towards the mouth, and in direct contact with it during the drinking phase.

The approach proposed in this work aims at presenting a preliminary study about human-robot cooperation with a Baxter Research Robot [26], in order to realize a motor task: pick and place of an object via a brain computer interface. This study has requested the use of the Robot Operating System (ROS) environment in order to allow the communication between the BCI system and the Baxter robot and the development and implementation of all the algorithms related to the robot itself. The goal is achieved through different consecutive steps: firstly, the user has to focus his/her attention on one among six different common used objects, selected also on the base of their shape suitable for the grasping of the available robot gripper. This phase is necessary to train both the user and the BCI classifier in order to analise the EEG signals produced by the visio-stimuli of the objects, highlighted on a monitor of the computer dedicated to the BCI system. Once the desired object is detected, this PC communicates, via ROS node, the selected object to the computer connected to the Baxter where a feature extraction and recognition algorithm analyses the picture of the robot workspace captured by the arm camera. The algorithm identifies the user selected object through the HAAR cascade classifier [27], matching the features extracted for each object to those previously extracted during a training phase. The idea consists of inscribing the borders of the selected object into a rectangle and rotate the arm gripper to find the right side to grasp the object. The robot arm pose to grasp the selected object is successively calculated and fed to the robotic arm. Finally, the object is picked by the robotic hand and placed into another place within the robot workspace, thus simulating a possible assistive scenario.

This work is organised as follows: the used methods for each single steps are presented in Sect. 2. The experimental trial are described in Sect. 3, and the obtained results are presented in Sect. 4. The paper ends with the conclusions presented in Sect. 5.

2 Methods

The approach proposed in this work is structured into different steps, from the BCI selection of the object, its recognition, to the pick and place by the Baxter robot arm. Two computers have been used for this approach, one dedicated to the BCI system and another one for the Baxter robot. Each step is described as follows and summarized in Fig. 1:

- *Object Selection*: realized by using BCI. The subject wears the BCI device with 8 selected electrodes to record the electroencephalographic signals (*Raw EEG extraction*), and he/she is asked to point his/her attention on the highlighting object picture of the desidered target object (*visual stimulus*) on the pc monitor, after a training phase. Once the object is selected by the *BCI classifier*, it is communicated to the Baxter system via a ROS node.
- *Object Recognition*: obtained via the *HAAR classifier* which is trained to recognize each object among six of common use on the table. The *image elaboration* is performed by a features extraction and creating a classifier related to each object. The recognition phase ends inscribing the object inside a blue rectangle that contains the object borders.
- *Robot Motion Planning*: performed by grasping the recognized object, after an *object pose estimation* and moving it from its original position to an external point

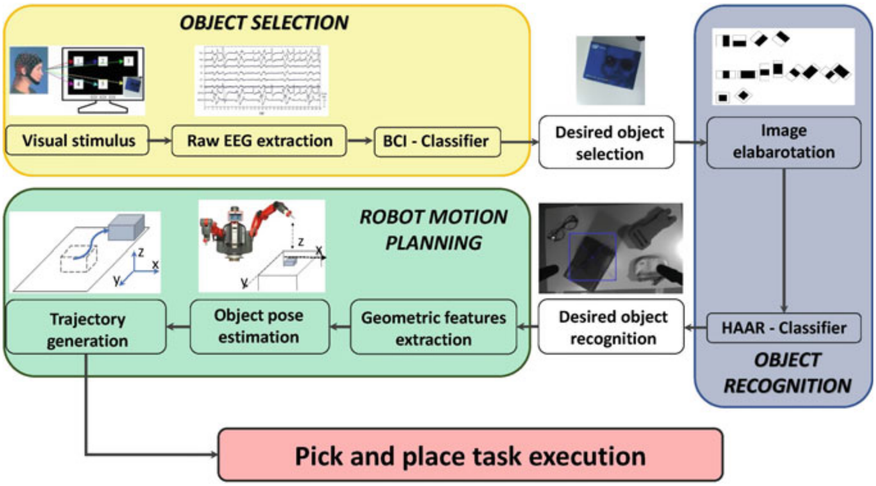

Fig. 1 Scheme of the three differents steps involved to realize all the tasks of pick and place via BCI

(*trajectory generation*) with respect to the image coordination system (namely pick and place). The gripper is also rotated respect to its original position on the base of the orientation angle calculated for the object in the extracted image (*geometric feature extraction*).

2.1 Object Selection

The emergence of non-invasive EEG and its applicability to human-robot collaboration tasks has concerned much research over the past decade. For example, EEG signals have been used with motor imagery tasks to control robots such as a wheelchair or a robotic arm [28–30]. While this certainly showcases the promise of using EEG for robot applications, typical approaches often require several training phases, based on task proficiency and for the human operator to learn how to appropriately modulate thoughts. The most common tasks, for EEG-based control, use signals produced in response to stimuli (usually visual ones). These include the P300 signal, in conventional grids or during Rapid Serial Visual Presentation (RSVP), and the Steady State Visually-Evoked Potentials (SSVEP) [31, 32].

The P300 RSVP is used in our approach [18]. The EEG was monopolary recorded using an electrode cap with 8 active high-purity gold (Au) electrodes (g.tec medical engineering GmbH) following the American Electroencephalographic Society modified version of the 10-20 system [33]. These are located at positions Fz, Cz, Po7, P3, Pz, P4, Po8 and Oz, as shown in Fig. 2. Channels are referenced to the left earlobe and grounded to the left mastoid.

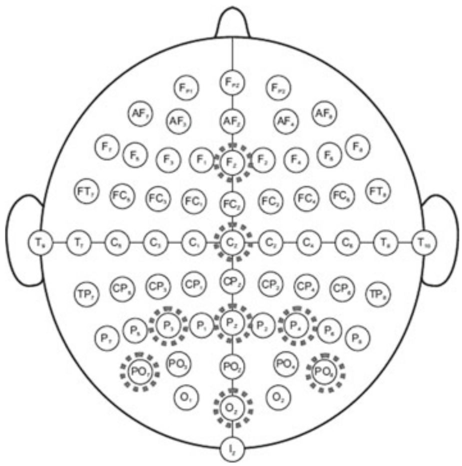

Fig. 2 Electrodes set configuration on the cap for data recording and analysis. The electrodes used for the acquisitions, namely Fz, Cz, Po7, P3, Pz, P4, Po8 and Oz, are highlighted

Signals were acquired and amplified using a g.MobiLab+ (g.tec medical engineering GmbH, Germany). Data collection and stimulus presentation were controlled by the BCI2000 software package [34]. The data have been filtered applying a Notch Filter at 50 Hz, a high pass filter at 1 Hz and a low pass filter at 30 Hz, Fig. 3a. The duration of each stimulus, namely the time each object image is highlighted, is set to 150 ms, and the number of subsequent sequences of highlighting objects is 60 as it is possible to see in Fig. 3b.

The BCI, together with the BCI2000 software package implementing the P300 RSVP, permits to identify the object focused by the user, among a choice of six different objects, provided that a training phase is successfully performed. Prior to recording data, participants were asked to minimize eye movements and muscle contractions during the experiment. Objects were chosen among daily life objects namely: glasses, a book, an orange, a banana, a box and a small pocket, as shown in Fig. 4. Each participant was equipped with the electrode cap and was requested

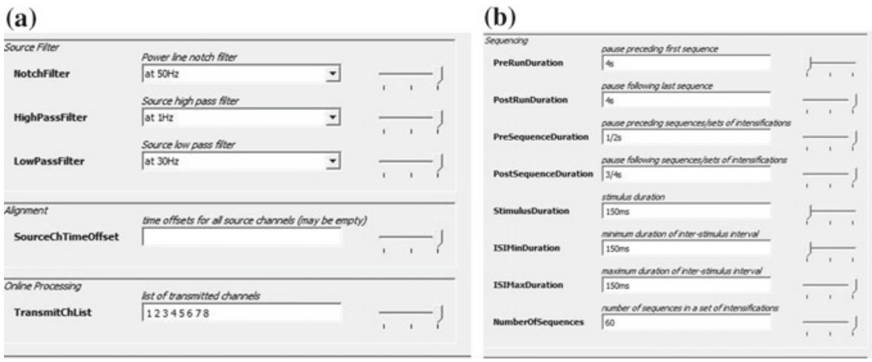

Fig. 3 Parameters configuration of the BCI system

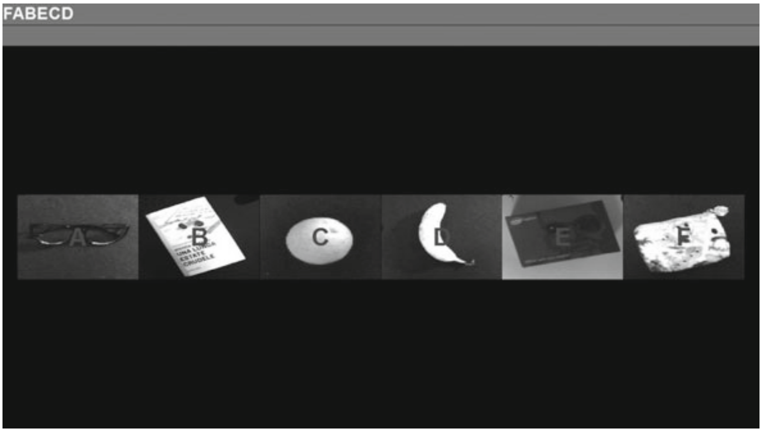

Fig. 4 Stimuli presentation with the object pictures randomly highlighted

to mentally count each time the target object was lighted up in a random sequence. This request was done in order to emphasize the focus attention. Each run contains one target object and five other objects (see Fig. 4), the same objects are placed on a table under the Baxter robot arm camera. During the training phase, a letter was associated to each object, to suggest which one focusing the attention on. Each run was repeated 60 times for a total of 360 stimuli, of which 60 were target stimuli and 300 not target stimuli. The target stimulus related to the desired object was randomly highlighted among the non target ones. The subject was exposed to three sections of training before tests.

2.2 Object Recognition

For the object recognition phase, the Baxter Research Robot is equipped with two colour cameras with an effective resolution of 640 $\times$ 400 pixels, located on each arm, namely "$left\_hand\_camera$" and "$right\_hand\_camera$" (Fig. 5a). The goal of this stage is to recognize via the gripper camera, one among the six objects already introduced in Sect. 2.1, which are physically placed in the robot workspace, on a desk 40 cm under the robot arm camera (Fig. 5b). Once the BCI user-selected object is recognized from the image captured by the Baxter camera, the object image is inscribed within a rectangle whose center point falls within the object image itself.

In order to realize this goal, it is important to create a XML model file for the OpenCV Cascade Classifier algorithm, which will be used to detect the objects. The model creation process involves a large amount of positive and negative images, which do not contain the desired objects at all.

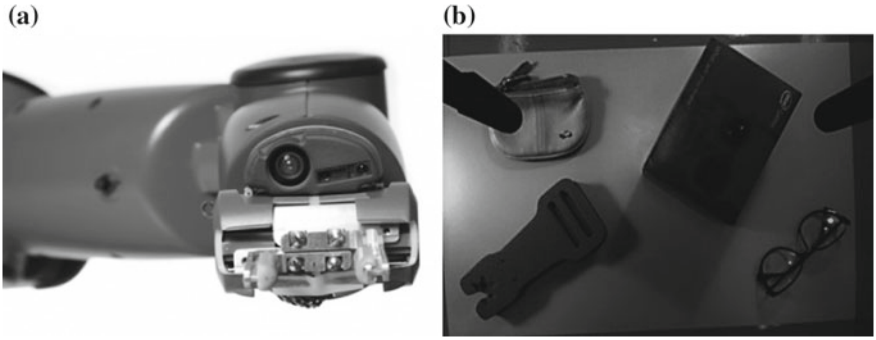

Fig. 5 In (**a**) position of the RGB camera under the left arm, and in (**b**) image of different objects taken by the $left\_hand\_camera$

HAAR-like features introduced by [35, 36] and used for this study, are the input for the Cascade Classifier. A variant of AdaBoost [37] is used to select a small set of features and train the classifier. The HAAR-like Cascade Classifier is composed by a cascade of classifiers which achieves increased detection performance while reducing the computation time. It is a powerful machine learning algorithm which can learn a strong classifier based on a large set of weak classifiers by re-weighting the training samples. The 14 feature prototypes include 4 edge features, 8 line features and 2 centre-surround features. Covering the difference scales and locations of the feature areas, several calculations are realized in order to generate a rich, over-complete set of features. For each object, 200 images have been overall taken in 6 different positions (about 30 for each position). After cropping and resizing (75 $\times$ 75 pixels), the original images have been converted to gray-scale and resized, editing them by different transformations to get more positive images, for a total of approximately 2000 positive images. The transformations realized for each image are related to:

- rotation of 90°, 180° and 270°;
- flip in horizontal/vertical and horizontal+vertical directions;
- smoothing bilateral filter/blur and blur median;
- brightness minus/plus.

For the negative images, two different approaches have been used: in the first training the classifier was obtained with a pool of all the other object images without the desired object to be detected. In the second training of the classifier, a random amount of totally different images have been used, related to people and sports images. After generating the descriptor file for the negative images, the training dataset has been prepared, to produce a set of positive samples. Once the preparation of the data was complete, the training of the HAAR Cascade Classifier was realized generating the XML model file. The object is detected and recognized by drawing a blue rectangle around the object. Also the center of the rectangle was calculated as reference point for the straight line useful for the orientation estimation of the object as described in Sect. 2.3.

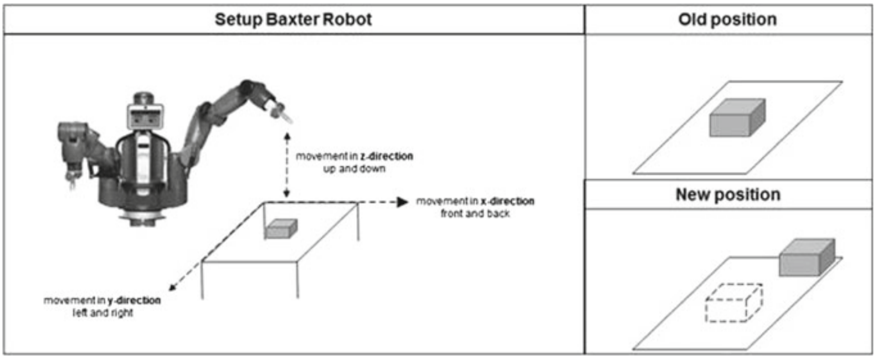

Fig. 6 Description of the pick and place realized by Baxter Robot with the old and new position of the box

2.3 Robot Motion Planning

To complete the motor task of taking the desired object, the movement of the Baxter arm for picking the object and placing it to a different position was studied and controlled applying the Inverse-Kinematics (IK) Pick and Place. This method combines a simulated IK service to obtain the joint angle solutions for a given cartesian orientation endpoint, with a controlled position movement and followed by a grasping and release of the object. The Visual Servoing was used to convert the image pixel to workspace Baxter coordinates. This has been realized by knowing the pose of the Baxter arm, its height from the table where the object is located, the camera calibration factor and using the following formula:

$$B = (Ip - Cp) \times cc \times d + Bp + Go \quad (1)$$

where B is the Baxter point in x or y direction, Ip is the image pixel, the center in x direction and y direction, Cp is the centre image pixel: half the height (x direction) or width (y direction), cc is the camera calibration factor (0.0029), d is the distance from the table (0.30m), Bp is the Baxter point in pixels coordination and Go is the gripper offset. It is important to note that the calculation in the x-direction is for the front/back movement of the Baxter arm and the calculation for the y-direction for the left/right movement of the Baxter arm. The setup of the Baxter Robot Pick and Place experiment together with the old and new position related to the box detection, can be seen in Fig. 6.

This formula can be directly applied if the starting position of the gripper is inbuilt with the object orientation. Otherwise, in order to correctly grab the selected object it is necessary to know the orientation of the object with respect to the camera arm and the Baxter coordinates.

To realize this step, the position angle of the object respect to the Baxter camera has been extracted from the acquired image calculating the orientation angle of the object, expressed in radiant. Summarizing, the obtained orientation is the result of a cascade of different transformations where the calculated angle in radiant in the camera coordinates has been added to the orientation of the gripper respect to the Baxter coordinates expressed in quaternions. The angle is obtained in order to align the gripper with the short size of the rectangular that inscribes the object. The angle transformation sequence is following reported:

- transformation of the gripper initial rotation from quaternions to Euler angles;
- sum of the gripper rotation and object orientation;
- transformation of the obtained rotation from Euler angles to quaternions.

In this way, the final rotation to apply to the gripper has been obtained in order to grab the selected object. Finally, the Baxter arm is brought back to its initial position.

3 Experimental Trial

The experiment was realised in the robotics laboratory of Università Politecnica delle Marche (Ancona, Italy) with a subject (male, age 31) enrolled for the study. With reference to Fig. 7, the single steps of the experiment can be described as follows:

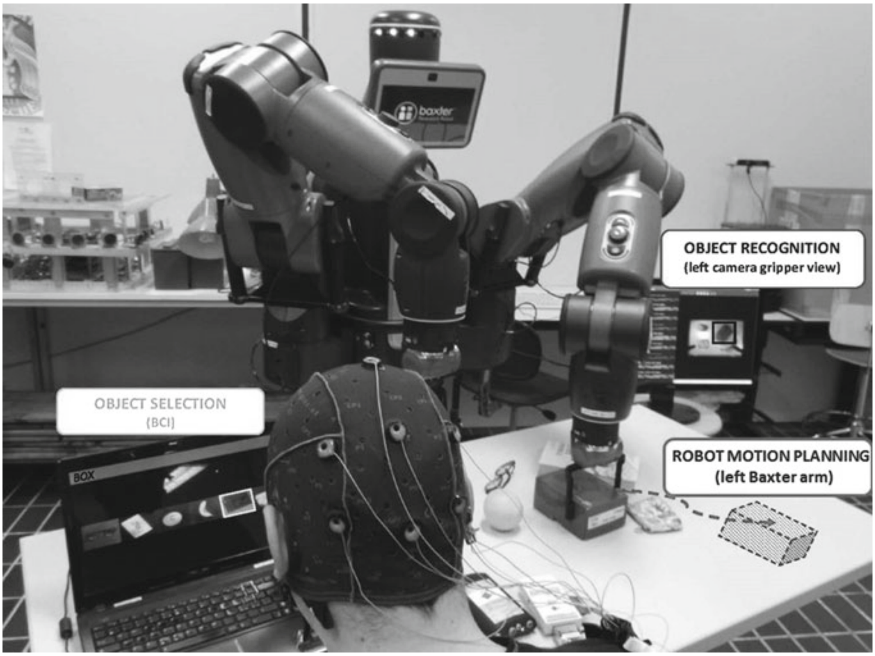

Fig. 7 Experiment conducted in laboratory with a subject

- *Object Selection (via BCI)*
  The participant to the experiment sat in front of a PC monitor wearing the electrode cup, connected to the BCI system, and he was asked to focus his attention when the desired object, among the 6 proposed, was highlighted, counting in his minds each time he saw the object well-lighted. After a training phase with the BCI device, realized for the subject and necessary not only for the data analysis, but also to facilitate the confidence of the person with the requested task, the testing phase for the object selection was performed. After three consecutive choices of the same object, that object was confirmed as the desired one.
- *Object Recognition (via left gripper camera)*
  The name of the chosen object was then sent to the object recognition algorithm and read through a ROS node. The classifier associated to the object to find analysed the image provided by the $left\_hand\_camera$, of the Baxter robot, which is located behind the $left\_gripper$ with a top view over the objects placed on the table. Once the recognition of the object was performed (HAAR-like Cascade Classifier), a blue rectangle was drawn around the detected object, and its center point was used as reference point to raise for the position. Then the object angle orientation, with respect to the image coordinates of the acquired picture, was calculated in order to turn the gripper in the best way to take the object and realise the grasping.
- *Robot Motion Planning (left Baxter arm)*
  After the center point definition, the transformation from the pixel image coordinates to the Baxter coordination system was realized, and the $left\_hand\_gripper$ placed on the calculated point. At the same time, the value of the orientation angle of the object respect to the acquired image was obtained through different transformations from Euler angles to quaternions. Once the gripper was placed on the selected object, an infrared sensor, near the camera, measured the distance to cover from the object in order to realize the grasping. The pick and place phase was realized taking the object and positioning it on a fixed point, referred to the vertix on the top left of the selected acquired image, and far away from the other objects. Please note that the final position of the object can be chosen anywhere within the robot workspace, while the distance between the gripper and the object has to be included into a range of 4–40 cm. How to choose the final position is typically related to the object and the specific task to accomplish, and is outside the scope of the paper.

4 Results

Since the proposed experiment is composed by three main steps (see Figs. 1 and 7), it is possible and significant to report the obtained results for each step, in particular: BCI classifier accuracy, HAAR-like classifier object recognition accuracy and pick and place performances.

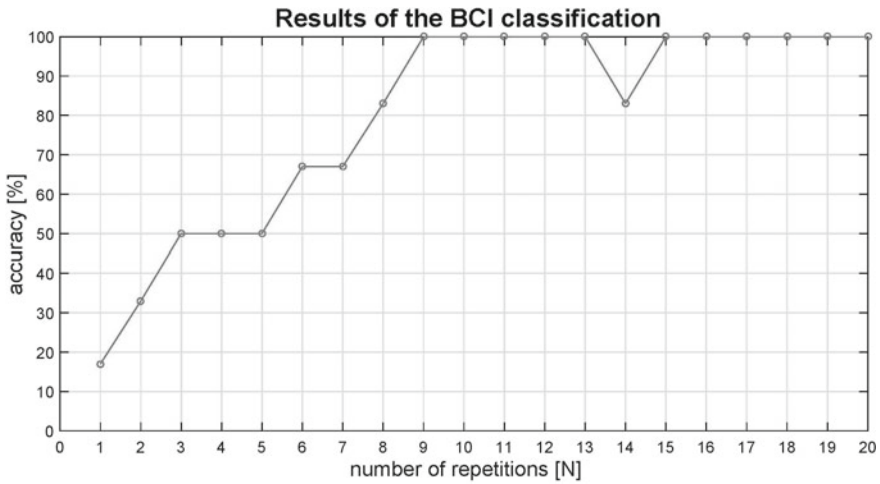

Fig. 8 BCI classification accuracy related to the recognition of the box

4.1 BCI Classifier Accuracy

Figure 8 shows the BCI classification accuracy obtained by the user during the experiment. The results demonstrate that the accuracy level is comprised between 80 and 100% after 8 repetitions. This means that after 8 highlighted visual stimuli of the desired object, which appeared randomly with the other objects, the system is able to associate the evoked $P300$ signals with the correctly chosen object.

This result has been tested on a user, which performed the training procedure for three times with a complessive duration of thirty minutes. In this way, the user's confidence with the BCI results considerably improved.

4.2 Object Recognition Accuracy

Table 1 shows the HAAR Cascade Classification accuracy for the 6 considered objects. The results were obtained analysing 10 pictures for each object, taken by the $left\_hand\_camera$ with different orientations. The best accuracy is related to the orange (100%), while the worst case is the banana (30%). The shape, particularly for the orange, but also some details of the objects as in the case of the book (80%), the box (90%) and the pocket (80%) that raised high classification accuracy, improved the recognition results. On the contrary, the light conditions affected sometimes the quality of the pictures and the related results, while the presence of the gripper, that can partially occlude the object in the scene, did not influence the recognition.

In Fig. 9, the recognition of the book in different positions and with a different pool of negative images is proposed. The difference between the two sets of negative

Table 1 HAAR classification result for each of the 6 considered objects

Object	N. full detection	N. partial detection	N.wrong detection	Efficiency[a] (%)
Glasses	6	4	0	60
Book	8	2	0	80
Orange	10	0	0	100
Banana	3	5	2	30
Box	9	1	0	90
Pocket	8	2	0	80

[a]N. full detections/N. total trials

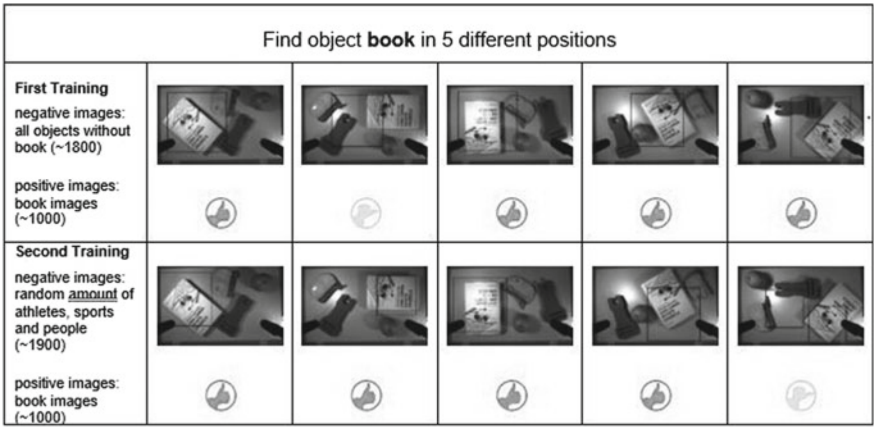

Fig. 9 Book recognition among other three objects (i.e, orange, key and pocket) detected in different positions and with different set of negative images for the training phase of the classifier

images lies in the choice of them, in the first group they are related to all the images of the other objects different from that requested, while the second group is composed by images related to different scenes, people or pictures of sports, not objects at all. As it is possible to notice, this aspect does not affect the object detection that is well recognised 4/5 times for each group. The two observed errors are due in one case to a partially recognition of the book that is not inscribe in the blue rectangle, while in the second case even if the book is partially covered another rectangle appears in the image.

4.3 Pick and Place Performance

The manipulator has been able to properly grasp the box, the book, the orange and the pocket. The grasping was not possible for the glasses and the banana, due to the employed gripper: target definition and path planning where however successfully performed.

Some errors about the estimation of the distance of the object placed on the table were observed due to the infrared sensor, which has an accuracy error of the 10% with respect to the distance.

Sometimes the estimation of the angle for the gripper orientation presented some errors, particularly for the book that for its dimensions, respect to the gripper, needed a very accurate angle value. The obtained results have shown that the angle estimation were correctly realised for different objects and in different positions.

5 Conclusions and Future Works

The paper investigates the human-robot cooperation in a possible assistive scenario. The task of choosing and moving an object is performed by combining a Brain Computer Interface and an anthropomorphic robot. Preliminary laboratory results show that the proposed approach is actually a viable solution to select an object without physical interaction, and move it by means of an automated arm. At the present stage, the proposed approach is still under development, and could be further improved to design an assistive robotic systems in a properly structured environment, for autonomy of users with different motor impairments.

For each step of the proposed approach some considerations and possible improvements are proposed in the following. About object selection via BCI, the classifier accuracy can be improved increasing the number of training sections and changing also the parameter related to the number of sequence. These two aspects are essential for improving the confidence of the user with the BCI system allowing him/her to train also his/her attention on the task requested. At the same time, this aspect can be considered a limit for the application because of the great effort for the subject to focus the attention on the visual stimuli for a long time. The object recognition via HAAR classifier offered good results for the object detection with short times for the matching of the extracted features, once the classifier was selected on the base of the object desired. On the contrary, the training phase of the classifier requested several hours suggesting to search another kind of approach, particularly for the features extraction. About the pick and place execution, the obtained performances are acceptable, few errors about the pose estimation and the angle orientation did not affect the correct task execution and the proposed approach in this phase results robust and repeatable.

The authors are actually working to improve several aspects of the proposed method. First of all, the current solution is under validation using an higher number of subjects, in order to understand the real usability and the mean accuracy results. Moreover, the authors are studying different types of hardware for better performances (mainly gripper type and distance sensor) particularly to manipulate different kind of objects. Finally, a future improvement is that of providing a mobile base to allow the robot to move in a domestic environment, thus reaching also those objects which are not within its workspace.

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ACCRA Project: Agile Co-Creation for Robots and Aging

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Abstract The mission of ACCRA (Agile Co-Creation for Robots and Aging) is to enable the development of advanced ICT Robotics based solutions for extending active and healthy aging in daily life by defining, developing and demonstrating an agile co-creation development process. ACCRA project consists of three robotic applications which aim to promote the independent living by means of personal mobility application, to support the daily life management thanks to housework application and to promote conversation rehabilitation tailored on personal attitude by means of dedicated software programme. Additionally, ACCRA project will be

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designed and developed on open source framework (i.e. ROS, FIWARE, universAAL and Rospex) to promote the interoperability among scientific community.

Keywords Service robotics · Agile programming · Co-creation · Active aging

1 Introduction

European population is getting older. This is the result of a simultaneous drop in fertility rates, longer life expectancies and a shift of the post-war baby boom generations to the top of the age pyramid. In particular, by 2060, the demographic old-age dependency ratio is projected to rise from the current 28–50% [1]. Consequently, this demographic shift implies the understanding of healthy aging and age-related diseases as one of our future challenges.

"European innovation partnership on active and healthy aging action group" states that older people can age in better physical and mental health within age-friendly environments [2]. These environments would promote the social inclusion of elderly population. In this context, robots can contribute to make those environments more friendly [3].

In this context, over the last years, researches in the field of Ambient Assisted Living (AAL) aim to develop technological solutions which are devoted to enhance the quality of life of elderly population, promoting their independent living, supporting their daily activity and encouraging preventive actions [4].

In a not remote future scenario, service robotic platforms will be machines that aims to cooperate with human-beings to help and assist persons of all ages in daily activities at home, in their workplace and in other environments. They will be able to perform a multitude of roles thanks to their capabilities to act and interact physically, emotionally, socially and safely with humans, providing for an easier and healthier life.

As state from literature evidence, Robot and Information and Communication Technology (ICT) have the potential to enable older adults promoting their independent living and active aging [5]. Personal service robot could be classified into seven main areas according to their main applications: Social interaction, Information, Safety, Health, Leisure, Physical Support and Mobility [6]. For instance, Paro and Nao are developed mainly for leisure purpose [7]. Other robots, like Dustcart, are designed for shopping and garbage transportation [8]. On the contrary, other robots are general purpose, in other words, they are not designed to perform specific tasks, but they could provide a range of services, such as DoRo [9], Care-o-Bot®4 [10], Pepper [11]. Recently, some of these robots become commercially available, like Buddy from Blue Frog robotics [12], Roomba robot [13] devoted to cleaning task, or Pepper from SoftBank [11] used as a commercial promoter in Japan mall.

In this context, over the last years, several EU projects have been founded to design, develop and test robotic solutions that could support elderly people and stakeholders in daily life tasks.

Within these projects, different robotic platform are customized and tested with real older users to estimate the usability and the acceptability level of the proposed services [9, 14, 15]. For instance, Teresa and Giraff+ projects use Giraff robots; Robot-Era and Astromobile projects customize SCITOS G5 with a co-design approach with end-users. Whereas Kompaii robot is used in Domeo, Mobiserv and Mario projects. It is worth to mention that each of this robot can provide different services aligned with the different projects' aims.

Particularly a total of 13 European service robotics project had been founded between 2011 and 2015 under FP7 and H2020 funding scheme. They are: Mobiserv, SRS, Ksera, Florence, Giraf+, Hobbit, Accompany, Robot-Era, Radio, Mario, Enrich-me, GrowMeUp and Ramcip. The aims of these project are various but could be grouped into six big domains namely: Support to the caregiver, Promote Health, Promote social inclusion, promote well-being, physical support, and safety at home. Of course a single project can belong to multiple domains.

If we imagine to cluster the selected projects according to this domains we can obtain an overview of the main service domains investigated by the most relevant service robotic projects. The results of this analysis are reported in Fig. 1.

As summarized by this analysis, the past EU projects are mainly devote to the promotion of social inclusions and the well-being. Whereas only 5 projects are focused on the physical support service. Additionally, there is not always a clear reference to the needs of formal and informal caregivers (5 out of 10). Indeed, ICT and robotics solutions often are developed without deeply knowing the end-users' needs and what are the social and infrastructural conditions in which such technology should work. The robotic systems are not extensively tested in real operative conditions.

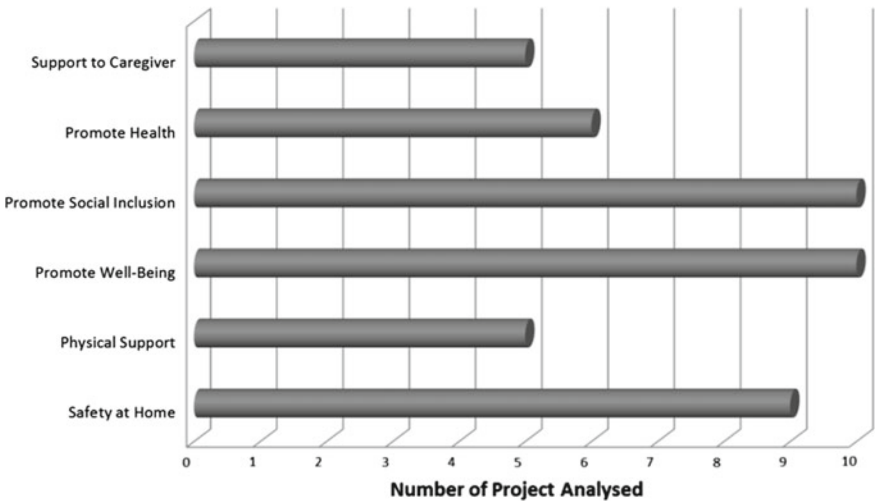

Fig. 1 Service domain distribution

Furthermore, all those projects do not adopt a common methodology to evaluate the effectiveness, the acceptance and the sustainability of the proposed solutions.

In this context, the objective of ACCRA project (Agile Co-Creation for Robots and Aging) is to become the reference co-creation methodology for the development of robotics solutions for aging and to become the reference assessment framework for the evaluation of robotics solutions for aging. ACCRA solutions will be designed and developed to be tested in three different applications: walking support, housework, conversation in four countries (i.e. Italy, France, Netherlands and Japan). For this reason, specific technology has been created and integrated at application, API and platform levels as described in Sect. 5.

Finally, in order to achieve the proposed goals, ACCRA researchers will focus their work on the following aspects: to (i) define a methodology for robotics solution for aging based on agile co-creation; (ii) develop an assessment framework for impact of robotics solutions for aging; (iii) built a platform for agile co-creation based on open solutions provided by existing initiatives, integrating important enablers; (iv) develop a robotics application for aging focusing on walking support; housework and socialization services.

This paper is organized as follow: Sect. 2 will introduce the ACCRA project, Sect. 3 will present the three applications, Sect. 4 details the ACCRA methodology; Sects. 5 and 6 describes the architecture and the impact of ACCRA solution respectively, finally Sect. 7 concludes the work.

2 ACCRA Project Overview

ACCRA project started in December 2016. It was founded under H2020 PM-14-2016 call as a joint research project between Europe and Japan (NICT). The multicultural consortium guarantees complementary expertise from different fields such as engineering, robotic, informatics, social and marketing.

As regard the European partners the researches come from France, Italy and Netherlands. Particularly Trialog, the ACCRA leader, Paris Dauphine University and Bluefrog Robotics come from France; Scuola Superiore Sant'Anna and IRCCS "Casa Sollievo della Sofferenza" come from Italy, and Erasmus University comes from Netherlands. As concern the Japanese side The Kyoto University, ConnectDot and Kobe University belong to ACCRA project.

In order to achieve the proposed goals, the state of art of methodology for design and the technology evaluation in the context of "aging-well" is united to build the ACCRA Methodology. It brings together expertise from robotics, software development, marketing, health services research, and health economics.

3 ACCRA Applications

Firstly, it is important to notice that (as remarked in [6, 16]) the understanding of stakeholders' needs play an essential role in the design of acceptable, usable and near-to-market research products. The needs of older citizens are mainly related to the physiological and physical disorder due to natural decline, chronic diseases of physical impairments. Firstly, older persons want to actively contribute to their families and voluntary organization as long as possible, they do not want to be considered as a burden for the family and the society. Additionally, older persons want to reduce negative feelings, like vulnerability and insecurity, and to reduce loneliness and depressions. Furthermore, they want to increase their social activities, because of the decreasing of traditional social network and infrastructure they reduce their social contacts and engagements. Sometimes they need help in managing chronic diseases because complex care procedures can generate confusion.

On the basis of these outcomes, ACCRA will develop three robotic applications:

(A1) mobility application for aging focusing on walking support,
(A2) daily life application for aging focusing on housework, and
(A3) socialization application for aging focusing on conversation.

These application aim at addressing the main elderly needs as depicted in Table 1:

- **Mobility application** will be addressed to people presenting risk of falls or returning from hospitals further to falls. The application will integrate features for physical support for walking (i.e. the robot can physically help). Particularly, the primary goal of this application will be related to the design and the development of the following of robotics features: detection of lack of movement, mobility coaching, help in maintaining independent mobility (Fig. 2).

Table 1 Correlation between elderly and caregiver needs [3] and ACCRA applications

Elderly needs	**A1**	**A2**	**A3**
Enhance personal mobility and autonomy	+		
Help in managing chronic diseased		+	
Living independently without feelings of loneliness and vulnerability	+	+	+
Help in managing housework activities		+	
Support conversation abilities			+
Caregiver needs			
Recognize dangerous situations	+	+	
Remote monitoring of elderly persons	+	+	
Support in the performance of motor and cognitive rehabilitation exercises	+		+
Reduced burden for caregivers due to work sharing with robots	+	+	
Efficient management of multiple requests support	+	+	+

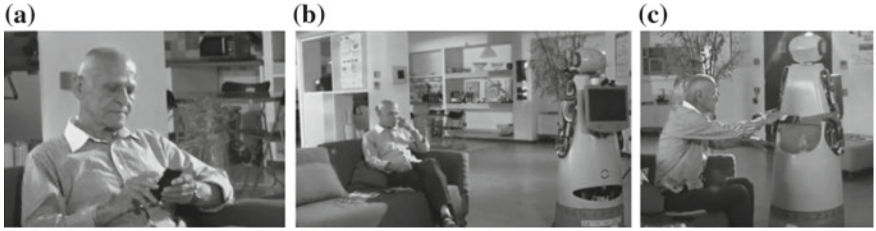

Fig. 2 Mobility application **a** the elderly user calls ASTRO robot because he needs to go to another room, **b** ASTRO robot arrives, **c** the user uses ASTRO handle and together go to the desired room

Table 2 ACCRA experimentation site

Application	Italy	France	Netherlands	Japan
A1	×		×	
A2		×	×	
A3	×			×

– **Daily life application** will be addressed to people with first signs of loss of autonomy (pre-dependency) promoting behaviors favorable for aging well (i.e. mobility, good hydration, social links, etc.) and for detecting signs/risks to reduce autonomy. In this context, ACCRA will focus on the demonstration of well-being features through the help of robotics solutions such as the medicine reminder, social links, alerts and diagnosis management.
– **Conversation rehabilitation**. The proposed paradigm will be similar to physical rehabilitation where patients are provided with challenging exercises to stimulate their body; indeed, in ACCRA application, people will be provided with challenging interactions exercises to stimulate their intellectual curiosity on different topics (i.e. fashion and golf) which are modulate on their preferences and psychological profile [17].

Additionally, in order to investigate how the cultural background could influence the personal attitude toward the robotic service. Each application will be refined and tested in different countries as reported in Table 2.

4 ACCRA Methodology

ACCRA proposed methodology distinguishes four steps, aligned with the general structure of the ACCRA project:

- **Step I: Needs analysis**, aim at identifying needs and at investigating the context in which the applications will be used.

- **Step II: Agile co-creation**, aims at developing the robotics solutions in close collaboration with end users, informal and formal caregivers, using agile programming tools.
- **Step III: Experimentation**, aims at testing the robotics solutions in a real context by a larger group of end users.
- **Step IV: Sustainability analysis**, aims at defining the potential market for the robotics solutions, and assessing the large scale impact of up scaling robotics solutions on the health system. Particularly, it aims at investigate this scientific and economic aspects: (i) What are the differences between pilots experimenting with the same robot, and what does that say about (cultural) contextual factors? (ii) Is there a potential market for the robot? (iii) What could be the future effects of robots when used more intensively in care organizations and houses?

The following paragraphs will details step I, step II and step III.

4.1 Step I: Needs Analysis

The purpose of this step is the identification of needs and behaviors of the elderly and the caregivers and, consequently, the re-definition of the applications. The needs analysis is based on a qualitative approach consisting of in-depth interviews. Particularly, it includes twenty in-depth interviews (ten elderly persons and ten formal/informal caregivers) per application and per country.

The interview will be divided into two parts, the first one aims at investigating the general impression of a robot solutions in each particular application. Whereas at the beginning of the second part, ACCRA application will be introduced by using video and introducing possible scenario in order to collect feedback thus to refine the applications. Example of ACCRA scenarios are:

Help to maintain independent mobility
Stefanie is a 76 years old with difficulties in walking and standing. She is still able to move from a room to another one, but she feels unsafe and needs a constant help. Andrew is a caregiver working in the care facility, that help elderly people to walk from the bed to the restaurant or the gym, but he is not able to accomplish all the requests on-time. For moving from an ambient from another one, Stefanie can use ASTRO robot to get assistance, avoiding Andrew of heavy physical tasks. The service provided by ASTRO can be requested both using a web interface or interacting directly with ASTRO if in the same room. Stefanie needs to go to the common area to play cards with her friends, she calls ASTRO and together go to the desired place.

Support in housework activities
Mario is 82 years old and he lives alone in his house since his wife died two years ago. Three years ago he started to suffer from cognitive problems, he has trouble in remember things. Mario needs to be reminded some daily activities like take the correct medicaments at the right moment, eat correctly and follow a regular number of meals per day, preparing the meals correctly avoiding medical restrictions because of high levels of cholesterol. Mario has a help assistant caregiver three times a week to do the household (cleaning, laundry and helping if necessary in bathing). Mario also receives the visit of his/her daughter almost every weekend or week, they are usually in contact. Thanks to ACCRA system the caregiver and the daughter could be always in touch with Mario and receive a feedback on the correct assumption of meals and medicine.

The inclusion/exclusion criteria for mobility, housework, and conversation interview guides are shown below:

1. Mobility
   a. Inclusion criteria: (1) age $\geq$60 years; (2) elderly with mobility issues (elderly with reduced mobility capabilities, elderly who are at risk of falling, and elderly who are rehabilitating and are in need of a mobility coach); and (3) elderly who gave their informed and signed consent.
   b. Exclusion criteria: (1) elderly who do not have any mobility issues (EMS score > 13); and (2) elderly with any cognitive issues.
2. Housework
   a. Inclusion criteria: (1) age $\geq$ 60 years; (2) elderly who have difficulty engaging in housework; (3) AGGIR grid with the following scores: GIR 4, GIR 5 and GIR 6.
   b. Exclusion criteria: (1) elderly who do not have any engaging in housework.
3. Conversation
   a. Inclusion criteria: (1) age $\geq$ 60 years; (2) Elderly without or with mild cognitive impairment: Mini Mental State Examination (MMSE) score $\geq$ 24/30; and (3) elderly who gave their informed and signed consent.
   b. Exclusion criteria: (1) elderly with any cognitive issues: Mini Mental State Examination (MMSE) score < 24/30.

This step of the methodology also includes a thorough analysis of the current situation in each pilot site from a local, regional or even national level. It is important to know about the rules and regulations in each country that are relevant for AAL and robotics, the way the health system is organized (who pays for innovations like these), and the way society perceives technology.

4.2 *Step II: Agile Co-Creation*

The central core of ACCRA methodology is the "AGILE co-creation". AGILE co-creation is a developmental approach by which intensive cooperation between users and IT-professionals is the center. Value co-creation is a collective process through which the interactions of a firm and its customers facilitate the creation of value [18, 19].

As state from literature evidences, researches have not only recognized that value co-creation is a way to achieve service innovation, but have also acknowledged the need to further explicate the service innovation structures that facilitate value co-creation [20].

In this context, Information Technologies (IT) play an important role in value co-creation. Technology can enhance the experience environment by enabling a value co-creation platform in which the firm and the customer interact and co-create value together [21].

The important role of the processes used to create IT-enabled products and services that are aligned with the evolving needs of the customer, has received much attention in the literature. Specifically, agile development methods that have gained immense popularity in recent years recognize the central role of customers in the development of products and services [22]. Agile methods prioritize customer satisfaction through the early and continuous delivery of valuable IT solutions, mainly software [23]. In particular, agile methods facilitate fast, intense, focused, and adaptive software development [24]. Researchers [21] define agility as "*the ability to act fast…and respond quickly to changes*."

Agile methods have been recognized for their emphasis on value creation and their potential to facilitate value co-creation by involving customers throughout the project life cycle [25]. In order for managers to successfully co-create value, they need to have the capacity for agility [21]. Recent research and practice has recognized the need to incorporate distributed development through agile practices. However, though agile distributed methods have been recognized for their emphasis on value creation, there is limited research on this topic [26].

On the basis of the aforesaid researches, the main objective of ACCRA project is developing the robotics solutions in close collaboration with end users, informal and formal caregivers, using agile programming tools.

Agile Co-creation of ACCRA robotics solution and service platform is divided in two step:

I Sub-step: Services Co-creation

By placing users (i.e. elderly people with loss of autonomy and caregivers) in the centre of the innovation process, the aim of this step in ACCRA is to design a robotic solution and services offering that effectively meet needs, expectations and uses of elderly people with loss of autonomy and caregivers. The aim is to improve the robotic solution and services by proposing concrete optimization solutions, perceived as operational both by the elderly people with loss of autonomy, family/professional caregivers and technology/robotics professionals. This approach is strategic in the context of a social innovation project as the ACCRA project. Indeed, researchers in social innovation [27] show that the diversity of actors involved in the innovation process and the active participation of users (here, the elderly with loss of autonomy and family and professional caregivers) [20]. Features are essential in the creation and implementation of new solutions. This provides a more complete representation of the problems, causes and possible solutions and allows to better respond to the problems of individuals by developing better solutions. This finally encourages the implementation of the identified solutions. From the first prototypes developed by the consortium, a working group (co-creation group) is created per application and per pilot site, consisting of seniors losing their autonomy (corresponding to use cases), informal (e.g. family) or formal caregivers (e.g. nurse, physiotherapist), technology/robotics professionals, and researchers with a double expertise on elderly people and marketing services. These co-creation groups will be working on the optimization of ACCRA robotic solutions and services platform to best meet the users' needs. Primarily these are the needs of the elderly people with loss of autonomy, but also family and professional caregiver needs are incorporated, because the use of robotics is also meant to complement or even substitute their tasks. The process embroils elderly people with loss of autonomy and family/professional caregivers who test the robot and the related service platform (on the basis of a prototype), a first co-creation group that involves elderly with loss of autonomy, informal caregivers and professional caregivers who are asked to deliver constructive criticism on previously experienced services (explaining how ACCRA services, functionality and ergonomics of the robotic support meet their needs and uses). The multidisciplinary group then exchange on possible improvement tracks and selects the priority axes of rework. After the first group, the ACCRA consortium reworks the robot and related service platform, and the optimized version of the robotic solution will be again submitted to the co-creation group. At least three other iterations of the group then take place, according to the previously exposed process

II Sub-step: Agile Programming

Figure 3 explains the principles of conventional agile programming: product development is carried out in short periods called sprints. The objectives of sprints are agreed by the agile programming team (e.g. engineers who apply the agile approach), the product manager and the product owner. The result of a sprint is executable and can be demonstrated. It can be therefore assessed by both the product owners and managers. Because of this constraint, there is pending work that is not mature yet to be integrated. It is managed through project and iteration backlogs. There are a wide number of methodologies and framework available such as SCRUM [28].

Figure 4 shows how agile programming will be adapted to ACCRA. The agile team is now the agile co-creation team, i.e. it includes specialists of co-creation. As co-creation is user centric, users (elderly, family, carers) are also part of the overall team.

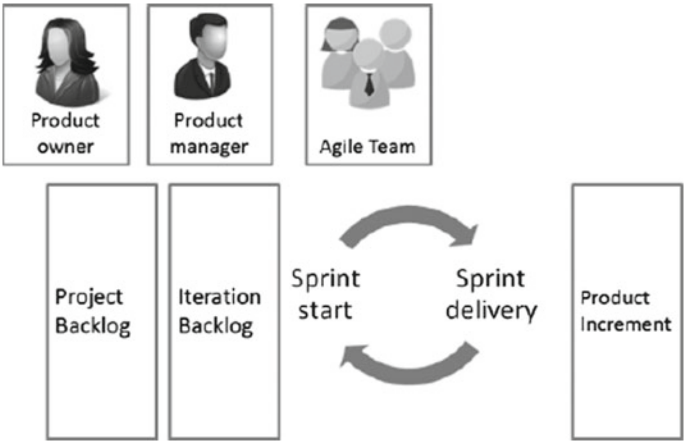

Fig. 3 Conventional agile programming

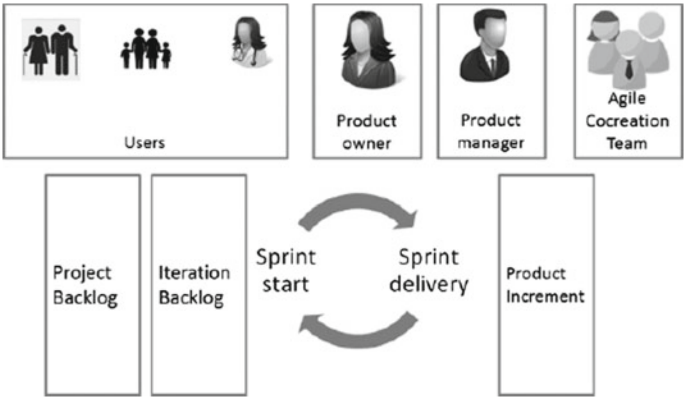

Fig. 4 ACCRA agile programming

It is important however in the ACCRA methodology to ensure that the members of the agile cocreation team as well as their interactions with users are at the right level. This will be one of the important challenges of the project. The proposed approach is the following:

1. It starts with the ACCRA methodology 4 steps
2. The co-creation phase is iterative
3. Each co-creation phase consists of three programming steps:
   a. Application modifications/extensions
   b. Resulting API modifications/extensions
   c. Resulting Platform modifications/extensions

4. Applications modifications/extensions are then subject to a number of sprints (at least 1)
5. Platform modifications/extensions are also subject to a number of sprints (at least 1)
6. As expected, application sprints and platform sprints are carried out separately in parallel. For integration reasons, a common final sprint could be organized.

4.3 Step III: Experimentation

The co-creation is followed by an experimentation in France, Italy, Netherlands and Japan (Table 2). Both in this step and in step 4 the MAST model (Model for Assessment of Telemedicine) will be used as a guideline, although it will be adapted to the robotics context where needed [29].

The MAST model is an international, validated model, which was originally developed for telemedicine, but has been applied in other domains as well. It is used for the assessment of costs and effects of innovations from a multidimensional perspective (also taking contextual factors such as organizational, ethical and legal issues into account). MAST has been used in large telemedicine studies like RCTs, but it is also relevant for smaller experimentations, such as the one done in ACCRA. One of the strong points is that it also involves the outcome of all the actors involved.

The use of the MAST evaluation framework facilitates the assessment of effectiveness and contribution to the quality of care of the robotics application. It includes three elements: (1) Preceding considerations, (2) Multidisciplinary assessment and (3) Transferability assessment. The experimentation phase of ACCRA is based on the second element of MAST: multidisciplinary assessment.

5 ACCRA Architecture

From the point of view of system architecture, the main important feature of the ACCRA architecture is the use of a system integration approach between robotics devices and intelligent living environments, which can support novel service delivery models, including the integration of robots, sensor networks, and handling data in the cloud, in a cloud robotic approach.

Recently, Cloud Robotics has been defined as "*Any robot or automation system that relies on either data or code from a network to support its operation, i.e., where not all sensing, computation, and memory is integrated into a single standalone system*" [30].

According to this specific, ACCRA solution is based on the FIWARE cloud platform. The FIWARE platform is characterized by a simple set of APIs (Application Programming Interface) the ease the use of the platform and the development of Smart Applications. Besides, FIWARE provided a multitude of FIWARE components (also

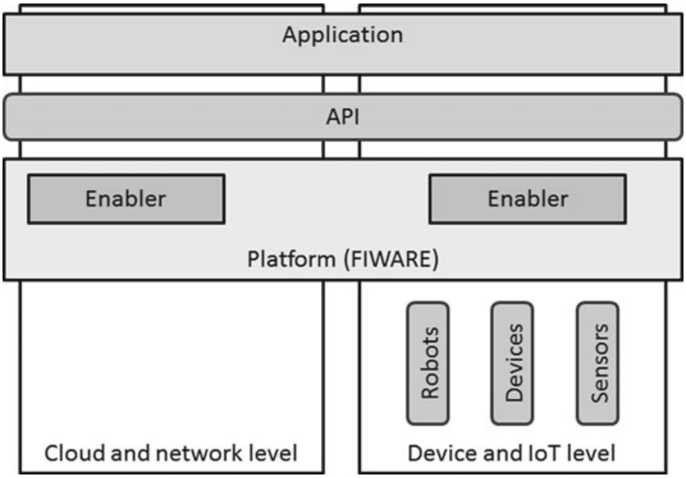

Fig. 5 ACCRA system architecture concepts

referred as enablers) that can be easily combined to perform more complex tasks. FIWARE enablers cover a wealth of applications in several domains, including IoT, Big data and Cloud Computing. Figure 5 shows how ACCRA technology will be constructed: applications uses APIs (application programming interfaces) that allow access to the platform capabilities. The capabilities are structured through simpler enablers. Figure 5 also shows that applications, APIs and platform capabilities can be located at different levels, i.e. cloud and network level, device and IoT level. For instance a robotics solution could run entirely at the robot level, without any issues on networks or cloud accesses. It can as well run as a distributed solution, with the application running at network level and making use of platform capabilities running at network and robot level [31]. According to specific addresses of ACCRA project, three types of applications are involved as described in the previous section.

As previously mentioned, the whole platform is based on FIWARE, for integration of capabilities already available, as management of personal data through the security enablers or processing of complex event through data management enabler.

Furthermore, in order to demonstrate the generalization performed during ACCRA project, two different robotic platforms are involved in the project: Astro (for Application 1—Support and coach for walking) and Buddy (for application 2—housework, and application 3—conversation).

– **Astro** is an assistive smart robotic platform dedicated to mobility and user interaction. It has been designed for moving within unstructured home and residence environments. It is a big robot, solid enough to become a smart walker. It can identify the location of the user at home and to interact with him using natural language, touch screen and visual LED system. On its back, the robot has an adaptable physical support to help people to walk. Along the ACCRA project, the

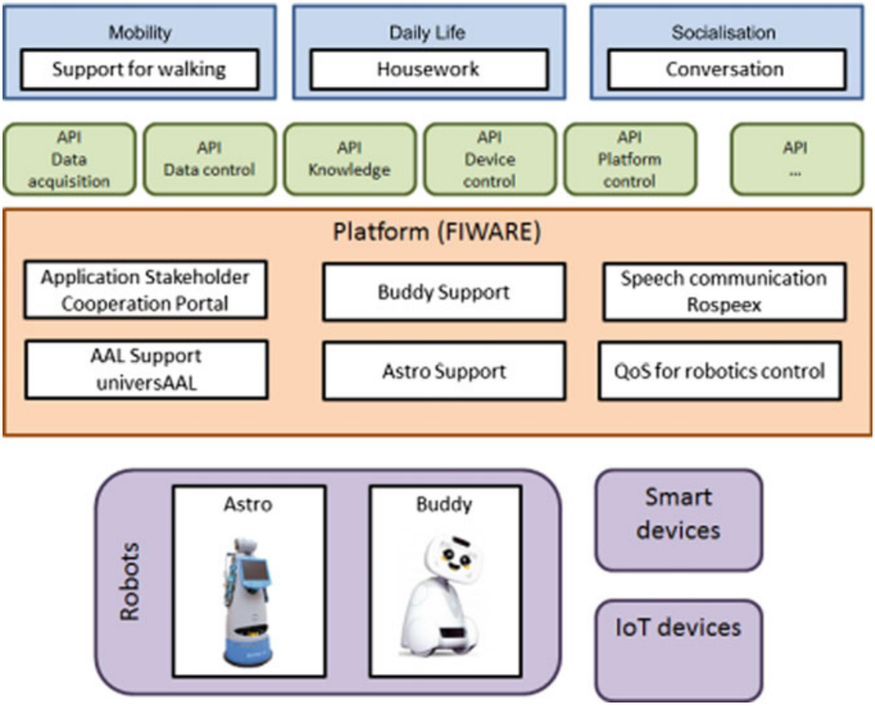

Fig. 6 ACCRA system architecture components

work on Astro robot is aiming at improving its smart walker capability and other services.

- **Buddy robot** is the physically opposite of Astro robot. It is a small-size robot and designed as a companion home. He cannot be physically a support for walking. The Development Tools (SDK), based on the Open-Source technologies such as Unity3D (video games) and OpenCV (aimed at real-time computer vision) to develop advanced applications for the robot. Along the ACCRA project, the work on Buddy is aiming at integrating new applications and potentially new hardware in order to meet the use cases requirements in a different approach than the Astro robot. The Buddy robot can be connected to the home and internet environment in order to fulfil its tasks. In Fig. 6, the ACCRA architecture is summed up.

6 Discussion

The greatest challenge for Europe and Japan is to create a sustainable health system. In this context, AAL researches focus they efforts onto three main pillars: Prevention, Compensation and Support and Independent Living [16]. These pillars represent the effect that AAL services have on the life of older persons. Prevention pillar focuses mainly on action to avoid or delay the onset of morbidity. Compensation and Support pillar includes the AAL services and devices that compensate physical and cognitive limitations. Whereas Independent Living pillar includes all the services and activities that allow older people to live independently and to participate to the community life. These pillars are complementary and partially overlapped because the same service can produce effects in different areas. ACCRA will develop and demonstrate three applications for two out of three pillars, particularly for "Compensation and Support" and "Independent living", since the three scenarios are mainly focused on these aspects:

- Supporting indoor mobility
- Problems with ADL tasks and housework
- Lack of social interaction.

Additionally, in order to overcome the limitation of the previous research works [6], the proposed applications are co-created with users to optimally meet their needs. Furthermore, in the extensive experimentation phase the impact of the robots on daily life will be studied using a multidisciplinary assessment.

Additionally, ACCRA services will not be evaluated in a lab environment, but in real care organisations and private homes of four different countries (i.e. France, Italy, Netherlands and Japan). This approach allows ACCRA researches to investigate how the cultural differences and attitudes could influence the perceived usefulness toward robotic solutions. It is important to notice that, because of the relatively small sample size per application and per pilot, a complementary research is planned through a scenario analysis to corroborate the statistical significance of the results. This action, indeed, will improve the robustness of the results, so that impacts on quality of life in the broadest sense (covering autonomy, health, wellbeing, safety, dignity, etc.) can be demonstrated.

If elderly people can live independently as long as possible, this will have a financial impact on the health system but also have an impact on the roles in health care: older persons and their carers will be more independent and autonomous. In this sense, the results of ACCRA project can be used to forecast health system sustainability. The number of users, and duration of experimentation is relatively small, but the data collection gives a basic understanding of the types of advantages robotics will have for the health systems.

It is worth to mention that ACCRA project will focus they efforts on the definition of carers and family needs in order to include in the co-creation process also these points of view which could enrich the design and the evaluation phases.

Summarizing ACCRA will have an impact on four aspects:

- ***Agile co-creation***: ACCRA project aims to constitute of a FIWARE-based platform environment for agile co-creation of robotics solutions for aging, focusing on the needs of the end users (elderly persons and formal/informal caregivers), integrating domain specific capabilities.

- ***Open solutions***: ACCRA project relies on technologies and enablers which are mostly open platforms. Indeed, FIWARE, universAAL, Rospeex are all open source solutions that will be used to build the ACCRA platform. ACCRA researches will use existing standards, supported by the European Community, thus, thanks to the international consortium, ACCRA project contributes to further adoption of open platforms internationally.
- ***Interoperability***: ACCRA co-creation approach also integrates flexible APIs definitions. It therefore promotes a practice that will allow for adoption and therefore agreement on interoperability aspects. ACCRA methodology promotes "interoperability-by-design", i.e. interoperability requirements are integrated in the creation process.
- ***Methodology***: As ACCRA focuses on a novel co-creation methodology (1) that fully integrates programming and (2) that is dedicated for the development of robotics solutions, ACCRA plans to seek standardisation of its agile co-creation methodology. Different standardisation options are possible, e.g. focusing on ergonomics related standards, on system engineering related standards, on robotics related standards, or on health informatics related standards.

7 Conclusion

In this paper, an overview of ACCRA project has been presented. Within ACCRA project an integrated framework for cloud robotics-based solutions will be developed and experimented to promote active and healthy aging. The proposed methodology integrates both co-creation and agile programming. It includes all the elements for flexibility, for user/stakeholder centric design and for multidimensional evaluation. It has been conceived to overcome the limitation of the other robotics projects and to became a referring methodology for this kind of project. ACCRA architecture will be developed on open platforms such as ROS, FIWARE, Rospex and universALL in order to promote the adoption of this platform in the scientific community. Additionally, ACCRA focus its effort on the analysis of cultural and economic aspects on ACCRA's applications in four countries (Italy, France, Netherlands and Japan).

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The CARESSES EU-Japan Project: Making Assistive Robots Culturally Competent

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Abstract The nursing literature shows that cultural competence is an important requirement for effective healthcare. We claim that personal assistive robots should likewise be culturally competent, that is, they should be aware of general cultural characteristics and of the different forms they take in different individuals, and take these into account while perceiving, reasoning, and acting. The CARESSES project is a Europe-Japan collaborative effort that aims at designing, developing and evaluating culturally competent assistive robots. These robots will be able to adapt the way they behave, speak and interact to the cultural identity of the person they assist. This paper describes the approach taken in the CARESSES project, its initial steps, and its future plans.

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1 Introduction

Designers of personal assistive robots are often faced with questions such as: "How should the robot greet a person?", "Should the robot avoid or encourage physical contact?", "Is there any area of the house that it should consider off-limits?". Intuitively, the correct answer to all those questions is "It depends", and more precisely, it depends on the person's values, beliefs, customs and lifestyle. In one word, it depends on the person's own *cultural identity*.

The need for cultural competence in healthcare has been widely investigated in the nursing literature [17]. The fields of Transcultural Nursing and Culturally Competent Healthcare play a crucial role in providing culturally appropriate nursing care, as the presence of dedicated international journals and worldwide associations reflects [7, 24].

In spite of its crucial importance, cultural competence has been almost totally neglected by researchers and developers in the area of assistive robotics. Today it is technically conceivable to build robots, possibly operating within a smart ICT environment [28], that reliably accomplish basic assistive services. However, state-of-the-art robots consider only the problem of "what to do" in order to provide a service: they produce rigid recipes, which are invariant with respect to the place, person and culture. We argue that reasoning only about "what to do" is not sufficient and necessarily doomed to fail: if service robots are to be accepted in the real world by real people, they must take into account the cultural identity of the assisted person in deciding "how" to provide their services.

The CARESSES project[1] is a joint EU-Japan effort that will design culturally aware and culturally competent elder care robots (see the Fact Sheet in Fig. 4 at the end of this paper). These robots will be able to adapt how they behave and speak to the culture, customs and manners of the person they assist. The CARESSES innovative approach will translate into care robots that are designed to be sensitive to the culture-specific needs and preferences of elderly clients, while offering them a safe, reliable and intuitive system, specifically designed to support active and healthy

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[1]Culture-Aware Robots and Environmental Sensor Systems for Elderly Support, www.caressesrobot.org.

ageing and reduce caregiver burden. Moreover, from a commercial perspective, the cultural customization enabled by CARESSES will be crucial in overcoming the barriers to marketing robots across different countries.

The rest of this article describes the CARESSES project. We start by clarifying, in Sect. 2, the type of "cultural competence" that we address. Section 3 gives an overview of the CARESSES approach. The following three sections present the developmental methodology, the technical solutions, and the evaluation strategies, respectively. Finally, Sect. 7 discusses the project's status and future plans, and Sect. 8 concludes.

2 Facets of Cultural Competence

Culture is a notoriously difficult term to define. In the CARESSES project, we have adopted the following definitions [22] in order to make our discussion precise and to help us identify the key components of a culturally competent robot.

Culture. All human beings are cultural beings. Culture is the shared way of life of a group of people that includes beliefs, values, ideas, language, communication, norms and visibly expressed forms such as customs, art, music, clothing, food, and etiquette. Culture influences individuals' lifestyles, personal identity and their relationship with others both within and outside their culture. Cultures are dynamic and ever changing as individuals are influenced by, and influence their culture, by different degrees.

Cultural identity. The concept of identity refers to an image with which one associates and projects oneself. Cultural identity is important for people's sense of self and how they relate to others. When a nation has a cultural identity it does not mean that it is uniform. Identifying with a particular culture gives people feelings of belonging and security.

Cultural awareness. Cultural awareness is the degree of awareness we have about our own cultural background and cultural identity. This helps us to understand the importance of our cultural heritage and that of others, and makes us appreciate the dangers of ethnocentricity. Cultural awareness is the first step to developing cultural competence and must therefore be supplemented by cultural knowledge.

Cultural knowledge. Meaningful contact with people from different ethnic groups can enhance knowledge around their health beliefs and behaviours as well as raise understanding around the problems they face.

Cultural sensitivity. Cultural sensitivity entails the crucial development of appropriate interpersonal relationships. Relationships involve trust, acceptance, compassion and respect as well as facilitation and negotiation.

Cultural competence. Cultural competence is the capacity to provide effective care taking into consideration people's cultural beliefs, behaviours and needs. It is the result of knowledge and skills which we acquire during our personal and professional lives and to which we are constantly adding. The achievement of cultural competence requires the synthesis of previously gained awareness, knowledge and sensitivity, and its application in the assessment of clients' needs, clinical diagnosis and other caring skills.

An analysis of the literature on personal, social and assistive robots reveals that the issue of culture competence has been largely under-addressed, and that a lot of work is still to be done to pave the way to culturally competent robot.

Several studies support the hypothesis that people from different cultures not only (i) have different preferences concerning how the robot should be and behave [8], but also (ii) tend to prefer robots better complying with the social norms of their own culture [25], both in the verbal [1, 27] and non-verbal behaviour [6, 13]. Despite these findings, little work has been reported on how to build robots that can be easily adapted to a given cultural identity. An interesting example is the framework for the learning and selection of culturally appropriate greeting gestures and words proposed by Trovato et al. [26]. This work, like the ones mentioned above, considers adaptation at a personal level, and follows a "bottom-up" approach, i.e., which identifies nations as clusters of people with similar cultural profiles. As such, adaptation to a different culture is a demanding process which requires either a long time, or a large corpus of data to begin with.

A "top-down" approach would be better suited for encoding cultural information expressed at national-level, and how such information influences preferences in the robot behaviours. Among the most popular metrics for a top-down description of culture at a national-level, Hofstede's dimensions for the cultural categorization of countries are six scales in which the relative positions of different countries are expressed as a score from 0 to 100 [12]. As an example, the dimension of *Individualism versus Collectivism* examines whether a nation has a preference for a loosely-knit social framework, in which individuals are expected to take care of only themselves and their immediate families, or for a tightly-knit framework, in which individuals can expect their relatives or members of a particular in-group to look after them, a notion which Hofstede called *Collectivism*. Hofstede's dimensions have been used in the field of assistive robotics to express the influence of culture on the gestures and words that a robot should use at a first meeting with a person [16], or to decide certain motion parameters like the approach distance depending on the cultural profile of the person [3].

3 The CARESSES Approach

The CARESSES approach to design *culturally competent robots* combines the above top-down and bottom-up approaches. When a robot interacts with a person for the first time, it uses a top-down approach to bootstrap its behavior using a cultural identity based on his or her cultural group; over the course of time, the robot then uses a bottom-up approach to refine this cultural identity based on the individual preferences expressed by that person.

Figure 1 illustrates this concept. For CARESSES, a culturally competent robot: (i) knows general cultural characteristics (intuitively, characteristics that are shared by a group of people); (ii) is aware that general characteristics take different forms in different individuals, thus avoiding stereotypes; and (iii) is sensitive to cultural differences while perceiving, reasoning, and acting.

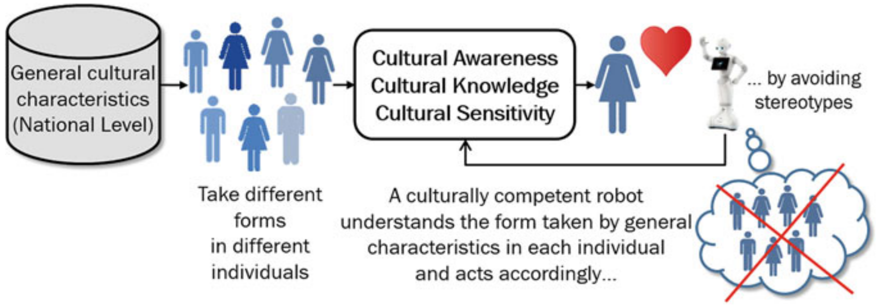

Fig. 1 The CARESSES concept of a culturally competent robot

More concretely, the culturally aware solutions developed in CARESSES will be used to expand the capabilities of the Pepper robot, which is designed and marketed by Softbank Robotics, a partner of the project. The new culturally aware capabilities will include:

- communicating through speech and gestures;
- moving independently;
- assisting the person in performing everyday tasks, e.g., helping with to-do lists and keeping track of bills, suggesting menu plans;
- providing health-related assistance, e.g. reminding the person to take her medication;
- providing easy access to technology, e.g., internet, video calls, smart appliances for home automation;
- providing entertainment, e.g., reading aloud, playing music and games.

One of the key questions addressed in CARESSES is what added value does cultural competence bring to an assistive robot. In order to precisely answer this question, the CARESSES culturally competent robots will be systematically evaluated at different test sites in Europe and in Japan, namely: the Advinia Health Care care homes (UK; project partner); the HISUISUI care home (Japan); and the iHouse facility at JAIST (Japan; project partner). These facilities play complementary roles in the evaluation: the Advinia and HISUISUI care homes provide access to real end users, who will take part in the evaluation; the iHouse, a duplex apartment fully equipped with sensors and smart appliances for home automation, will allow us to explore the integration of culturally competent robots in smart environments.

The ambitious role of CARESSES requires the close interaction of actors from different areas and different sectors. Accordingly, the CARESSES consortium includes experts in Transcultural Nursing, in Robotics, in Artificial Intelligence, in Human-Robot Interaction, and in the evaluation of technologies for the elderly. These are complemented by end users, and by a company with a long experience in developing and marketing assistive, social, educational and entertainment robots. Figure 2 shows the competences and geographical distribution of the partners in the CARESSES consortium.

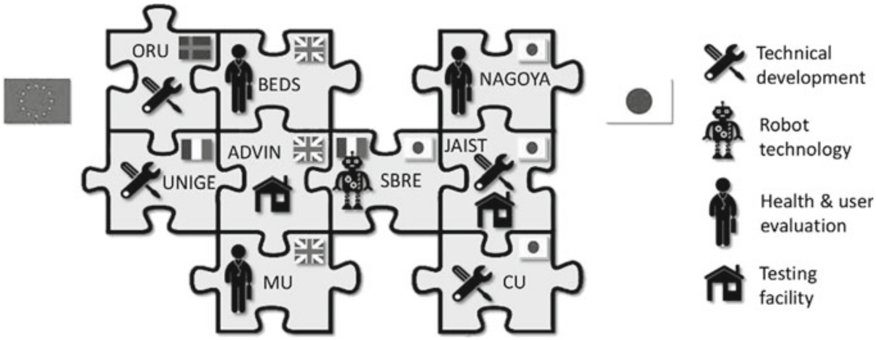

Fig. 2 The CARESSES consortium. See the Facts Sheet in Fig. 4 for the list of partners and their short names

Cooperation between the EU and Japanese partners is key for the successful accomplishment of the objectives of CARESSES. First, it offers the possibility to investigate the outcomes of interest of CARESSES through a robust user-testing approach: the impact of cultural competence in assistive robotics will be evaluated in very different cultural contexts in the EU and Japan. Second, it allows CARESSES to benefit from the complementary competences and resources of EU and JP partners. Among the others, EU and JP participants will pool two extremely valuable resources for system integration and testing: (i) the universAAL software platform for open distributed systems of systems, developed in the context of EU projects [9]; and (ii) the aforementioned iHouse facility at JAIST. Finally, this cooperation is expected to foster Transcultural Studies in Japan. While the study of Transcultural Nursing is supported by international journals and associations in the EU [7], similar studies and associations do not yet exist in Japan. As the number of foreign residents in Japan is significantly increasing, CARESSES will contribute to draw the attention of health-care professionals and public decision-makers on the role of cultural competence in health-care.

The project management structure has been designed to adequately address the peculiarities of CARESSES, a joint EU-Japan project whose research activities are performed in the context of two coordinated projects funded by different agencies: the EU Commission and the Japanese Ministry of Internal Affairs and Communications. The management of CARESSES also benefits from the support of an Ethical Advisor, an Exploitation, Dissemination, and IPR Board, and an External Expert Advisory Board.

4 Development Methodology

CARESSES follows a strongly user-driven methodology to develop relevant technological solutions, where requirements and knowledge come from the end users and domain experts, and validation is done with the end users.

The research in the areas of Transcultural Nursing and Culturally Competent Healthcare constitutes the theoretical foundations of CARESSES, paving the way to the development of culturally competent robots. The robot's attitude towards users initially relies on data available on the Hofstede's dimensions [12], complemented with specific information about the user's cultural group. This allows for making preliminary assumptions about the expected behaviour of a culturally competent robot, described in terms of Cultural Awareness, Cultural Knowledge and Cultural Sensitivity [22].

4.1 Initial Scenarios

In order to arrive to a set of technical requirements, we have grounded the above concepts in concrete examples. These are summarized in Tables 1, 2 and 3, that describe possible scenarios of interaction between a culturally competent assistive robot and an elderly person. The scenarios have been written by experts in Transcultural Nursing and draw inspiration from the rationale and actions of culturally competent caregivers. Each table reports a pattern of sensorimotor and/or verbal interaction, the required robot skills, as well as the cultural competence (in terms of cultural awareness, cultural knowledge and cultural sensitivity) that may contribute to determine the robot's behaviour.

Table 1 Introduction scenario: Mrs. Christou, a 75 years old Greek Cypriot who migrated to the UK when she was 20 years old

Scenario	Robot skills	Cultural competence
ROBOT: Hello Mrs. Christou!	Perception (Face recognition)	
The robot hugs Mrs. Christou	Moving (Arms)	
MRS CHRISTOU: Hello!		
Mrs. Christou smiles and hugs the robot		
ROBOT: Would you prefer me to call you Kyria Maria?	Speaking (Asking for yes/no confirmation)	[Cultural Knowledge: general (1)] The Greek Cypriot culture is very similar to that of Greece, in which hierarchy should be respected and some inequalities are to be expected and accepted.
MRS CHRISTOU: Yes, that's how one calls an older woman in Cyprus. What is your name?		[Cultural Awareness (2)] Mrs. Christou values her culture and its customs. She expects others to treat her older age status with some respect: this is why she likes that the robot calls her Kyria Maria (Kyria is Greek for Mrs).
ROBOT: I don't have a name yet. Would you like to give me a name?	Speaking (Catching key words and reacting)	
The robot leans slightly forward	Moving (Body posture)	
KYRIA MARIA: I will call you Sofia after my mother, God rest her soul.		[Cultural Awareness (3)] She names the robot after her mother, a common custom to name one's children. She shows her respect to the dead through signs of her religiosity.
The robot asks for confirmation for the name, infers that Sofia is the name of Kyria Maria's mother and asks for confirmation	Speaking (Catching key words; asking for yes/no confirmation)	
ROBOT SOFIA: Thank you, I like the name. I am honoured to be called after your mother.		
The robot smiles and hugs Kyria Maria	Moving (Arms)	

Table 2 Health-care scenario: Mrs Smith, a 75 year old English lady, a former school teacher

Scenario	Robot skills	Cultural competence
The robot Aristotle detects that Mrs. Smith is in a bad mood and adopts a more cheerful voice	Perception (Understanding facial expressions)	
ROBOT ARISTOTLE: How do you feel today Dorothy?		
MRS DOROTHY SMITH: I feel OK but it's time for my tablets. I have diabetes.		[Cultural Knowledge: general (4)] The UK has a pragmatic orientation.
A: Do you take tablets for diabetes?	Speaking (Catching key words; asking for yes/no confirmation)	[Cultural Knowledge: specific (5)] The robot is matching what Mrs. Smith says with pre-stored knowledge about her health.
D: Yes.		
A: Do you want me to remind you to take them?		
D: Yes! I take them three times a day: morning, midday and evening. But sometimes I forget them.		
A: OK. I will remind you! Please select your schedule on my screen.	Planning (Reminder)	[Cultural Knowledge: specific (6)] The robot knows that Mrs. Smith, a former school teacher, is already familiar with using a tablet.
The robot leans forward. Mrs. Smith selects morning, midday and evening on the screen	Moving (Body posture), Multi-modal Interaction (Using multiple input modalities)	
A: Is there anything I can do for you? Can I get you some water for the tablets?		[Cultural Knowledge: specific (7)] The robot is acquiring knowledge about what it means to Mrs. Smith to have diabetes.
D: Yes. That would be very nice Aristotle.		
The robot goes to fetch a glass of water	Planning (Retrieving an object), Perception (Locating an object), Moving (Legs, hands)	

Table 3 Home and family scenario: Mrs. Yamada, a 75 years old Japanese lady who performed tea ceremony in Kobe for 40 years

Scenario	Robot skills	Cultural competence
ROBOT YUKO: It is possible to test the video call with your family, if you like it.	Speaking (Avoiding direct questions)	
The robot checks for Mrs. Yamada's reaction. She smiles.	Perception (Understanding facial expressions)	
MRS NAOMI YAMADA: Really? My son and daughter both live in Tokyo. My son is always busy, but he visits me during holidays. I miss my daughter so much. Her husband is Korean so she often goes to Korea. I want to call my husband, but he's now giving a lecture at school.		[Cultural Knowledge: specific (8)] Naomi provides her personal details only when the robot brings up the topic.
Y: I can make a video call to your daughter, son or husband if you want.	Speaking (Catching key words and reacting)	
The robot checks for Mrs. Yamada's reaction	Perception (Understanding facial expressions)	
N: Maybe later. I don't know how to do it. Can you give me a manual on how to do it?		[Cultural Knowledge: general (9)] Japan is one of the most uncertainty avoiding countries on earth.
Y: Just tell me who you want to call, then I can help you. You are welcome to try.	Planning (Video call)	[Cultural Sensitivity (10)] Empowering: the robot is sensitive of the fact that Naomi is frightened by using unknown technology, and encourages her.
N: Ok, let's try. You will be my assistant!		

Albeit short, these scenarios show that the following capabilities are key for a robot to exhibit a culturally competent behaviour:

- *cultural knowledge representation*, this refers to the capability of storing and reasoning upon cultural knowledge, see for example the interaction between the robot Aristotle and Mrs. Smith in Table 2, in which the robot first uses knowledge (6) about Mrs. Smith's work experience to tune how to introduce a new interaction modality (its tablet), and later acquires new knowledge about her habits and medical prescriptions (7);
- *culturally-sensitive planning and execution*, this refers to the capability to produce plans and adapt such plans depending on the cultural identity of the user.

Cultural sensitivity, in the interaction between the robot Yuko and Mrs. Yamada in Table 3, allows the robot for planning to help Mrs. Yamada make a video call (10);
- *culture-aware multi-modal human-robot interaction*, this refers to the capability of adapting the way of interacting (in terms of gestures, tone and volume of voice, etc.) to the user's cultural identity. Cultural sensitivity makes the robot avoid asking direct questions to Mrs. Yamada (see Table 3) and perform the proper greeting gesture with Mrs. Christou (see Table 1);
- *culture-aware human emotion and action recognition*, this refers to the capability of interpreting sensor data acquired by the robot during the interaction in light of cultural knowledge. As an example, in Table 2 the robot Aristotle correctly labels Mrs. Smith's facial expression as indicative of a bad mood, while in Table 3 the robot Yuko relies on Mrs. Yamada's facial expression to get feedback on its suggestion to make a video call;
- *cultural identity assessment, habits and preferences detection*, this refers to the capability of adapting general cultural knowledge and acquiring new knowledge to better define the individual profile of the user. As an example, in Table 1 the robot Sofia uses knowledge about the Greek culture to guess how Mrs. Christou would like to be addressed (1), and her answer to validate its hypothesis (2). In Table 2, the robot Aristotle learns Mrs. Smith's habits in dealing with her medical prescriptions (5), and in Table 3 the robot Yuko brings up the topic of video calls (8) to learn about Mrs. Yamada's family.

4.2 Elicitation of Guidelines

To ground the assumptions into observations in real-world scenarios, the robot's cultural competence is now undergoing a process of iterative refinement on the basis of the cultural behavioural cues collected from video-recorded encounters between older people living in sheltered housing and their caregivers. Specifically, having identified and verified the relevant verbal and non-verbal behavioural cues, a panel of experts shall refine the assumptions made and update the prototype robot's cultural competence. In doing this, a great care should be paid to eliminate stereotypic notions [18].

This process will ultimately produce *guidelines* describing how culturally competent robots are expected to behave in assistive scenarios. The knowledge acquired in all these steps, both through comprehensive literature reviews on the topics and video-recorded encounters, shall be formalized using tools for knowledge representation, as the availability of formal languages for knowledge representation constitutes the basis for the robot to exhibit autonomous reasoning, planning and acting skills depending on such knowledge. Also, in the perspective of a commercial exploitation, it will allow the development of robots that are able to autonomously acquire information and update their own knowledge about the cultural context in which they are operating, and, ultimately, to re-configure their approach towards the user.

5 Technical Solutions

From a technological point of view, the first steps of CARESSES have been: (i) to identify the basic technical capabilities required for cultural competence; (ii) to define a system architecture that enables the integration of these capabilities into a fully autonomous assistive robot, possibly embedded in a smart environment.

5.1 System Architecture

Figure 3 shows the main modules of the CARESSES architecture: the *Cultural Knowledge Base*, the *Culturally-sensitive Planning & Execution*, and the *Culture-aware Human-Robot Interaction*, which are briefly described in the next sections.

All the components are integrated in universAAL [9], a software platform for open distributed systems of systems that resulted from a consolidation process conducted within an EU Project. The universAAL platform allows the seamless integration of heterogeneous components within an environmental network through the extensive exploitation of two base concepts, that turn out to be very well suited for the integration of components developed by different partners of a complex RTD project: (i) the usage of ontologies to define the services provided by network nodes as well as the procedures and data formats to access such services; (ii) the usage of three dedicated communication buses for topic-based communication among network nodes, namely a Context Bus, a Service Bus, and a User Interface Bus.

A bridge between universAAL and ECHONET [20], the Japanese standard for home automation, is being designed. This will allow the robot to communicate with a smart environment. In CARESSES, this will be provided by the iHouse, a Japanese-based duplex apartment fully equipped with sensors and actuators for home automation.

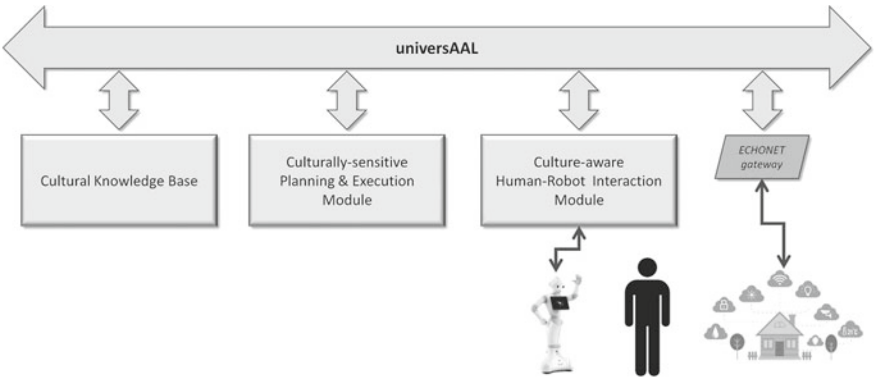

Fig. 3 A coarse view of the CARESSES architecture

5.2 Cultural Knowledge Base

Properly encoding guidelines for cultural competence in a framework for knowledge representation requires to take into account both methodological and architectural aspects.

Methodological aspects include: (i) how to represent the relationship between quantitative and qualitative knowledge about different cultural groups; (ii) how to avoid stereotypes by allowing for differences among individuals, while using the information about their national culture as a hint about their cultural identity; (iii) how to automatically reason on cultural knowledge to produce a culturally competent robotic behaviour, i.e., plans and sensorimotor behaviours aligned with the user's cultural identity; and (iv) how to update the knowledge base as new cultural knowledge is acquired through user-robot interaction.

Architectural aspects include: (i) which languages and tools should be used for knowledge representation, e.g., Description Logics [2], Bayesian networks [23], OWL probabilistic extensions such as PR-OWL [15]; (ii) which languages and tools should be used for querying the knowledge base: e.g., standard OWL functions, SPARQL[2]; (iii) which reasoning tools should be adopted, e.g., basic mechanisms such as subsumption or instance checking, rule-based languages such as SWRL,[3] Bayesian inference; and (iv) which Application Programming Interfaces, data formats, and protocols should be used to allow the robot to access the knowledge base.

CARESSES will consider the above aspects to produce a portfolio of solutions to be included in the general framework for Knowledge Representation. It will also define procedures for the knowledge base creation and updating. Indeed, Cultural Knowledge can be: (i) defined and introduced in the system a priori by experts in Transcultural Nursing, formal and informal caregivers; (ii) acquired at run-time through user-robot interaction. Specifically, run-time knowledge acquisition raises the most important methodological and technological issues, e.g., in terms of which questions should be posed to the user, how answers should be interpreted, how the information retrieved should be used to pose subsequent questions and to update the Knowledge Base. It also raises issues on how general cultural information known a priori (e.g., at National level) impact on individual characteristics, and how the information acquired during interactions (i.e., observed through sensors or direct communication) can be merged with the already available knowledge in order to perform a more accurate cultural assessment.

Finally, Knowledge Representation raises ethical issues in data privacy and protection, which are all the more relevant whenever the system stores sensitive information not only about the user, but also his/her family (e.g., names, domicile).

[2]https://www.w3.org/TR/rdf-sparql-query/.
[3]https://www.w3.org/Submission/SWRL/.

5.3 Culturally-Sensitive Planning and Execution

Once cultural knowledge has been explicitly produced, the challenge is to make the robot use this knowledge to modulate its own behaviour to match the cultural identity of the user. Technically, this translates into the ability to: (i) form plans to achieve the robot's goals while being aware of, and sensitive to, the user's culture; and (ii) execute the actions in these plans in a way that is also culturally aware and sensitive. As an example, the three robots in Tables 1, 2 and 3 may have the same goal to help preparing the lunch, but they may achieve this goal using different plans. These plans may include different actions (e.g., Aristotle helps Mrs. Smith by ordering the food online, whereas Sofia listens to Mrs. Christou chatting about cooking), or different ways to perform an action (e.g., Yuko collaboratively prepares the lunch with Mrs. Yamada).

The field of Artificial Intelligence has a long tradition in developing techniques for the automatic generation and execution of action plans that achieve given goals [10]. Cultural aspects can contextually influence the generation and execution of action plans in three ways:

- Discourage the use of certain actions; for example, to avoid suggesting recipes to Mrs. Christou;
- Include additional preconditions or goals, which may result in the inclusion of new actions; for example, with Mrs. Yamada, the robot Yuko performs an inquiry action before committing to one action plan or another;
- Induce a preference for some actions; for example, Yuko may encourage Mrs. Yamada to cook instead of ordering food online, because this better complies with Mrs. Yamada's need to make physical activity.

To take these influences into account, state-of-the-art approaches to constraint-based planning [19] have been considered. In addition to requirements in terms of causal preconditions (e.g., the robot's hand must be empty to grasp an object), spatial requirements (e.g., the robot must be in front of the user in order to interact), and temporal constraints (e.g., the tea must be served before it gets cold), constraint-based planning can also include constraints that pertain to the human-robot relation, e.g., to encode the fact that the robot should never clean a room where the user is standing: this extension of constraint-based planning is particularly suited to generate plans that take into account cultural constraints and, in general, "human-aware planning" [14].

5.4 Culture-Aware Human-Robot Interaction

Once a proper course of actions (including both motion and speech) has been planned taking into account the user's cultural identity, actions must be executed and feedback must be considered to monitor their execution. In this context, Human-Robot

Interaction plays a crucial role in endowing the robot with cultural competence. On the one hand, the way the robot behaves and speaks can produce different impacts and subjective experiences on the user; on the other hand, what the user says and does is the key for the robot to acquire new knowledge about the user, and consequently refine and improve its cultural competence.

As a prerequisite, the robot shall be equipped with motor capabilities that are sophisticated enough to allow it to exhibit its cultural competence through motions, gestures, posture, speech; similarly, it is mandatory that the robot (and possibly the environment) is equipped with sensors and devices for multimodal audio/video/haptic interaction that provide feedback to the modules for planning, action execution and monitoring, and are able to perceive the nuances of human behaviour in different cultures. Moreover, communication devices allowing for a simplified interaction may also be fundamental for frail older adults.

The role played by robot-user *verbal communication* has been carefully considered, as it is the primary way of interaction, possibly allowing for acquiring new knowledge and update the Cultural Knowledge Base. Due to the current limitations in natural language understanding, semantic comprehension is limited to the recognition of relevant keywords, that the robot will use to react by asking a confirmation through a simple multiple choice (e.g., yes/no) question. Additional touchscreen-based interfaces (either embedded on the robot or carried by users, e.g., tablets and smartphones) are used to complement the verbal interaction modality.

The robot's perceptual capabilities include the ability to estimate human *emotions* (joy, sadness, anger, surprise) and recognize human *actions*. As the robot operates in a smart ICT environment, the usage of lightweight wearable sensors that do not interfere with daily activities is explored (e.g., smartwatches or sewable sensors). The robot will be equipped with a module to detect and recognize *daily activities*, i.e., combinations of primitive actions performed in different contexts and places of the house (e.g., walking, cleaning, sitting on a sofa, etc.) [4]. As time progresses and the robot has more and more interactions with the user, daily activities and manners (a subset of social norms that regulate the actions performed by the user towards other humans, or even the robot itself) may be assessed to determine the long-term *habits* of the person.

Verbal interaction, as well as the assessment of the user's emotions, actions, daily activities, manners, and habits, will ultimately provide an input to perform a cultural assessment of the user, updating the knowledge that the robot has about the user's cultural identity.

The aforementioned capabilities involve procedures to merge and interpret sensor data acquired by the robot and by the smart ICT environment in light of cultural knowledge that is already stored in the system. Indeed, cultural knowledge can play a fundamental role at all levels of perception, ranging from basic object recognition to the detection of daily activities, manners and habits. For instance, if the system is uncertain if a purple object in the fridge is a slice of pig liver or an eggplant, cultural information about the alimentary customs of the users (who may be vegetarians) could help to disambiguate.

6 Evaluation Strategy

For the testing and evaluation with elderly participants, an ethically sensitive and detailed protocol that describes the screening, recruitment, testing and analytical procedures is being produced and scrutinised by relevant ethics committees. Once ethical approval is obtained, testing will commence. Testing will involve older adults belonging to different cultural groups, who possess sufficient cognitive competence to participate and who are assessed as sufficiently unlikely to express aggression during the testing period. Nominated key informal caregivers (e.g., close family members) shall also be recruited.

The impact of cultural competence will be quantitatively evaluated by dividing participants in experimental and control arms, i.e., interacting with robots with and without cultural customization, and by using state-of-the-art quantitative tools to measure the impact of healthcare interventions.

End-user evaluation will be aimed at evaluating the capability of culturally competent systems to be more sensitive to the user's needs, customs and lifestyle, thus impacting on the quality of life of users and their caregivers, reducing caregiver burden and improving the system's efficiency and effectiveness. The evaluation will take place at the Advinia Health Care network of Residential and Nursing care homes (UK) as well as in the HISUISUI care facility (Japan). The evaluation in the UK care homes will include at least ten clients who primarily identify themselves with the white-English culture and ten who primarily identify themselves with the Indian culture, while the evaluation in Japan will include at least ten clients who primarily identify themselves with the Japanese culture. Each group will be divided into an experimental and a control arm. Each client will adopt a Pepper robot for a total of 18 h over a period of two weeks. This shall allow for enough time for a culturally customized Pepper robot to acquire knowledge about the individual cultural characteristics of the assisted person and provide culturally competent interactions and services, which will then be evaluated through quantitative tools and qualitative interviews. Quantitative outcomes of interest and measurement tools shall include (pre and post testing):

- Client perception of the robot's cultural competence. Measurement tool: Adapted RCTSH Cultural Competence Assessment Tool (CCATool) [21] that shall measure clients' perceptions of the robot's cultural awareness, cultural safety, cultural competence and cultural incompetence, and shall include items associated with dignity, privacy and acceptability.
- Client and informal caregiver health-related quality of life. Measurement tool: Short Form (36) Health Survey (SF-36) [11]. The SF-36v2 is a multi-purpose, short-form health survey proven to be useful in surveys of general and specific populations, including older adults. It measures: general health, bodily pain, emotional role limitation, physical role limitation, mental health, vitality, physical functioning and social functioning. Each dimension score has values between 0 and 100, in which 0 means dead and 100 perfect health.

- Informal caregiver burden. Measurement tool: The Zarit Burden Inventory (ZBI) [29] is a widely used 22-item self-report inventory that measures subjective care burden among informal caregivers. Its validity and reliability has been widely established. The scale items examine burden associated with functional/ behavioural impairments and care situations. Each item is scored on a 5-point Likert Scale, with higher scores indicating higher care burden among informal caregivers.
- Client satisfaction with the robot. Measurement tool: Questionnaire for User Interface Satisfaction (QUIS) [5]. This scale evaluates whether the clients are satisfied with the interaction process including its efficiency and effectiveness. It will be adapted so that "the software" is replaced by "the robot".

The clients and their informal caregivers will also be invited to participate in qualitative interviews to elicit discussions about their perceptions of the robot's cultural competence, the quality of provided service, and its impact upon independence and autonomy. Discussions with informal caregivers shall focus upon caregiver burden, impact on quality of life, and experiences related to configuring the system by injecting cultural knowledge before operations.

During evaluation, differences between the pre- and post-testing measures shall be considered. However, given that, to the best of our knowledge, this is the first time that the above tools are proposed to be applied in a robotic context, there are no sufficiently similar previous experimental outcome data to use to statistically power our trial in order to sensitively detect clinically meaningful differences in pre- and post- outcome measures. Therefore, we shall describe observed statistical differences in outcome measures within and between arms, and report, using appropriate inferential tests, whether these differences are statistically significant.

7 Current Status and Future Work

The CARESSES project started on January 1, 2017 (Fig. 4). Its workplan spans 37 months, implementing the methodology discussed above. The starting technology includes the Pepper robot[4] as well as the *iHouse*, a Japanese-based duplex apartment fully embedded with sensors and actuators for home automation.[5] Cultural competence will be achieved through an investigation phase aimed at producing guidelines for Transcultural Robotic Nursing[6] as described in Sect. 4, and then through the development of three main technological components described in Sect. 5 above,[7]

[4]Pepper is produced by SoftBank Robotics Europe.

[5]The iHouse has been developed by the Japan Advanced Institute of Science and Technology.

[6]This investigation phase will be led by Middlesex University (UK) with the deep involvement of Nagoya University (Japan).

[7]The development of these three components will be led, respectively, by University of Genova (Italy), Örebro University (Sweden), and Japan Advanced Institute of Science and Technology, with the deep involvement of SoftBank Robotics Europe (France) and Chubu University (Japan).

CARESSES

MIC
Ministry of Internal Affairs and Communications

EU-Japan coordinated research project "CARESSES" - Fact Sheet

Full name: Culture-Aware Robots and Environmental Sensor Systems for Elderly Support (CARESSES)

Duration and starting date: 37 months from 1st January 2017

Funding:

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- 60,000,000 JPY from the Ministry of Internal Affairs and Communication of Japan.

Partners:

CARESSES is a multidisciplinary project involving researchers from different European countries and Japan, with backgrounds in Robotics, Human-Robot Interaction, Artificial Intelligence, Smart Home Automation, Transcultural Nursing, Culturally Competent Healthcare, Social Psychology, Human-Behaviour Analysis, Evaluation of Health- and Wellbeing-related Technology, along with a world leading Robotics Company, and a Network of Residential and Nursing Care Homes.

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Fig. 4 CARESSES Facts Sheet

and integrated in universAAL. Testing and end-user evaluation will follow the procedure in Sect. 6.[8]

In the first months of the project, all partners of the consortium have closely cooperated to define the initial specifications, produce scenarios of human-robot encounters, and design the system's architecture in all its details. A skeleton

[8]End-user evaluation will be led by Bedfordshire University (UK), with the deep involvement of Nagoya University.

implementation of this architecture, embedded in the universAAL framework, has been produced.

The definition of scenarios is particularly important, as it has driven the investigation of guidelines for cultural competence in robotics, the technical development of the required robotic capabilities (in terms of motion, perception, planning, knowledge representation, etc.) as well as the design of experiments for testing and evaluation since the early stages of the project. All partners of the consortium, led by Middlesex University, have cooperated to the production of these scenarios using online tools for collaborative working (e.g., Google Drive and the CARESSES GitLab repository). The close collaboration of domain experts with the technical partners has been pivotal to the success of this stage, as it has been the close collaboration between the EU and Japanese partners.

The CARESSES project is centred around the following major milestones:

October 2017 The basic guidelines for the development of culturally competent robots are ready to be used to start populating the cultural knowledge base. On the technical side, a fully integrated, albeit simplified version of the CARESSES system is implemented and integrated in the universAAL application layer. This includes a basic version of the Cultural Knowledge Base, the Culturally Sensitive Planning and Execution Module, and the Culture-aware Human-Robot Interaction Module. The latter includes the main motion and perception capabilities required by Pepper in the scenarios. Each component will subsequently be iteratively expanded, standalone debugged and tested, and refined up to its final form.

October 2018 The detailed protocol that describes the screening, recruitment, and testing procedures is complete and approved by Ethics Committee. On the technical side, the culturally competent robot is ready for final integration, deployment testing and evaluation. All the software modules have been properly integrated in universAAL and standalone tested as they were developed, and can be properly configured to produce the desired culturally competent behaviour. The Cultural Knowledge Base has been populated with the guidelines for culturally competent robots.

August 2019 The tests in Health-Care Facilities and iHouse are completed. Data and logs of robot-user encounters have been collected. These include data from pre- and post-testing structured interviews as well as post-testing qualitative semi-structured interviews with clients and informal caregivers, and are ready to be analysed.

The CARESSES project will end in January 2020. It will release its technical components for culturally competent robots as Open Source, in a form suitable to be executed in the application layer of universAAL. Most of the CARESSES deliverables are public and they will be widely disseminated. The current status of the project and related material can be accessed at the CARESSES web site www.caressesrobot.org.

8 Conclusions

Assistive robots can help foster the independence and autonomy of older persons in many ways, by reducing the days spent in care institutions and prolonging time spent living in their own home. Cultural competence allows assistive robots to be more acceptable by being more sensitive to the user's needs, customs and lifestyle. In this article, we have discussed the notion of cultural competence that is put forward in the context of the CARESSES joint EU-Japan project. We have provided an overview of the project, discussed the problems that it has to address and its methodology, and presented its initial steps.

To the best of our knowledge, CARESSES is the first attempt to build culturally competent robots. We believe that cultural competence is a necessary, although so far understudied ingredient for any social, personal or assistive robot. In this respect, we are persuaded that CARESSES is a ground-breaking project. Even if CARESSES only produces a prototype that shall need to be further evaluated and refined before drawing definitive conclusions about the impact of cultural competence in assistive robotics, we claim that our pilot will be invaluable in paving the way for future similar studies.

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The Role of Social Robots in Public Space

Leopoldina Fortunati, Filippo Cavallo and Mauro Sarrica

Abstract The purpose of this research is to understand what might be today—on the edge of the social robotics era—the role of robots in public spaces. In Europe, there was a strong tradition of automata exhibition in the '600 and 700' with ostensive purpose. Exposing automata in various fairs was meant to inspire awe towards the advancement of technology and science in the public who attended numerous public events. This study aims to investigate whether in the modern world the robot may have the same or other functions in public space. The study has analyzed the public display of the robot DORO: a technological artifact created by the Sant'Anna School during the European project ROBOT-ERA. Two distinct public moments were examined. The first was the night of researchers in Pisa on 30 September 2016 in Martiri della Libertà's square, where DORO was exhibited to the public. The second occasion was the inauguration of the 39th academic year of the University of Udine. On this occasion, DORO brought to the rector his inaugural lecture and exchanged—in front of a large auditorium—a brief dialogue with the rector of the University of Udine, prof. Alberto de Toni.

Keywords Social robot · Public space · Public events
Social robot role in public space · Social robot audiences

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1 Introduction

Robotics laboratories are full of prototypes of social robots that need to be tested in the everyday life spaces, we may say in the 'reproduction sphere', which includes homes, health care facilities, education systems, and so on. The aim of this study is to analyze the role of robots in public spaces as it has emerged in two different public situations. Although there is a rich corpus of scholarly work on the role of robots at home [1], in healthcare [2], in social care [3], in education [4–6], in entertainment [7] and so on, there are few studies on the object of our research [8–11]. These studies have especially focused on studying the use of robots in museums or shopping malls. We intend to contribute with this study to this specific area of robotics research, presenting an explorative research in two public situations, which have been scarcely studied so far. An antecedent, which inspired this study, is the experimentation carried out in Peccioli within the European funded project Robot-era (http://www.robot-era.eu), with robots circulating in the small center of Tuscany. In this study, we brought DORO [12], one of these domestic robots, in two different public events in Pisa and Udine. The first was in "The night of the researchers", an event that the universities in Europe organize every year in order to communicate to and involve citizens in the scientific discoveries they produce. In this case, we brought the robot DORO in the Martiri della Libertà's square in Pisa, a mid-sized city in central Italy. The second event we examined is the opening ceremony of the 39th academic year of the University of Udine. Here, the robot DORO was brought in a public building, and it was not open to interaction with all the audience but only with the authorities on the stage. Both these events concern the academic life and thus they are biased in terms of audience involvement and expectations. Nevertheless, they provided an interesting observation, which can stimulate researchers' self-reflection on how robots are perceived 'out of the labs', and on the methodologies which could be applied to investigate lay-people perceptions and attitudes.

2 The Robot in Public Space

The issue of the robot in public space is not a new one. It is a question, which the antiquity and middle age, renaissance and modern times have always dealt with. Automata in Hellenistic times, according to Ferrari [13], p. 225 onwards, were not only mere objects of entertainment but they were also "ostensible equipment," that is general instruments of application and demonstration of mechanical principles, and particularly pneumatic ones. They were also silent messengers of the wonders produced by the development of science in combination with art [14]. Placed as a hybridization between nature and art, the automaton belonged in fact to the 'heterogeneous' class of wonders and 'effects and extra'. In the Renaissance, the idea of the automaton-regained momentum and, as consequence, automata turned out to be placed in pleasant spaces, like the garden of lilies [15]. Historically, gardens are privileged places in which automata become fountains where the flow of water obeys a rhythm adjusted on the regular intervals of a gesture metric [16], p. 156 and p. 169.

One of the first issues that emerges when robots are exhibited in public spaces is their two-faced nature, which is trapped in-between physicality and illusion. At the end of the eighteenth century, Jacquet-Droz developed three androids (the Scribe, the Designer and the Musician), which represent the best results obtained with traditional mechanics [17]. However, they were so perfect that the polemics on the aspect of automata flared up because of the magic halo that surrounded them and that derived from the delay with which the public could understand the truth of the artifact, or even from the impossibility on the part of the public to understand it.

Beyond the religious problematic connected with scientists challenging God power to create living creatures, the difficulty to distinguish between automata and humans had to deal also with a secular issue: that of 'authenticity' [18]. The "social contract", in fact, in order to function requires a high degree of authenticity of the individuals and their social identity. Although humans do not always pursue authenticity and thus grant themselves various degrees of freedom in playing with inauthenticity, it is assumed that at a certain point one has to come back to authenticity. As Baron points out, the problem of the infringement conveyed by automata depends on the fact that their purpose was not only to surprise but also to trick the public. The issue of authenticity becomes dramatic today, especially in their representation as androids or gynoids. Hence, the theme of authenticity brings further elements inside the question of the possible role that social robots can play in contemporary societies, that is, whether the anthropomorphic shape is actually the most suitable for robots to stay in the public places [19].

Another important issue concerning robots in public is that of art and fashion [20]. The automaton belonged to the 'heterogeneous' class of wonders and 'effects ad extra'. To which class do the contemporary robots belong? Due to their cost, they belong to the category of affluent technological artifacts for sure. For this reason, social robots require a good design. However, as Fortunati [21] showed regarding mobile phone, the new genealogies of technologies deal with design and fashion. Social robots, especially in their anthropomorphic shape, will also need to deal with fashion, because humans deal with it. Should they become fashionable or should they be dressed? There are several elements, which would point to personalization and fashionization of these artefacts.

A mass production of social robots would produce undifferentiated artefacts, but a robot entering the public space needs to be recognized by its owner. This is a problem that social robots share with the mobile devices, especially the mobile phone. The answers that ICTs have found so far are on the one hand the personalization [22] of the devices and on the other hand seeking help on from fashion. Personalization of the mobile phone, for example, is a tactic that has manifested in various practices of use such as the adoption of particular ring or music, particular ornaments and so on [23].

Fashion, instead, is a system that humankind has created in order to increase personal differences. Fashion is born as a social filter between the natural state of the body and its "civilization" [24]. In the case of humans, the clothed body embodies the social norms that the repression and regulation of sexuality have elaborated and imposed [25]. The clothed robot is set even more precisely in a particular social public context. As Fortunati wrote [20], we have reasons to believe that also robots will need to become fashionable to stay in public spaces. A personalized and fashioned robot waking in a street allows bystander's greater mutual control as it is more reassuring.

A third main issue of the robots in public is the transformation they bring to the public space. Far from being merely physical settings, places acquire meanings due to their connections to individual and social activities. Place meanings involve the self (e.g. connections to individual identity and life path), the self-other relationships (e.g. meeting places), the self-environment link (e.g. symbolic and instrumental opportunities offered), and the other-environment connections (e.g. place atmosphere) [26, 27].

The public space, in particular, is the place in which encounters and social interaction take place. It is the social arena where people expose themselves to the others and constitutes, by using the theatrical metaphor, the place of the front stage [28]. On the fore people represent themselves to the others, play social roles, provide information about themselves and their intentions but also leave other information transpiring unintentionally. All this implies a network of expectations and actuations regarding social practices as well as controlled and formal actions, which correspond to socially defined etiquette and behavior appropriateness [29]. The public space is also strongly regulated by laws, norms and institutionalized values, by daily routines and rituals, by cultural, social and political content and meanings. Public places, moreover, are relevant for defining citizenship and belongings: "Public spaces are the natural arena of citizenship, where individuals, groups, and crowds become political subjects. They are socio-physical settings where public life occurs on the basis of open visibility, scrutiny, and concern, supporting public interest and citizens' well-being" [30], p. 124. In this sense we may also say that the public space has a particular feature of safety, because it conveys a sense of protection from the risks of the unexpected [31].

A robot entering the public space has to deal with the complex dispositive of the public space: will it be considered part of the environment, or included in the self-other relationship? How does its presence interact with norms and societal regulation?

In our case, we have two different public spaces: the Martiri della Libertà's square in Pisa and a building of the University of Udine. The square and the University auditorium had different scales, but they were also the stages of different interactions: an open encounter between science and citizens happened in the former, a highly ritualized ceremony involving authorities and cultural elites was held in the latter. Will the social robots be able to enter and have a space in both settings?

3 Methods

In this study, we triangulated three different research methods: non-participant observation, a brief semi-structured interview with open and closed questions to the public who approached and interacted in some way with robots, and audiovisual records

Fig. 1 The social robot DORO in Pisa

of the interactions with the robot aimed at integrating the information gleaned from interviews.

The interviews collected in Pisa were N = 49 and in Udine N = 51. In both cases, we have two convenience samples that are self-selected on the base of spontaneous interest and willingness to participate in the research. The convenience sample consisted of 53 females and 47 males, age ranging from 8 to 80 years with a mean of 38.1 (SD = 18.312). Age was recoded into three broad categories: youth (8–24 years), adults (25–49 years) and elderly (50 and more). As to education, only 9% have an elementary or junior high diploma, 27% have a high school diploma and 42% have a college degree and often a Ph.D. It is a group with a rather high level of education and with great interest in the scientific discoveries (among those who responded to the question "How much are you interested in scientific discoveries?" overall 82.5% said they were very interested compared with a 17.5% that has stated that they are moderately interested). This group is also particularly well equipped from a technological point of view: 88.0% says that they use the smartphone and even more, that is 99.0% use the computer. The answers provided during the interview to open-ended questions were subject to qualitative content analysis and to similarity analysis performed using open access software Iramuteq [32, 33].

Both the events were also video recorded (Figs. 1 and 2). In Pisa 39 persons (17 males and 22 females) had an interaction with DORO.

By estimation these persons belong to all the age groups, with a concentration of children between 5 and 10 years. The analysis of the videos enabled us to investigate essentially three elements: the sequence of two typologies of contacts, a sequence of three actions taken by people and the dialogues that some people undertook with DORO. In Udine the main interaction happened on the stage between the Rector and Doro, the analysis of the videos enabled us to monitor the reactions of 64 spectators (30 males and 34 females). Essentially, this analysis has allowed us to analyze the reactions of the public sitting in the front left and right rows and in the second left row (the second right row was not visible).

Table 1 Interactions with DORO in a first and second moment

Contact	First moment	Second moment
1. Shake hands with Doro	31 (79.5%)	0 (0.0%)
2. Take the bottle and hand it to bystanders	0 (0.0%)	12 (30.8%)
3. No contact	8 (20.5%)	27 (69.2%)
Total	39	39

4 Results

4.1 Video Analysis

In Martiri della Libertà's Square, Sant'Anna School had prepared a display counter with two robots: DORO and Nao.

DORO turned out to be the most attractive for the people who passed by. DORO did two actions: first gently took a bottle of water and handed it to bystanders [34]; second, it managed some dialogues with those who tried to talk to it [35].

Table 1 illustrates the sequence of the direct interactions with DORO on the part of bystanders.

In a first moment, the large majority of people shook DORO's hand, while a fifth of them avoided any contact. In a second moment, only a third of them took the battle from DORO. This table is very interesting because it shows the majority of people tended to introduce and replicate with robots the same rituals such as to "shake hands" that they perform in public encounters with humans.

But apart these direct interactions, what are the other actions performed by bystanders? In Table 2 we report the actions in sequence. It can be noted that the large majority of bystanders fundamentally looks at DORO (action 3), a fifth of people wave at DORO (action 1), and five persons try to talk to it and elicit a reaction (action 2). Five bystander do not start any action towards DORO. The contingency table coming from the cross tabulation of the actions highlights that only one person tries different approaches (waving and moving the hand).

Fig. 2 DORO leding to the chancellor of the University of Udine his inaugural lecture

Table 2 Actions taken by the public in sequence

Action typology	Action 1	Action 2	Action 3
1. Wave at Doro	8 (20.5%)	1 (2.6%)	
2. Move the hands in front of DORO to elicit a reaction		5 (12.8%)	
3. Only look at DORO			34 (87.2%)
No action	31 (79.5%)	33 (84.6%)	5 (12.8%)
Total	39	39	39

Crossing the three actions, it emerges that of the 39 persons recorded only three (7.7%) did not perform any action. Apart, we explored also the dialogues that developed during the interaction between bystanders and DORO. More than a third of the bystanders (N = 15; 38.5%) had no dialogue with DORO, and these were mainly females (N = 10; 66.7%). As to the dialogues with DORO, particularly interesting are those between children and the robot. DORO approached people by saying: "I am pleased to meet you. My name is DORO". Several children answered by saying their names. A strong empathy with DORO has emerged in several cases, as it often happens with animals. A child (F, 5–10 years) answered DORO greeting by saying: "I love you. Hello". Another "I like you". Others said: (F, 5–10 years) "You are very kind", (F, 5–10 years) "You are very sweet and cute", (F, 5–10 years) "You're like a good little soldier", (F, 5–10 years) "Ooh DORO, I adore you! You are so cute", "You're so funny and cute". A child was asked by DORO: "What do you think about robots?" The child answered: "You are marvelous". Then, he asked DORO: "Do you know SIRI?"

Children replicate to DORO as if they were adults talking to a little child, encouraging it after an appropriate action. In fact, when DORO gives then a battle of water they say to it: (F, 5–10 years): "Thanks, little one" or (F, 5–10 years) "You have been very good".

To many children DORO personifies a young woman. One (M, 5–10 year) asked: Do you have a boyfriend? Another (M, 5–10 years) "What is your favorite food?" Another one (M, 10–15 years) said to DORO: "Prepare to me a sandwich" and its peer: "DORO, sing a song".

A woman (40–50 years) was asked by DORO: "What is the most beautiful thing you saw today?" and she answered: "It is you, DORO". Then, this woman said "DORO, look at me that I want to take a picture of you". DORO answered "Let us do a selfie together". In Udine, overall 85.9% of the public showed a great interest, only 12.5% were puzzled and only one person was very indifferent (it was a girl who, when DORO took action, continued to read a book). Public's behavior was recorded also in Udine and we report the actions that people took in the following Table 3.

Table 3 tells us that the first reaction is to *smile* as we do in any public encounter with somebody. Then, a behavior that involves the public in all of the sequences of the actions is *to applaud*. Applauding involves more than half of the public as second action. It is surprising the few people who took a picture of the robot. Maybe

Table 3 Actions taken by the public in sequence (participants N = 64)

Action typology	Action 1	Action 2	Action 3	Action 4
1. Smile	**57** (89.1%)			
2. Talk to your neighbor	1 (1.6%)	14 (21.9%)		
3. Move to see better		6 (9.4%)	4 (6.3%)	
4. Take pictures of the robot		5 (7.8%)	1 (1.6%)	
5. Applaud	5 (7.8%)	**33** (51.6%)	15 (23.4%)	2 (3.1%)
6. Indicate the robot			4 (6.3%)	7 (10.9%)
7. No action		6 (9.4%)	40 (62.5%)	55 (85.9%)

because, being the inauguration of the academic year a ceremony, it is not considered appropriate to take a picture with the smartphone.

4.2 Analysis of Self-report Questionnaires

Free words association to the term robot gave the following results. A dictionary of 317 words was created by respondents (Table 4).

The eight dimensions emerged by content analysis describe the conceptual map of DORO. This map includes the elements of which the robot is made, its functions, its positive and negative characteristics at physical and at psychological levels, where robots come from and where they go. These categories are in line with those emerged in previous research that investigated the computer, the mobile phone and the Internet [36, 37].

We then investigated respondents' opinion about DORO. The first open question that we have posed was "Does DORO correspond to the idea of robot that you had before?" The qualitative content analysis of the answers to this question highlights 4 categories of meanings, as it is reported in Table 5.

More than a third of respondents who answered this question found a correspondence between the idea that they had about robot and DORO. This means that this particular robot embodies people's imagination of and expectations towards robots. Nine people only have found DORO very different from their expectations. More than a quarter of the attributions to DORO are positive in the sense that DORO overcomes the expectations and as many are negative in the sense that DORO is less than what they thought. To investigate more deeply inside the expectations of people towards robots we also asked: "To what extent DORO has satisfied your expectations?" on a 10 points scale. The answers obtained were very positive: the average was 7.28, SD = 1.983. A univariate ANOVA ($F(3) = 6.282$, $p < 0.01$) shows that the most satisfied by DORO ($M = 8.20$) were those who found DORO different from the idea of robot they had were, followed by those who found DORO more beyond their expectations ($M = 7.79$) and then by those who found DORO very in line with their expectations

Table 4 What is a robot?

Dimensions	Frequencies	Content
What the robot is made of?	82	Cables, circuit, gears, tin, metallic 5, humanoid 3, automation 18, automaton 2, mechanics 6, machine 8, electronic object, domestic appliances, vacuum cleaner 3, instrument, technology 18, tablet, television, Playmobil, giant, terminator game, industry 2, programming 3, artificial intelligence 4, software
The positive characteristics of the robot at psychological level	53	Reliable, amicable, beautiful 2, enjoyable, fun 2, Company 4, Interactive 4, socialization, availability, curiosity 4, amazing wonder, provocative, charm, interesting 3, kindness 2, fast 3, intelligent 5, sophisticated, smart, hardworking, brilliant, ingenious, special, complicated, funny 3, effective, efficient, special, great potential, important for children
The positive characteristics of the robot at physical level	14	Agile, color, fashion, fast 3, elasticity, flexibility, bright, alive, precise, movement, hands, view
Robot's functions	49	Aid 13, aid for existence, service, convenience, comfort, substitute 2, slave, servant, utility 24, functional 2, use, indispensable
Where does it go?	36	Innovative 8, ideas, ingenious, new 2, modernity 3, progress, one step ahead, evolutive, you really have to work more, the future 12, improvable, distant hope, progress 3
From where does it come?	15	Science 3, Asimov, science fiction, knowledge, information, scientific discoveries, inventions, engineering, learning, robotics, electronics 3
The negative characteristics of the robot at psychological level	24	Coldness 4, aloof, disturbing, disquieting, pseudo-clever, complicated, silly, simple, heartless, I do not trust, threat, strange 3, unreal, surreal, ridiculous, reductionist, imitation, spectacle, magic
The negative characteristics of the robot at physical level	12	Slow, humanoid 4, static, not autonomous, the better a fool machine, bad copy of the human being 3, snowman

(M = 7.59). The lower satisfaction towards DORO was experienced coherently by those who were deluded by it (M = 5.75). Finally, respondents' satisfaction does not differ in Pisa and in Udine.

Second, we asked (open question) an evaluation of the dialogue with Doro. The answers are illustrated in Table 6 and show that they have been perceived by our respondents, half natural and half artificial.

When we asked "Would you like to bring DORO at home?" 46.5% of the respondents answered yes, 51.5% says no or is uncertain. There are no significant differences by gender. On the contrary, age affects answers. Adults are the least ready to bring a robot like DORO at home, while youth and the elderly are more likely to do so ($\chi^2 =$

Table 5 Does DORO correspond to the idea of robot that you had before?

Dimensions	Frequencies	Content
Similar	28	Consistent enough, quite appropriate, close enough to the idea that I had, tight, it looks a lot like a robot I had imagination, similar to other robots developed by the university around the world, similar to the imaginary, similar 3, similar especially the face, equal 2, the same idea I had, almost respected my idea 5, mirrors 2, reflects the idea of the slow robot with recorded voice, reflects the expectations, I already know Doro, in line with the idea I had, in line with the idea of simple and experimental robots, I study robotics thus I have an idea, more or less
Different	9	Very different, different 2, away from the robots of science fiction but anyway, made as a person, humanized, human above all expectations, more humanoid than I expected, it is like an innocent and asexual child
More	22	Beautiful 2, interesting, companion, made well, very useful, simpler than the one depicted on television 2, more funny 5, it looks a bit "Star Wars", advanced robot-like autonomous with fluid movements and words, I especially liked the female voice, a first approach to what you could do, an innovation, a very good surprise, useful, a living thing that in the future will be important to every day, we come to something that can be useful
Less	22	Disappointing shape, the use of robotic voice presented various flaws, slightly clumsy, less evolved than I thought 2, less innovative, slightly smart, more stupid, I fear the slow pace of the operations + Fast, quite slow, a bit 'too slow, a bit slow', a bit 'stiff', static, I expected the robot would be useful, not very useful, this however is unusable, it seemed much less tech than the robots I see on the web, bad, primitive compared to movies, but very technological, rudimentary, it moves in a way which is slightly human

Table 6 What did the dialogue with DORO look like to?

Dimensions	Frequencies	Content
Natural	24	Nice 5, somewhat surreal, funny, interesting 2, surprise, fluid 3, natural, normal conversation between humans, alive, solid, prepared, good 2, positive but unrealistic, clear, I did not understand though if DORO interacted with the Rector autonomously or if it was silent because it understood what the rector was saying, normal, short
Artificial	27	Rather ridiculous 2, limited, trivial 3, poor, elementary, simple 4, embarrassed, little fluid, very few humane, strange, impersonal, formal, mechanical, machinic 2, artificial 3, an interaction similar to that occurring with SIRI, it gave the impression that it was planned, prepared 2

9.178, df 2, $p = 0.010$). This study confirms results from the Eurobarometer survey that highlighted a need expressed by the elderly people to be helped by a social robot [38, 39]. Education also affects results, but it works in reverse of what we expected: the higher the level of the education the lowest availability there is to bring at home a robot like DORO ($\chi^2 = 6.079$, df 2, $p = 0.048$). While the attitude towards scientific discoveries is not related to the availability to bring DORO at home, the type of public event and the place where it occurs have significant effects on this availability, which is higher in Pisa than Udine ($\chi^2 = 9.701$, df 1, $p = 0.002$). Finally, a univariate ANOVA shows that those who would be available to bring DORO at home, are convinced more than the others that robots will not steal jobs (M = 4.62 vs. M = 5.96, F(1) = 4.522, $p < 0.05$), that robots will help humans in their jobs (M = 8.93 vs. M = 7.73, F(1) = 8.347, $p < 0.01$), that they feel more safe towards DORO (M = 9.18 vs. M = 7.87, (F(1) = 9.010, $p < 0.01$) and that they had a certain sensation that DORO looked in their eyes (M = 5.42 vs. M = 3.33, F(1) = 8.425, $p < 0.01$).

Given these results, it is not surprising that to the question "Do you appreciate the presence of a robot in public space?" 83.2% of the respondents' statements were affirmative, which is an important result for this study because it confirms that these people are ready to accept that social robots could play a role in public space. Here age, gender, education and the attitude towards scientific discoveries are not producing significant differences. The typology of the event and the place have instead significant effects: in Pisa respondents appreciate the presence of a robot in public space more than in Udine ($\chi^2 = 9.248$, df 1, $p = 0.002$). Moreover, a variable that is relevant in this concern is the availability to bring a robot at home. The more people are likely to do so, the more they are likely to appreciate the robot in public space ($\chi^2 = 15.979$, df 1, $p = 0.001$). A more vivid appreciation of the presence of a robot in public space is also connected to the opinion that robots will support humans in their jobs (F3.553 = 15,684, $p < 0.0001$), that with DORO respondents felt safe (F3.593 = 23,863, $p < 0.0001$). By contrast, the fear that robots will rob people's jobs does not generate differences in this concern.

To investigate the extent to which respondents appreciate the presence of a robot in public space we asked "From one to ten how much did you appreciate DORO in public space?" The answer was an average of M = 8.10 (SD = 1.857).

Then we asked the respondents if in their opinion it could be useful a robot that give information in public space. To this question 83.2% of respondents answered yes and they expressed an average of this usefulness of M = 8.38 (SD = 1.612).

At this point, we passed to ask also "What do you need in order to feel save in respect to a robot that moves in public space?" To this question, a third of the respondents answered they do not need anything particular because they feel safe with a robot. Some of them hoped in a better interaction with robots and for others the most important thing was that robots should "not hurt children and the elderly" or "do not suddenly go crazy". Less than 10 people wished a good control over them: "a good and fair management" and "knowing that obey the laws of robotics". Other respondents stressed the importance of knowing the purposes of their functionality, to what exactly they were designed for, who have programmed them, to know their operating instructions and safety instructions, their proper role in preventive information and on

Table 7 Feelings of danger and safety

	Robots will steal jobs	Robots will help humans in their jobs	I felt safe in respect to DORO	I have had the sensation that DORO looked into my eyes
N	96	96	96	88
Average	5.31	8.34	8.57	4.44
St. Dev.	2.996	2.025	2.111	3.376

how to intervene. Others put the accent on the need that they must be done properly, with a protected software and not hackable, well programmed and comprehensive, that they understand human commands 2, which can recognize the obstacles 2, with good sensors and programming mechanisms, made of non-ferrous material such gels and with a comfortable look. Finally, others underlined the necessity to limit their power, by having the capability to predict their movements, that they should have limited mobility, intelligence and strength, that they are easily deactivated, a switch to be informed of their presence and ability to disable functions, they are armless, that there is an easy way to lock them, to shut them down, to slow down them if they move. The robots should be safe, teasers that have not weapons.

Table 7 reports that our participants, first, did not perceive any sense of danger or fear from DORO presence in the public space. Second, they are strongly convinced that robots will be of help to humans in their jobs and activities. This belief is significantly stronger than the fear regarding robots stealing jobs. The application of the non-parametric Friedman test for K dependent samples has shown that the difference among these averages is significant ($\chi^2 = 117.874$, df 3, $p = 001$). At this point, we explored also what effect did DORO's movements cause on our respondents, as Table 8 reports.

Table 8 shows clearly that respondents' evaluation of the movements made by DORO was more negative than positive, meaning with this that we have to go a long way before the gestures of robots will be considered acceptable. Finally, we investigate the extent to which respondents have appreciated the presence of a robot in public space. Our respondents showed a large appreciation of their presence in public space (M = 8.10). In particular, they stated that robots could be useful to give information (M = 8.38), being an attraction (M = 7.98) and entertain the public (M = 6.53).

5 Discussion and Final Remarks

These two studies show that robots are a mature technology to be used in public space for purposes at least of entertainment and information. Overall, our respondents have expressed a positive attitude towards them. As for the automata, it is still the illusion

Table 8 Evaluation of DORO's movements

Dimensions	Frequencies	Content
Strong points	25	Natural enough 3, arm movement was natural, normal, good 2, beautiful, I do not know how to explain, fluid 4, pretty loose, good impression, almost perfect, almost human, normal for a robot, wonder 3, curiosity 2, surprise 3 amazement 2, only the hand, it took the bottle to the kids, they were amazing I did not seem unreal, they are plausible, veritable, sweet, They have appeared familiar to me, they are well done, harmonious, interesting 3, liked to be fine but a bit slow 2, but good, coordinated, coherent, normal, very relaxing, delicate lenses of a newborn, graceful, gentle, spontaneous, delicate, calibrated, harmonic 2, at times mechanical, non-mechanical, loose movements, realistic, I liked them, precise, fairly fluid, at times fluid, that can be made more fluid or at least so hoping, robotic effect, but positive, it was what I was expecting, there were moments I expected, now I hope they start walking, well programmed 2
Weak points	37	Rigid 3, clumsy, little fluids 2, so… "impatience", lenses 6, I expected faster, fake, an unbelievable puppet, stereotyped, unnatural, I expected more naturalness, not spontaneous, they do not convey the idea of a humanoid robot, strange 3, skinny, limited, I thought it would move best, elementary, mechanical, robotic, artificial, driven, fear, lack of accuracy, no particular effect, no effect, there is no effect

and the unexpected that fascinate our participants. Those who were more surprised by the robot (it did not fit with their previous image) showed more positive evaluations of DORO's affordances and capabilities.

A second result shows that our participants overall have a positive attitude towards the presence of robots in public space, but only half of them (and namely the elders and the young participants) are ready to have one at home. Indeed, the analyses of interactions with the robot show that public patterns of behaviors are largely enacted (e.g. shaking hands), whereas it is mainly the children who show intimacy towards the robots. But children are more used than adults to cultivate a fictional world populated by puppies and toys in general, whereby they are more comfortable with the simulation expressed by the robot.

Finally, even if at an exploratory level, it seems that the two different settings suggested alternative interaction with the robots and alternative positioning in public space. The interaction with DORO is treated as a self-other encounter in Pisa square (with shaking hands and selfies), whereas it is much more limited to the attendance of a public performance in the Udine ceremony.

Fashion, clothing, personalization of the artifact did not emerge at this stage, but we are confident that the more robots will enter public space, the more this aspect will prevail over other factors such as illusion and surprise that are still prevalent.

A last line to underline the main limit of this studies, that is the limited number of participants involved, which allows only preliminary conclusion that need to be corroborated in future by a more robust sample of respondents.

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Part III
Assistance and Care Applications

Towards the Development of an Integrated Care Platform for Frail Older Adults: Setting the Technological Priorities from a Stakeholder Perspective

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Abstract The present contribution reports on the preliminary findings from a series of 6 focus groups conducted to explore stakeholders' attitudes toward the development of an integrated care platform to assist frail older adults. In the focus groups, older adults (n = 7), informal carers (n = 5), care (n = 6) and social (n = 8) workers, nurses (n = 4), health professionals (n = 7), were involved, for a total of 37 participants. Overall, a positive attitude towards the system was found from all stakeholders, but its effective implementation and use in daily practice would require a substantial cultural change. Results are discussed in light of future development steps of the care system. The activities described were conducted within the ProAct project, funded from the European Union's Horizon 2020 research and innovation programme, under grant agreement No. 689996.

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Keywords Integrated care · Multimorbidity · Digital health · Elderly · Frailty

1 Introduction

Italy has the largest proportion of elderly population in Europe [1]. Among the 60.6 million Italian inhabitants in 2015, 13.4 million (22%) are aged 65 and older [2]. By 2050, people aged 65 and over its expected to represent about 30% of the total population [3]. The percentage of individuals over age 65 between 1990 and 2011 increased from 14.9 to 20.6%; during the same period, the percentage of individuals over age 85 almost doubled, increasing from 1.2 to 2.8% [4]. Focusing in particular on the Emilia-Romagna Region, in which the present study is currently been conducted, people over 65 are almost one out of four of the total population (4.4 million), with a peak in the municipality of Bologna (242,233), which is the regional capital. In that city, demographic studies estimate that the group of so-called "older-old" (over 80 years old) in 2030 will be about 41,000, representing more than 10% of the total population [5].

The growth in lifespan has led to a higher incidence of chronic-degenerative diseases (e.g., heart disease, cancer, cognitive decline and dementia) and a greater demand for long-term care. According to the report "Piano della cronicità" (Chronicity Plan) of the Italian Minister of Health [6], in 2013 the percentage of people aged 65–74 that suffer from at least two chronic diseases was 48.7, and 68.1% of those aged 75 years and older. Again, in Emilia-Romagna, 60% of the population over 64 years reports to have at least one chronic disease (610,000 persons). 50% of those aged over 64 report having one or two chronic diseases, while 9% reports having three or more chronic conditions [6].

Empowerment of older adults and their primary informal carers is a way to achieving integration among all actors involved in the care process [7]. In this view, available evidence suggests that digital health solutions do have the potentials to assure continuity of care across health and social care services [8] as well as to improve self-management activities for older adults with multiple health conditions [9]. With the term digital health solutions, here we refer to the use of any information technology (e.g., the Internet, digital gaming, virtual reality, and robotics) in the promotion, prevention, treatment, maintenance of health, and the delivery of health related services. It embraces also mobile and wireless applications, including text messaging, apps, wearable devices, remote sensing, and the use of social media such as Facebook and Twitter [10].

The aim of the ProACT project (http://proact2020.eu/) is to develop a technology ecosystem, including new and existing technologies, that will support integrated care for older adults with multimorbidity. The ecosystem will connect and integrate four key models of care and support—(1) homecare (including informal care), (2) hospital care, (3) community and social care and (4) social support networks—and will be centred on the persons self-managing their conditions in daily living contexts, with support from their care networks. The ProACT solution will be evaluated in two main trials in Ireland and Belgium, with 60 older adults and members of their care/support networks at each site. The trials will take place over a 12-month period and will implement an iterative, co-design action research methodology to support the development of the system based on end user and health and social care professional feedback.

Part of the project is a transferability study, which will involve a specific pilot trial in Emilia Romagna (Italy). The scope of this trial is to assess the factors that impact on the transfer of digital integrated care solutions between one European region and another, and between one target group and another. As a part of the methodology for the transferability pilot study, a requirements study was performed. AUSL and ASP, being respectively the most important public health and social care providers in the capital of the Emilia-Romagna Region [11], could be considered typical future ProACT professional clients as providers of eHealth solutions to better serve the population in the region.

The aim of the present contribution is to report on preliminary findings from the requirements of the transferability study, which has explored stakeholders' attitudes towards the use of technology and their expectations regarding the benefits of the use of technology in the care system.

2 Methodology

2.1 Study Design

Requirements gathering involved an extensive scoping exercise to define the exact requirements of the ProACT ecosystem based around the needs of each care/support model and its relevant end users. For the scope of the present study, a series of 6 focus groups were carried out with a range of participants. All focus groups were conducted in person and were moderated by members of the research team. Focus groups lasted between approximately 120 min. Ethical approval for the conduction of the study was given by the Local Health Trust (protocol number 16034).

2.2 Participants

The recruitment has focused on potential target groups of the ProACT system. Older adults were recruited from users of sheltered apartments rented by ASP. ASP is the public social care company, with the municipality of Bologna as its main shareholder. End-users group consisted of "frail" elderly, older persons living almost independently but in a protected context and with the services calling daily on the basis of the care need. Most of them have some chronic conditions, or are at high probability to develop them, and the ownership of the apartments (allowing for the installation of

Table 1 Stakeholders involved in the focus groups

Group	N (females)	Age (range)	Living/working context	Overall technology skills
Older adults	7 (6)	79.8 (68–88)	Sheltered apartments	Use of standard phones to communicate with familiars and peers. Low confidence regarding independent use of technology for care
Informal caregivers	5 (3)	58.8 (56–65)	Home	Use of technology for daily activities: internet connection, smartphones, apps
Care workers	6 (4)	44 (30–52)	Day care center	Good level of confidence with technology. Aware about the IT problems of the structures they work
Social workers	8 (8)	41.7 (30–56)	Community social care	Good level of confidence with technology. Low availability of technology devices in work environments
Nurses and transition nurses	4 (4)	43 (41–44)	Community health care	Good level of confidence with technology. Low availability of technology devices in work environments
Healthcare professionals	7 (3)	51.3 (44–61)	Community health care	Good level of confidence with technology

home automation solutions), the relative closeness of health and social care services (upon request), make them an ideal testbed for the ProACT platform in the future. Alongside older adults, informal carers, formal carers and health professionals were also involved. Moreover, additional subjects relevant to the local context and needs were included in the discussions, these being managers in health and social care and social workers. In all, 37 participants were involved in 6 focus groups. Table 1 provides a detailed description of each stakeholder group involved.

2.3 Procedure

The focus group session was introduced by an informative slides presentation showing devices and systems on the market in order to stimulate the participants' awareness and imagination. Following the presentation (during which an expert was present to respond to all questions), the participants were invited to rate the perceived usefulness of the solutions for themselves and for other stakeholders. The slides presentation introduced at first the concepts of mobile and assistive technologies and the concept of the Internet of Things (IoT), thus allowing the participants to understand the impact that these technological revolutions are having on our daily lives. In particular, technologies and applications of technology were shown for the areas illustrated in Table 2. For each category, specific information communication technology (ICT) devices were shown together with concrete examples of their possible applications. Each member of the focus group was then solicited to provide comments regarding the devices showed by the moderator and to express an opinion concerning their perceived usefulness. To further structure the participants' opinions, following the presentation and discussion on each single area, the participants were asked to rate the following items: "usefulness for myself" (0 = not useful; 5 = very useful), "usefulness for others in the care ecosystem" (0 = not useful; 5 = very useful), and "likeliness of be used by myself" (0 = no way; 5 = for sure) for each application area. Overall, this methodology aimed at identifying concrete areas of applications and to set priorities for the next ProACT development steps.

2.4 Data Analysis

Descriptive statistics were used to analyze data collected. Data analysis was performed using Microsoft Excel 2017.

Table 2 Technologies used as input to stimulate discussions

Area	Application	Example technology
Monitoring	Physiological parameters	IoT wearable devices
	Self-reported wellbeing	Mobile specific apps
	Analysis of behavioral patterns and safety	Cloud based analysis applications
	Monitoring of general condition-improvement or deterioration in time	Smart environmental sensors
Education	Education and adherence to condition specific therapy	Social networks and digital media
	Education and lifestyle—prevention: activity, health, cognitive decline	Wellness apps and devices
Management	Collection and sharing of clinical patient data	Mobile apps and cloud based applications for data sharing
	Social connectedness and peer support	Social networks
	Scheduling and daily life management	Mobile social apps

3 Results

As showed in Figs. 1 and 2, regarding the perceived usefulness of technological devices, older adults gave very high rates both for what concerns perceived usefulness 'for myself' (M = 4.4, SD = 0.4), and 'for my formal and informal carers' (M = 4.4, SD = 0.7). In contrast, average informal carers' rates resulted relatively low, both for what concerns 'usefulness for the person I care' (M = 2, SD = 0.7), and 'usefulness for my work as a carer' (M = 2.9, SD = 0.7).

Care and social workers recognized safety, monitoring of physiological parameters and apps that help to organize daily activities as the most useful for frail older adults (Figs. 1 and 2). Conversely, health professionals gave lower ratings to these kind of apps, especially those concerning monitoring (Physiological parameters; Self-assessment of wellbeing; Safety and critical event management).

Concerning the likeliness to use the applications presented (Fig. 3), social workers (M = 2.9, SD = 0.6) and the multidisciplinary team (M = 2.6, SD = 0.7) were more cautious with regards to the use of the ICT presented compared to care workers (M = 4.4, SD = 0.7), informal carers (M = 3, SD = 0.6), and older adults (M = 4.3, SD = 0.5).

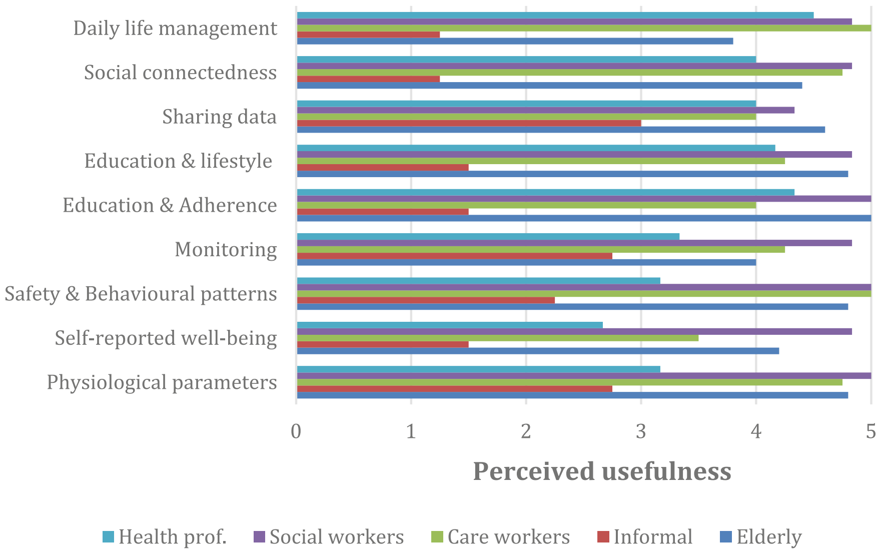

Fig. 1 Perceived usefulness ("usefulness for myself/the person I care for/my patients) for personal well-being of eCare solutions in different application areas

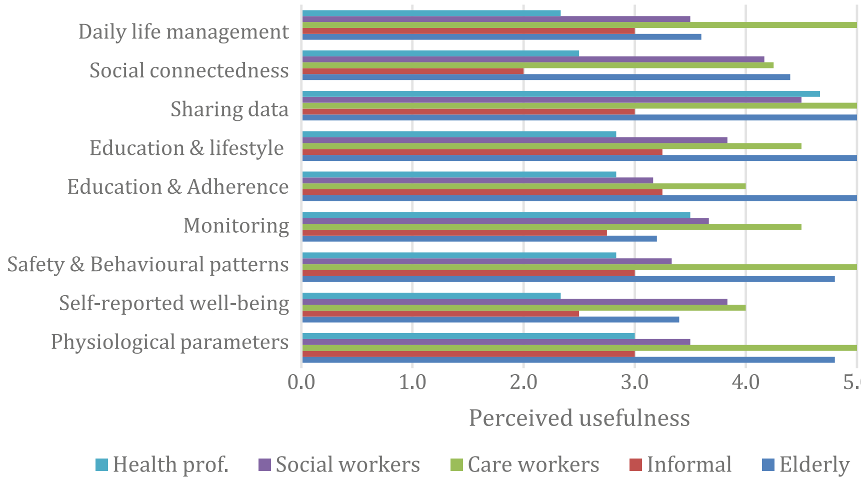

Fig. 2 Perceived usefulness ("usefulness for my carers/for my work) for care and assistance activities of eCare solutions in different application areas

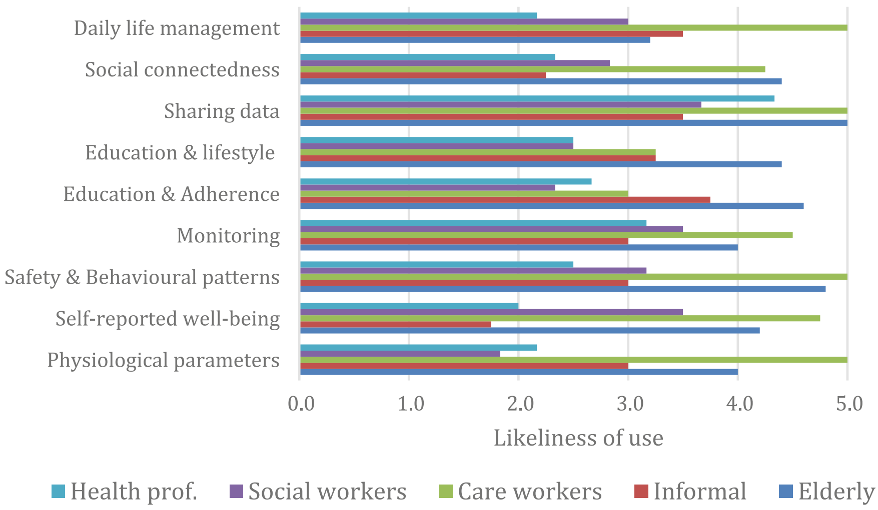

Fig. 3 Perceived likeliness of use of eCare solutions in different application areas

4 Conclusions

The data collected was of great interest for the ProACT system development and trial activities. Overall a comprehensive selection of potential end-users was evaluated with regards their views on the needs, requirements and future application of the system within the Italian context. The approach above is critical to the understanding of an integrated care ICT project such as ProACT, which covers both the vertical (primary, secondary and tertiary) and horizontal (health, social and community) levels of care for older adults. The analysis provides clear indications for the development of the ProACT system as well as for future related systems.

An interesting finding of the present study is the divergent opinion between end users and their informal carers about usefulness of ICT solutions. The analysis of these data must consider the difference of perspective of the specific groups involved: older adults had very low confidence with technology. To note that the group of informal carers was primarily composed of the relatives of older adult participants with severe cognitive impairment, and this may have influenced their perception of usefulness for a wider group of older adults. It is also important to note that while providing the ratings, informal carers tended to underestimate the ability of their relatives in using any device independent of support, regardless the level of complexity.

When asked about the usefulness of technological applications from the formal carers' perspective, rates about usefulness were generally low. In a follow-up discussion after the completion of the questionnaires, the group of the care workers agreed that all applications shown are potentially very useful as tools to enhance the quality of their work: the monitoring of physiological parameters and the safety of older adults at home. Informal caregivers however viewed the ICT as less useful and acceptable to support older adults managing multimorbidity and disability at home. This may be explained by the fact that they don't feel it is safe to let their relatives independently collect and act on the data presented. However, they agree that sharing such data with other stakeholders may be positive. Common to all the groups is the positive appraisal of applications and ICT to promote the collection and sharing of health data between older adult users and their caregivers.

Finally, when asked to rate likeliness to use the applications presented, differences emerged between care workers and health professionals, on one side, and social workers, informal cares and older users, on the other side. This difference may be due to the fact that care and health professionals are aware about the difficulties faced in introducing these technologies in health services.

The success in introducing and using these systems will be determined by a strong iterative co-design approach cognizant of cultural context and national/regional service delivery. It is important that all support actors to older adults are aware about what technology can offer and how it can be effectively utilized in the provision of care.

Another issue for a key approach to the development of systems such as ProACT by professionals is that their reliability must be demonstrated, information to this regard should be properly collected, analyzed and disseminated not only to technology teams but also to health services and policy groups responsible for procuring and implementing such technologies.

At a design level, end-user interfaces should be simple to use and appropriate for a daily use also by frail older adults. This is a critical factor in order to improve the confidence of informal care givers towards older adults using such solutions.

Care workers reflected they are in need of more support in their work and this is another reason why these systems may have a positive endorsement by this group if their reliability and effectiveness can be clearly shown.

Finally, participants in this study overwhelmingly endorsed solutions that support and enhance the exchange of information between the older adults and their respective care support actors. This sends a positive message particularly to health services and policy groups reviewing their potential future uptake in the Italian context, as part of a digital integrated approach to care.

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ViTA: Virtual Trainer for Aging

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Abstract ViTA (Virtual Training for Aging) is an experimental system that aims to strengthen the memory of the people who suffer the first symptoms of dementia and feel the risk of losing their ability to recall significant events in their lives due to the progression of the disease. ViTA exploits concepts of the reminiscence and behavioral therapies to improve cognitive, emotional and social functioning by supporting patients with dementia. Caregivers interact with ViTA to collect fragments of memory and organize them into a knowledge map in which each fragment is linked to the other through emotionally significant stories. A conversational interface allows the navigation of the knowledge map referring to each patient. Thanks to the Artificial Intelligence algorithms implemented in ViTA, patients can access the system to review their memories and stories, leveraging on a conversational interface based on speech and textual interaction modalities in addition to a more traditional interactive interface. ViTA will be tested and verified over the next months by a group of elderly people with early dementia symptoms at the Geriatrics Department and Long Term Care facilities of the Casa Sollievo della Sofferenza Research Hospital

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and it is implemented on top of the IBM Watson platform integrated with software tools derived by previous research experiences.

Keywords Dementia · Memory loss · Caregivers · Quality of life · Quality of care
Isolation reduction

1 Introduction

Aging is a risk factor for dementia, which counts around 10 million new cases every year and is the major causes of disability and dependency among older people worldwide [1]. The progress in fighting this class of pathology is progressing but a cure is still far to date [2]. A number of areas, which can complement the pharmacological approach, are under investigation to slow the pathology progression. Research efforts concentrate on contrasting malnutrition or having an appropriate physical as well as cognitive training and to contrast loneliness. This last factor can be considered as an emerging risk factor that has implications for personal, economic and societal well-being [3].

Several non-pharmacological treatments targeting cognition and functionality have been proposed for patients with dementia [4–7]. Among possible cognition-focused interventions for people with dementia, the Reminiscence Therapy (RT) is an individualized approach to help cognitively impaired older and their families in identifying personally relevant goals and devising strategies for addressing these [8], with emphasis not on performance enhancing on cognitive tasks as such, but on improving functioning in the everyday context [9]. Two studies explored group reminiscence [10, 11], and another reminiscence group intervention [12] evaluated effectiveness in preventing cognitive impairment progression and enhancing affective function. The results showed improvement in most variables including cognition and depression in treated patients with respect to controls [12].

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Other studies have reported that the cognitive and emotion-oriented care approach seeks to improve cognitive, emotional and social functioning by supporting patients with dementia [13, 14].

From a state of the art point of view, some researchers have investigated new solutions for cognitive assistance in the last three years (serious games, virtual reality environments including Augmented Reality technology, and robotic systems) [15]. The research consisted in exploiting software platform allowing the support of new assistive tools that are less expensive and more accessible and could be used as a re-education tool helping to slow the decline of people suffering from dementia [15].

Within this context and under the IBM Impact Grants Program, the ViTA (Virtual Training for Aging) project was developed thanks to the collaboration between the IBM Italia Foundation and the IRCCS Casa Sollievo della Sofferenza, a research hospital located in Apulian region (Italy). ViTA aims to strengthen the memory of those people who suffer the first symptoms of dementia and feel the risk of losing their ability to recall significant events in their lives due to the progression of the disease, eventually feeling the risk of isolation, loneliness and lose their own identity.

ViTA candidates itself as a "technological bridge" to break down the barriers and reconstruct links, that naturally exist, between the patient and their caregivers and would help preserving fading memories and the emotions they are able to generate.

On the one hand, ViTA allows patients to train and reinforce their ability to remember and, on the other hand, it allows those who assist the elders to gain a better insight in their lives being so more effective in their support.

Moreover, at the basis of the ViTA project, there is also the behavioral therapy.

Traditionally, behavioural therapy has been based on principles of conditioning and learning theory, using strategies aimed at suppressing or eliminating challenging behaviours. More recently, positive programming methodologies [16] have used non-aversive methods in helping to develop more functional behaviours. Moniz-Cook suggests that behavioural analysis is often the starting point of most other forms of therapeutic intervention in this area [17] and can be wholly consistent with person-centred care. Behavioural therapy requires a period of detailed assessment in which the triggers, behaviours and reinforcers are observed and their relationships made clear to the patient. The therapists use chart or diary to collect information about the behavioural symptoms, and interventions are based on the analysis of these findings.

For Emerson, planning an intervention should focus on three key features: identifying the individual's preferences; changing the context in which the behaviour occurs; and using reinforcement strategies and schedules that reduce the behaviour [18, 19].

Few studies have shown so far the efficacy of behavioural therapy in the context of dementia [17, 20]. There is some evidence of successful reductions in wandering, incontinence and other forms of stereotypical behaviours [21].

This is the context in which ViTA is intended to offer its contribution.

Specifically, ViTA collects fragments of memory and organizes them into a *knowledge map* or memory map in which each fragment is linked to the other through *stories* that help to query and navigate in multiple ways this map. A fragment of memory can be a text, a photograph, a piece of music like a song, or a video that raises an emotion and it is linked to an individual's past events which could involve people, objects, places, and feelings.

Thanks to ViTA, caregivers interact with the elderly and collect fragments of memory thus feeding the system. ViTA also enhances the link between people—the elderly and their caregivers—helping them to build paths into the memory map that correspond to individual experiences or tales actually lived by elders in the past.

ViTA would like to verify how listening back these stories and tales can be cognitively stimulating to improve well-being of the elderly.

Listening to tales and stories of your life could, in fact, counteract excesses due to negative emotional states such as agitation, sadness, and apathy or reinforce and stimulate some positive behaviors such as nutrition, hydration, and movement.

The stories will be tailored according to specific individual life story and needs.

Thanks to the Artificial Intelligence techniques that make up the base of ViTA, patients can talk, review their memories and stories, even simply scrolling through a "memory book". ViTA can be accessed in different ways: through a tablet or a smartphone (the interfaces that will be adopted for the clinical validation), through a collaborative companion robot or through objects of the everyday life made "smart" (such as a lamp or a portrait holder capable of performing audio-visual actions). ViTA communicates through voice, can be interrogated by text or, simply, its interface can be browsed by clicking on images and icons.

ViTA will be tested and verified over the next few months by a group of elderly people with early dementia symptoms followed by the Geriatrics Department of the IRCCS Casa Sollievo della Sofferenza and it is implemented on top of the IBM Watson platform.

2 Materials and Methods

2.1 General System Overview

The ViTA system will give an answer to the patient's need to collect, preserve and train individual memories, implementing a virtual "place" where relevant facts related to past people, locations, events are stored and ready to be linked and contextualized.

There will be two main families of users that interact with ViTA: (a) users that need to be supported, and (b) caregivers, both formal (physicians, nurses and other healthcare professionals) and informal, such as family members or semi-professional caregivers engaged by the family itself. ViTA offers to the first group of users its support leveraging multiple interaction paradigms and providing users to access to individual memory fragments or to recall *stories*. Stories are personal paths into the memory graph that are recorded and put in the system by caregivers that link a number of memory fragments with precise supporting purposes. To the second group of users, family members or caregivers, ViTA provides an environment which

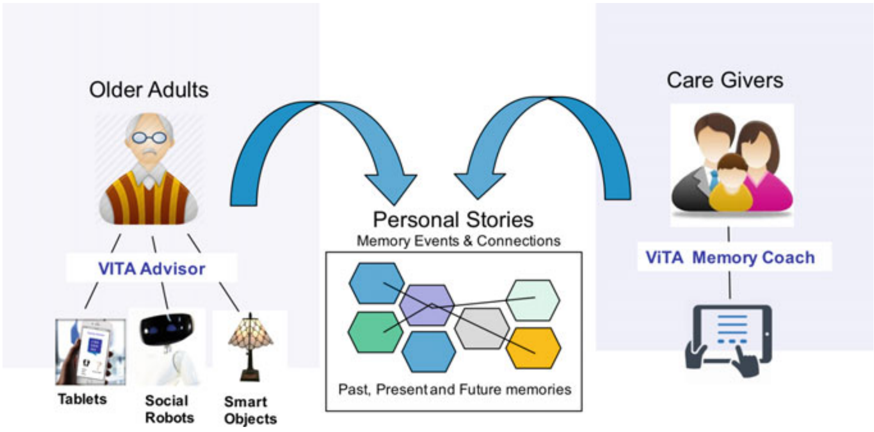

Fig. 1 Overall system context

offers the possibility to feed, organize and curate the content into the memory graph, building memory fragments as well as stories.

Figure 1 represents the overall system context.

2.2 *System Main Components and Architecture*

ViTA is built on top of the IBM Cloud cognitive platform integrating a number of cognitive services already available on that platform as well as other additional research components specifically developed for the project. The following picture provides the high-level architecture of the ViTA software platform (Fig. 2).

The system architecture is organized into 3 main layers:

(a) Interface/access control.
(b) Natural Interface Management.
(c) Short and Long Term Memory management.

The first layer has the responsibility to provide and manage a multi device interface component. It includes an interface system that has been developed with HTML5 which provides multiple access modalities including tablet/smartphones as well as the access to the system from smart objects such as a smart photo portrait as well as from an assistive robot. This layer manages also the access control to the system including identification as well as profiling of the user preferences.

The second layer has the responsibility to manage and understand the conversations and the interactions with users by leveraging a set of natural language processing components. The system provides three interface styles namely: interactive-touch, voice activated modality (leveraging speech-to-text and text-to-speech components) and the textual/chat modality. A user can "converse" with the system by utilizing

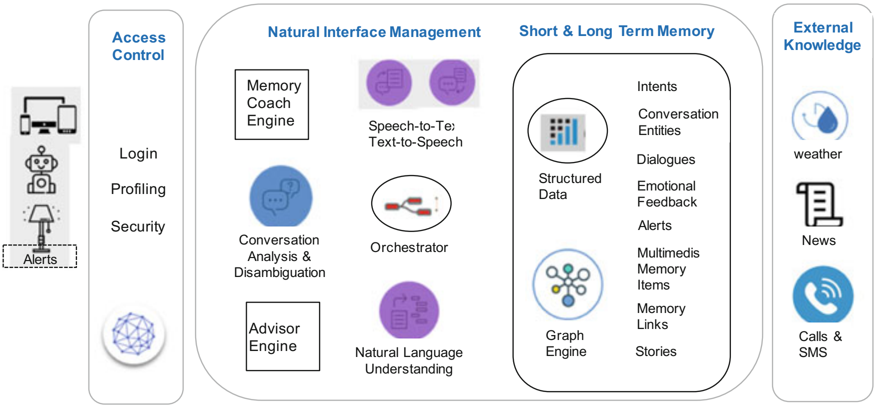

Fig. 2 ViTA was developed using the cognitive computing services on the IBM Watson platform, and other advanced components and data analysis systems

one or more interface styles. All conversations are interactively analyzed by using a machine learning layer to semantically decode and interpret user "intents and requests". The machine learning layer has been trained to understand, during the conversation, multiple user "intents" which are then identified by the system. Currently, the system is able to understand requests that are targeting the access to the memory as well as requests that require a form of "well-being" advisory.

The last layer manages the short and the long term memory. In particular, memory data are stored both in a structured database management system as well as in a Knowledge Graph upon which set of specialized cognitive services act. They are able to support various forms of reasoning, the retrieval of the contents and their analysis, as well as to provide natural language understanding to support conversational interfaces.

Eventually, ViTA is connected to a set of external services to enrich the conversation experience by collecting external facts such as the ability to access to general knowledge as simple as weather forecasts or daily news or to access to simple phone services such as making a call or sending a message.

3 Experimentation Phase and Expected Results

3.1 Procedure

Initially, ViTA will be experimented involving ten elderly people presenting the first symptoms of dementia selected on the base of a voluntary acceptance of being involved in the study and with compatible characteristics in order to interact with the system. Elderly people will be recruited by the multidisciplinary team of the

Geriatrics Department of the "Casa Sollievo della Sofferenza" Research Hospital in San Giovanni Rotondo (Italy).

The main research question will be to verify how listening back the stories and tales proposed by ViTA can improve the cognitive functions and overcome altered emotional states (i.e., apathy, agitation), stimulating positive behaviors (i.e., physical exercises, nutrition monitoring) and improving the well-being of the elderly.

The first phase of the trial will encompass the collection of meaningful memories of the patients through a guided survey, assisted by a formal (psychologist) and informal (family) caregiver, of a personal memory photo album. This session of storytelling will build the foundation upon which to build the elements of memory that the caregiver will load on to the system as the ground information.

The "stories" to propose to the patients will be built as an aggregation of the elementary contents of his/her memory. Patients and relatives will be formed on the use of the system. Patients will listen through a tablet the stories according to a program established by the medical-psychological team.

3.2 Experimental Protocol

At the baseline and end of the trial period, the following parameters will be collected by a systematic interview, clinical evaluation and review of records: demographic data, clinical and medication history, and a complete multidimensional and cognitive-affective assessment. In particular, cognitive status will be screened by means of the MMSE [22], Clinical Dementia Rating (CDR) [23], Clock Drawing Test (CDT) [24], and Frontal Assessment Battery (FAB) [25]. Neuropsychiatric symptoms will be evaluated with the Neuropsychiatric Inventory (NPI) [26] including the following 12 domains: delusions, hallucinations, agitation/aggression, depression mood, anxiety, euphoria, apathy, disinhibition, irritability/lability, aberrant motor activity, sleep disturbance and eating disorder. Affective status will be evaluated using the Hamilton Rating Scale for Depression (HDRS-21) [27]. A CGA (Comprehensive Geriatric Assessment) will be carried out evaluating the following domains: functional status with activities of daily living (ADL) index [28], instrumental activities of daily living (IADL) scale [29]; cognitive status with the Short Portable Mental Status Questionnaire (SPMSQ) [30]; comorbidity with the Cumulative Illness Rating Scale (CIRS) [31]; nutritional status with the Mini Nutritional Assessment (MNA) [32]; the risk to develop pressure sores with the Exton-Smith Scale (ESS) [33]; the number of drugs used by patients and the co-habitational status.

For all caregivers the Caregiver Burden Inventory (CBI) [34] will be administered.

At the end of the trial period, the System Usability Scale (SUS) [35] will be used to evaluate the usability and acceptance of the ViTA system.

3.3 Expected Results and Advantages

We expect to prove the usefulness of the ViTA platform to:

– increase cognitive performance and promote positive behavior. ViTA exploits concepts of the reminiscence and behavioral therapies leveraging, in the first case, cognitive and emotion-oriented care approach to improve cognitive, emotional and social functioning, and, on the other, leveraging principles of conditioning and learning theory using strategies aimed at suppressing or eliminating challenging behaviors.
– improve the quality of life of older persons and of their care providers. For persons at risk of dementia, it will serve as a tool to increase resilience. For persons with perceptions of loneliness, ViTA will provide connectivity to the community constituted by care providers, family and friends and, in the end, to connect them to their personal memories. Thanks to the ViTA technology, users and care providers will have access to information not previously available.
– on a more general level and as a consequence of the previous benefit, to reduce admissions and days spent in care institutions, prolonging the time spent living at home when emerging functional impairments occur because of ageing.

4 Conclusion

The main objective of the ViTA project is to generate an impact in stimulating memories, essentially when patients are at their home, the place where they spend most of their time, especially when their health status starts to worsen. Furthermore, the availability of the Watson components will allow for the development of smart applications within ViTA platform capable to maintain patient indipendence and safety giving a real support in daily-life-activities as well as in remaining integrated into social life, despite age and/or existing disabilities. Moreover, the whole system will provide the elderly with different types of emergency assistance and security features, automated timers, and alerts. These systems allow individuals to feel secure in their homes knowing that help is only minutes away. Finally, yet importantly, the platform will make it possible for family members to monitor their loved ones from anywhere with an internet connection.

Considering that the ViTA is based on some concepts emerging from both reminiscence and behavioral therapy, during the pilot trials we will focus on demonstrating that the use of the implemented platform can improve the functional, nutritional, cognitive, affective and neuropsychiatric state, and quality of life of older people with dementia. The ViTA system could prove a viable option in the support of caregivers too.

With the development and validation of ViTA, we seek to enrich the literature in this field taking advantage of this novel approach based on cognitive computing and human-machine interaction.

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Do the Right Task! Supporting Volunteers Timetabling with Preferences Through the SpONSOR Platform

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Abstract SpONSOR is an AAL project that aims at developing, testing and implementing an ICT platform to facilitate the posting, browsing and exchange of key information between competence-offering seniors and search-based requests from competence-demanding organizations within the public, private and voluntary sectors. This paper describes a specific aspect addressed in developing a pilot for the project dedicated to volunteering associations support. Very important when dealing with volunteers is their assignment to the right activities not only suitable for their capabilities but also for their current wishes. The paper describes a complete prototype called SpONSOR$_T$ developed to support a volunteering organisation called Televita. SpONSOR$_T$ helps managers to better allocate different activities to the volunteers with the overall aims to find the more suitable match in terms of aptitude and personal inclinations. Attention is given to the description of the end-to-end aspects of the prototyped application from the problem definition to its day by day use.

1 Introduction

Nowadays, as people's life expectancy is getting higher, it becomes crucial to find out solutions able to maintain seniors active and independent, by assuring them a decent Quality of Life and fostering their feelings of satisfaction and self fulfillment.

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It has been claimed that the most common perceptions of active aging were having/maintaining physical health and functioning, leisure and social activities, mental functioning and activity, and social relationships and contacts [5]. Of course, these perceptions need to be maintained despite any different life events by which they might be affected, and also retirement, which actually represents a major life event, can influence the life satisfaction levels of older adults [6, 12, 25]. In fact, although retirement often represents a voluntary transition, sometimes older workers actually perceive it as forced, mainly as result of health-related issues or organizational restrictions [16, 23], possibly undermining seniors' perceived well-being. Indeed, it has been reported that although retirement is related to freedom and flexibility in terms of living life without needing to work, it is also linked to losses in financial and social resources and a reduced sense of self-worth [20]. As a result, older adults may be anxious about how daily life will be structured in the absence of work-related activities [24]. A way to overcome with such issues can be found in "bridge employment". Bridge employment has been defined as "*the transition into some part-time, self-employment or temporary work after full-time employment ends and permanent retirement begins*" [15]. Through it, older adults find some help in balancing work and leisure time while remaining engaged in economically and socially productive activities. Additionally, they can fulfill subjective important aims, such as having a purposeful pastime, structuring one's time, and increasing self-esteem [17]. Consequently, bridge employment can therefore contribute to the well-being of individuals and their families.

Volunteering has been seen to be another post-retirement activity besides paid work that benefits the elderly [26]. In fact, it has been shown that volunteering retirees report better physical health, cognitive performance, and psychological well-being than non-volunteering retirees [22]. Additionally, previous findings unveiled that volunteering post-retirement activities are strictly related to the individual perception of generative meaning of the work, namely the seniors' need of sharing their experiences and knowledge to others, particularly to the next generation [14].

Within the above mentioned framework, it can be inserted the annual Call number 6 (2013) for project proposals of the *Active and Assistive Living* (AAL) Joint Program, a European funding initiative aiming at promoting the synthesis of new ICT solutions for supporting people to age well. It specifically asked for "the development of ICT-based solutions which enable older adults to continue managing their occupation at work in an office, a factory or any working environment; in a first or subsequent career, in paid or voluntary occupation including local social activities while preserving health and motivation to remain active". Additionally, the specific call was looking for solutions that promote, enhance and sustain:

- paid activities (including for example professional, entrepreneurial/small business and self-employment)
- unpaid activity (e.g., volunteering, knowledge sharing, counseling).

The next section is devoted to the description of selected works that face the problems of teamwork building by combining individual aspects and computational models. Subsequently, the paper provides an illustration of the SPONSOR project [8], one of the selected proposal for that call, which specifically focuses on volunteering activities for seniors. The remaining sections will describe the Televita case study.

2 A Selection of Works in Teamwork Building

Nowadays the composition and formation of effective teams is a highly relevant topic for a number of fields like, for example, educational scenarios, companies to assure their competitiveness, and within a wide range of emerging applications exploiting multi-agent collaboration (e.g., crowd-sourcing, human-agent collaborations). An effort has being carried out in order to consider as much as possible also individual characteristics in team building and to include them as variables in the proposed computational models. It is also worth noticing that there have been a number of theories developed over the years to profile human personality. The most popular ones are the Five Factor Model (a.k.a., “Big Five”), which uses five broad dimensions to describe human personality [10], and the Myers-Briggs Type Indicator (MBTI) scheme designed to indicate psychological preferences in how people perceive the world and make decisions [19]. Additionally, in the field of organization management it is worthy to mention the Belbin theory [4] which has been made operational through the Belbin Team Inventory, that is a behavioural test assessing how an individual behaves in a team environment according to nine team roles. Finally, it is worth mentioning some of the works on synergistic team composition which share, with our approach, an integration of psychological and computational aspects aimed at improving the quality of life of the people involved as well as the productivity of the organizations for which they work. Farhangian et al. investigated the effect of task dynamics on the teamwork [13]. In this work, after describing a general approach to select effective team members based on their personalities and skills, the authors compared two different sample strategies that managers could use to select team members: by minimizing team over-competency and by minimizing team under-competency. In [2] Alberola et al. proposed a tool which combines artificial intelligence techniques such as coalition structure generation, Bayesian learning, and Belbin’s role theory to facilitate the generation of working groups in an educational context. The proposed instruments aim at taking into account the feedback of other team-mates in order to establish the most predominant role of a student instead of self-perception questionnaires, trying to handle uncertainty with regard to each student’s predominant team role. Additionally, since it considers information from several interactions in order to improve the estimation of role assignments, it is iterative. Competences and personality of team members have been considered as key factors for team performance in [1]. In this work, the authors presented a computational model to form heterogeneous students teams that incorporates those key factors and proposed an algorithms based on an Integer Linear Programming (ILP) formulation, and a heuristic algorithm to partition a classroom into teams of even size and homogeneous performance. It resulted that the one based on an ILP formulation suited small problem instances, while the heuristic algorithm was more appropriated for larger problems. Finally, some other examples in this direction can be found in [18] and [3].

3 The SpONSOR Project

The SpONSOR project [8] aims at developing, testing and implementing an ICT platform that facilitates the posting, browsing and exchange of key information between competence-offering seniors and search-based requests, from competence-demanding organizations within the public, private and voluntary sectors. In particular, SpONSOR aims at enhancing senior persons' access to a wide range of occupational positions, in this way meeting the aims of the Call. Figure 1 shows the context in which the SpONSOR system operates. Specifically, the perspective taken is the one of supporting Organizations that favour occupation (upper part of the figure) creating a software platform that facilitates contact between people who offer their work and people in need of support (lower part). Indeed during the development of the project we have particularly focused on the relation between producers of work (the Organizations) and the consumers (the older workers). The third group of people (those in need for a work support) will be de facto integrated inside the role of the organizations.

Additionally, from the user requirement analysis it clearly emerged that loosing job when at an high age is really problematic. Job loss, for example, is associated with a 4.78% increase in depressive symptoms in the USA and to a 3.35% in Europe [21]. The older people risk to feel abandoned, marginal in the society and at high risk of depression. One of the characteristics that emerged from user requirement analysis is the one of adding to the platform capabilities for giving the sense of continuous assistance to people when they interact over time. In the paper, after a general presentation of the project, we especially report on a specific instance of the system developed to support the needs of an Italian volunteering association. In fact, being responsible, within the SpONSOR project, for the management of Italian case

Fig. 1 The context in which the SpONSOR system operates

studies, we focused mostly on the situation of the Italian older people who lose their jobs. In particular, we realized that realities which help older people in finding again a job, even because of the crisis situation that has continued since 2008, are few. In this context, however, volunteering organizations play an important role in retaining older people occupied. Thanks to these associations older people feel more useful to the society and less abandoned, resulting in a better attitude in searching new either paid or unpaid activities. This paper focuses on one of such organizations and show the application of the SpONSOR concept to its specific needs. The case is devoted to the problem of allocating older volunteers to a set of activities proposed by the organization, with the overall aim to find the best match and maximize the level of satisfaction of older users.

4 The Televita Case

Televita[1] is a volunteering association which is active since 1993 within the 2nd and 3rd municipalities in Rome. The association was born within San Frumenzio parish and it is moved by religious spirit. Among the activities we can mention tele-assistance services (tele-friendship) and a 24/7 active helpline addressed to lonely seniors who need support. Beside this, there are several laboratories that involve seniors both as attendees and conductors. Examples include a computer lab, a tailoring lab, an Italian language teaching for foreign people, etc. Furthermore, not seldom, the association organizes cultural events as concerts, museum visiting, theatre, etc. The overall objective is to maintain the older people active and motivated leveraging upon individual aptitudes and/or competencies.

At present time, the Televita's objective is pursued through the periodic screening of volunteers by means of a customized questionnaire (see Fig. 2) that investigates the volunteers' aptitude to teamworking. The idea is that the questionnaire allows detecting specific aspects of the volunteers that are best suited for specific activities. In fact, the interpretation of the answers allows a better assignment of activities to the volunteers, increasing their level of satisfaction and possibly reducing the number of drop-outs. Specifically, behavioural and emotional aspects of volunteers are construed and offered activities are tailored according to volunteers' aptitude and competencies. Such questionnaire is structured so as to allow the extraction of 8 relevant features (4 of them essential for the *internal* aspects of the organization and 4 for the *external* ones) for each volunteer. Specifically, the different foreseen roles/features are:

– The **President**, (**P**) coordinates common efforts so as to achieve the ultimate goals. This person is at least normally intelligent, yet not necessarily brilliant and gifted of creative thinking features. He is a dominant one, yet in a relaxed and not necessarily proactive manner. A president can clearly see strengths and weaknesses of the other members of the team. If in charge of taking an educational

[1] http://www.televita.org.

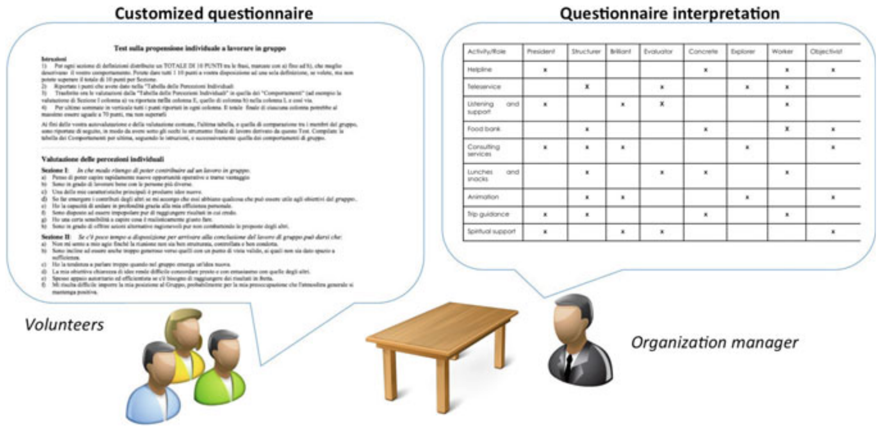

Fig. 2 The Televita current modalities in managing the organization. Volunteers answer a customized questionnaire and managers, by interpreting the results of the questionnaire, assign activities to them

or operational decision, a president can take it with confidence after everyone has expressed his opinion.

- The **Structurer**, (**S**) represents the leader of the working group. He gives “form”, “structure” to the actualization of the team’s efforts. He always has the concern of giving a logical sense to the discussions and unifying the ideas, goals and practical considerations. In fact, its goal is to make the decisions taken.
- The **Brilliant**, (**B**) is the source of original ideas, suggestions and proposals for the team. His ideas are often completely new and proposes a radically original attitude towards things to do. He has fully confidence in itself and is uninhibited. It may be unpleasant and often offensive when criticizing others ideas.
- The **Evaluator**, (**Ev**) contributes in producing precise and unbiased evaluations. He often tends to stop a team before he can engage in a wrong project. He might be slow in making an opinion, yet he has the most objective thinking within the team. One of its most significant abilities is to assimilate, interpret and evaluate large quantities of written, even complex, material. He can lower team morale with negative evaluations. He is solid and collaborative, but not “warm”, imaginative and spontaneous.
- The **Concrete**, (**C**) is the practical organizer. He can translate the team’s plans into accomplishments. He has a disciplined attitude to things to do. He is sincere, confident in others and is hardly discouraged. It works efficiently, systematically and methodically, even though sometimes he lacks in flexibility.
- The **Explorer**, (**Ex**) is the member of the team who goes outside of the organization so as to capture information and ideas, developing them for the common interest. He is able to quickly capture the relevance of new ideas. He can make mistakes by taking commitments due to its uncontrollable enthusiasm.

Table 1 The current Televita organization

Number of volunteers	activity type
65	Helpline
8	Psychological/spiritual support
30	Animation/socialization
15	Coordination/organization
3	Training
5	Technological support

– The **Worker**, (**W**) is the most sensitive of the team. He has major concerns about the doubts and needs of other components. He has the highest degree of internal active communication capacities, being friendly, popular, yet not too intuitive. It is the promoter of unity and harmony, an important ability especially when the team is under pressure.
– The **Objectivist**, (**O**) worries about what might end up badly. He is not necessarily a group's propositional component, yet he maintains a sense of duty that he can communicate to others. Its goal is to achieve goals and aims at doing things to the end. It may lose sight of the overall goals as a whole, losing himself into small details.

After the interpretation of the questionnaire, for each volunteer, each of these features is associated to an integer value representing the relevance of the specific feature for the specific volunteer. This information is, subsequently, exploited in order to better allocate persons in a work group. The following line, for example, describes a person with marked *president* feature. This characterizes the person as suitable to carry out decision-making tasks. The person is, nevertheless, evaluated as *brilliant* and as an *evaluator*, hence, suitable (albeit with lesser relevance) in performing other kinds of tasks.

$$\langle P = 21, S = 5, B = 11, Ev = 12, C = 5, Ex = 8, W = 7, O = 1\rangle$$

The relatively high number of volunteers, along with the high number of activities to be carried out, however, makes it extremely difficult to associate people to their "right" tasks. Specifically, Televita currently manages the work of 126 persons partitioned according to the schema in Table 1. The organization and the management of such a number of users makes manual coordination impracticable. Within this context, SpONSOR helps in defining the role which better fit with each volunteer's profile. Specifically, activities are automatically mapped into behavioural competences of users first (abilities to work in group with different roles) and then across other aspects (interests, background, etc.). The assignments are then made so as to maximize the level of satisfaction of volunteers.

5 Timetabling as a Binary Integer Programming Problem

We have interviewed a number of times some of the Televita coordinators. Thereafter we have chosen to model the problem of assigning a set of activities to a set of volunteers, while taking into account behavioral and emotional aspects, as a Binary Integer Programming problem.[2] In the following, we will summarize the proposed model.

Specifically, at the core of the model there is a set of volunteers V whose activities should be decided. Each volunteer $v \in V$ has his/her own temporal availability $\mathbb{T}_v = \left\{\left[lb_1^v, ub_1^v\right], \ldots, \left[lb_i^v, ub_i^v\right]\right\}$ representing the temporal intervals, up to the foreseen planning horizon, within which volunteers have provided willingness in performing volunteering activities. Furthermore, each volunteer has associated a *psychological profile vector* $\mathscr{P}_v = \left\langle p_0^v, \ldots, p_7^v\right\rangle$ representing the 8 values resulting from the interpretation of the questionnaire. As an example, we provide the temporal availability and the psychological profile vector for a fictitious volunteer.

$$\begin{aligned} \mathbb{T} = \{[8:00, 11:00], [13:00, 15:00], [32:00, 35:00]\} \\ \langle P = 15, S = 5, B = 8, Ev = 14, C = 5, Ex = 8, W = 10, O = 5\rangle \end{aligned} \quad (1)$$

At the same time, a set of activities A should be carried out by the above volunteers. Each activity $a \in A$ has its own *execution interval* $t_a = [lb^a, ub^a]$ representing the span of time within which the activity is carried on. In addition, each activity has associated a *skill vector* $\mathscr{S}_j = \left\langle s_0^a, \ldots, s_7^a\right\rangle$ of boolean values representing the relevant skills needed to perform the activity. As an example, we provide the execution interval and the required skills vector for a fictitious activity.

$$\begin{aligned} t = [8:30, 10:30] \\ \langle P = 0, S = 1, B = 0, Ev = 1, C = 0, Ex = 1, W = 1, O = 0\rangle \end{aligned} \quad (2)$$

Given these premises, the overall problem consists in associating to each volunteer one or more activities while taking care of making volunteers happy with their work. To this purpose, we create a binary decision variable $d_{v,a} \in [0, 1]$ for each of the $\langle v, a\rangle$ couples and assign it the following semantic: $d_{v,a}$=1 if and only if the volunteer v performs the activity a. The task of the solver will be to assign values to such variables while guaranteeing that (i) each volunteer performs at least one activity (we recall that volunteers should feel useful), (ii) each of the activities is performed by someone (more specifically, by exactly one volunteer), (iii) volunteers' temporal availability is compatible with the assigned activities temporal span and (iv) each volunteer performs at most one activity at a time.

Additionally, in order to consider the volunteers' attitudes and preferences, we introduce the concept of *adequacy* $w_{v,a} = \mathscr{P}_v \times \mathscr{S}_a^T$, representing how much a volunteer v is "adequate" in performing the activity a. As an example, assigning the

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[2] A complete description of the solver for SpONSOR$_T$ is given in [7].

activity described by expression 2 to the volunteer described by expression 1 would result in an adequacy of $15 \times 0 + 5 \times 1 + 8 \times 0 + 14 \times 1 + 5 \times 0 + 8 \times 1 + 10 \times 1 + 5 \times 0 = 37$.

The objective function, therefore, can be expressed by means of the following expression

$$\sum_{v \in V, a \in A} w_{v,a} d_{v,a}$$

Maximizing the above expression, given the premises, guarantees an optimal assignment of the activities to the volunteers.

Once the decision variables have been introduced, it is possible to enforce constraints among them. Specifically, guaranteeing that each volunteer performs at least an activity, can be expressed by means of the following expression

$$\sum_{a \in A} d_{v,a} \geq 1 \quad \forall v \in V$$

Analogously, guaranteeing that each activity is performed by exactly one volunteer can be expressed by means of the following expression

$$\sum_{v \in V} d_{v,a} = 1 \quad \forall a \in A$$

The following expression guarantees that temporal constraints are met

$$[\neg \exists t_k \in \mathbb{T}_v : t_k \subseteq t_a] \Rightarrow d_{v,a} = 0 \quad \forall v \in V, a \in A$$

where $t_k \in \mathbb{T}_v$ represents the temporal availability of the volunteer v, t_a the temporal span of the activity a and $t_k \subseteq t_a$ is true if the interval t_k *contains* the interval t_a (i.e., $[lb(t_k) \leq lb(t_a)] \wedge [ub(t_a) \leq ub(t_k)]$), guarantees that the temporal availabilities are met.

Finally, the following constraint forbids the assignment of more than one activity at a time to the volunteers

$$\sum_{a \in O} d_{v,a} \leq 1 \quad \forall v \in V, O \in Overlaps$$

where O represents the i-th set of all the temporally overlapping activities *Overlaps* within the foreseen plan's horizon. Notice that a viable strategy for computing the O sets consists in adapting the "collecting peaks" procedure described in [9].

Although there exist many solvers which can solve the above problem, we have developed a Z3 [11] based application and we have built two different interfaces addressed to, respectively, the association managers and the volunteers. At an early stage, we mostly rely on the above solver's specific solving abilities, without addressing the performance issues related to the resolution of the problem which, as long as the dimensions are kept within the size of the Televita organization, do not seem to be significant. With the increase of the problem size, however, being an NP-Hard problem, the problem will quickly become intractable forcing us to use more sophisticated techniques ranging from domain dependent heuristics to Large Neighbourhood Search approaches or Genetic Algorithm based techniques.

We have realized a complete system, called SpONSOR$_T$ (standing for "SpONSOR for Televita") that has the solver as the back-end and the Apps described in the next section as the front-end. Broadly speaking we can say that SpONSOR$_T$ represents an end-to-end product suited to serve small organizations with similar structure.

6 The SpONSOR$_T$ Front-End

This section describes some of the graphical user interfaces developed, within the SpONSOR$_T$ project, with the aim of facilitating both the definition of the problem and the view of the solution. To this purpose, two different Front-end applications have been developed: (i) a Desktop App, targeted to the association managers, that is aimed at defining the timetabling problem and (ii) a Mobile App, targeted both to the association managers and to the volunteers themselves, that is aimed, mostly, at visualizing the solution of the timetabling problem. As said before, the back-end service, hosted on a separate machine, is responsible for solving the timetabling problem and creates a communication bridge among the different front-end instances.

6.1 The SpONSOR$_T$ Desktop App

The SpONSOR$_T$ Desktop App is aimed at defining the timetabling problem and, hence, is targeted to the association managers. This application provides a general overview of all the volunteers of the association including personal data (e.g., first and last name, gender, date of birth, etc.), the interpretation of the compiled questionnaire, the temporal availability of the users, and more. In a similar way, the application provides access to all the planned activities including their name, their required skills and their temporal span. By introducing new (or editing existing) volunteers and activities, this application allows the definition of the timetabling problem that, through a simple button, is sent to the back-end for resolution. During the resolution process, the solver generates, incrementally, increasingly better solutions until either an optimal solution is found or the organization manager, satisfied with the best solution found so far, interrupts the resolution process.

As an example, Fig. 3 shows a list of the volunteers[3] with their psychological values assigned as a consequence of the interpretation to the answers they gave on the

[3]First and last names have been obscured for privacy issues.

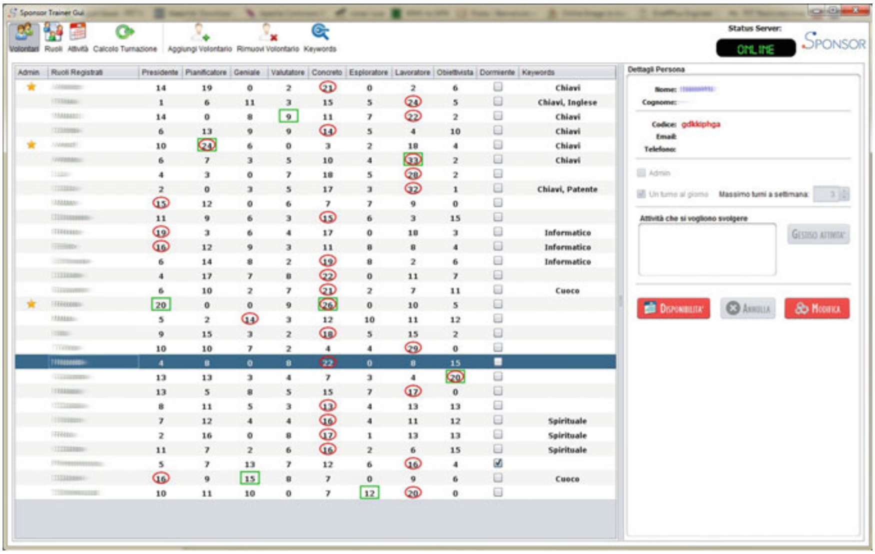


Fig. 3 The pool of volunteers with their specific features both assessed through the questionnaire and declared at the time of subscription

questionnaire. The most interesting aspect of this image is the profiles of the various volunteers resulting from the interpretation of questionnaire. An integer number describes the relevance, for each volunteer, of each feature. The red circles highlight the most relevant feature for each volunteer. On the contrary, the green squares highlight the most relevant volunteer for a specific feature. This formalism reflects the operating modes of the Televita organization which, before the introduction of the SpONSOR$_T$ platform, used a similar table to manually assign activities to volunteers.

Let us suppose that we want to create a new role related to the tele-assistance which requires specific features assessed through the questionnaire. As we can see from Fig. 4, in the devoted panel which is retrievable from the section for role creation, the user can select the required features.

The tele-assistance role is required in order to provide a basic service of Televita which offers daily phone support to seniors at home. As one can see in Fig. 5, a list of needed roles are selected in order to create the phone support activity (which we will call *Televita*, as it being the major activity provided by the organization) and it can be done through one of the forms used for entering new activities into the timetabling problem. Specifically, this form allows the selection of the required roles for the activity (each corresponding to a pre-set of skills, as described in Sect. 4). The presented example translates into four different activities requiring different roles and consequently, different skills. The ability of the manager will decide the proper composition of the working group.

The SpONSOR$_T$ Desktop App allows also the access to a calendar view of all the planned activities in order to have an overall view of the planned quarterly activities

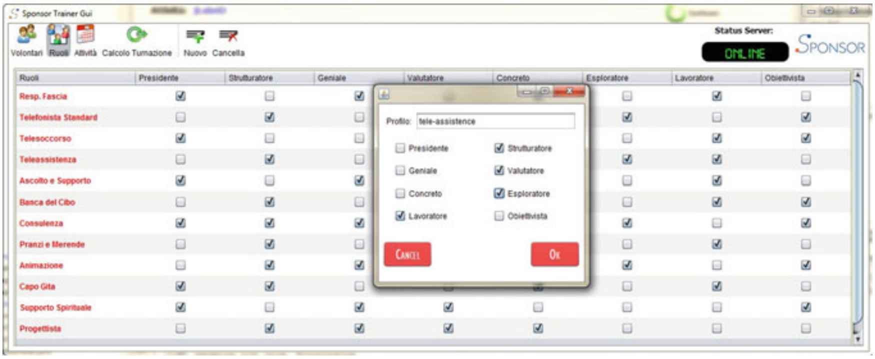


Fig. 4 The graphical user interface form for the creation of new roles based on the features assessed by the questionnaire. In this specific case, the tele-assistance role has been creating

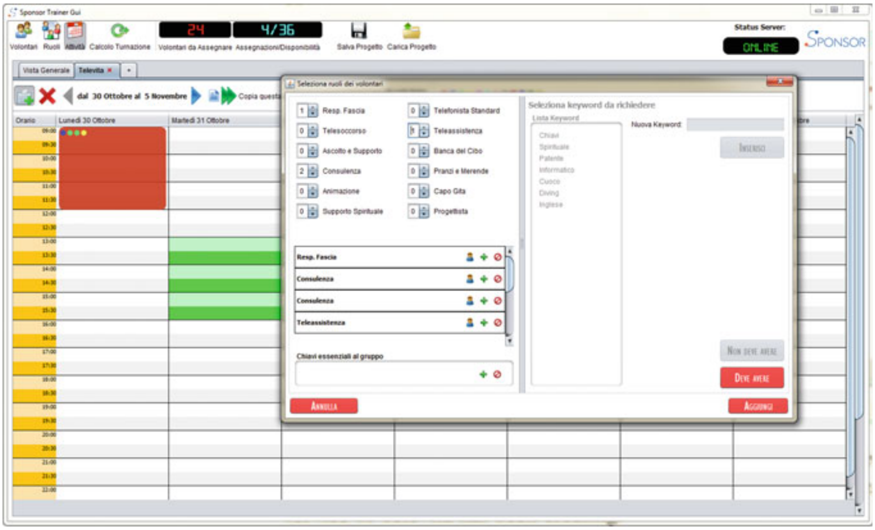


Fig. 5 The graphical user interface form for the creation of a new activity based on the roles needed for a successful service. In this specific case, the phone support service of Televita has been creating

(Fig. 6). Once the assignment problem has been solved, volunteers, having the profile as compatible as possible and compatibly with their temporal availability, will be assigned to these activities.

Finally, once the volunteers and the activities have been defined and a satisfying solution is found, the solution can be displayed as a whole (see Fig. 7) or, depending on the needs, filtered by the different volunteers or by the different activities. The varied solution views can be saved as a PDF and, easily, printed and distributed to the volunteers according to the standard ways of the organization. In addition,

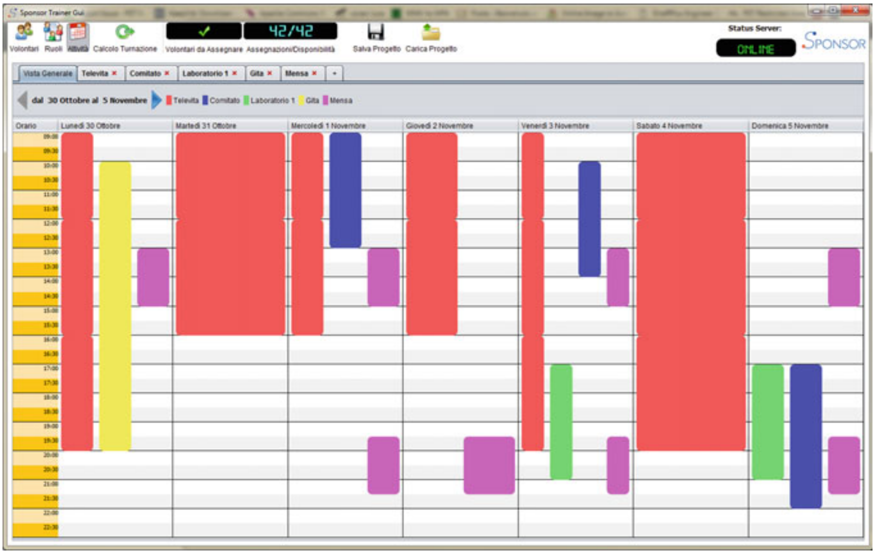


Fig. 6 The graphical user interface form to enter new activities, their required skills and their time span. In the background, the overall calendar view of the planned activities

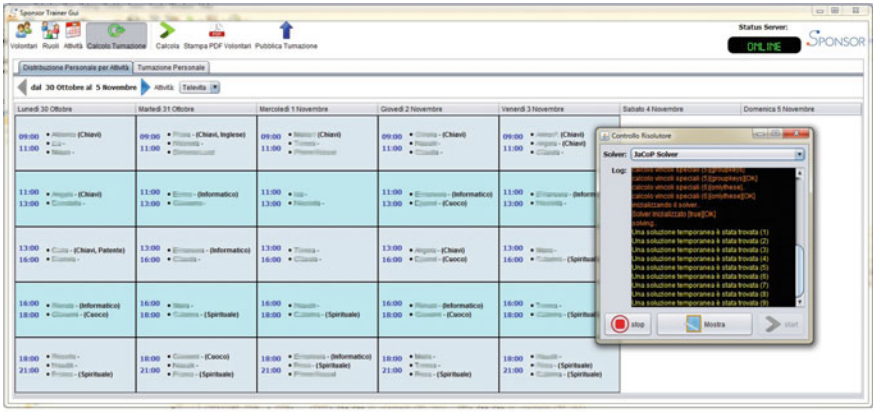
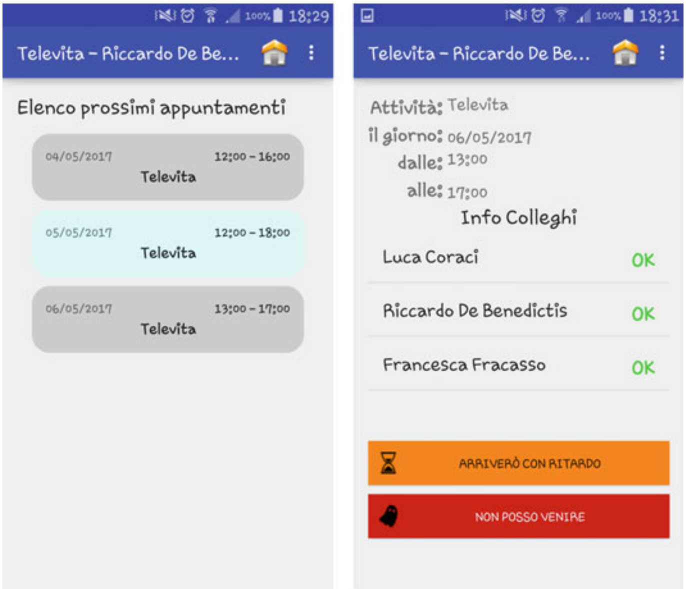


Fig. 7 In the background a possible solution is displayed, while in the foreground the solver is still searching for the optimal solution

the solution for individual volunteers can be transmitted, through Internet, to the volunteers which can cosily visualize it through the Mobile App and, in case of need, make some minor change.



(a) A list of the incoming activities.

(b) Ongoing adaptation of the generated solution.

Fig. 8 An example of use for the SPONSOR$_T$ Mobile App

6.2 The SPONSOR$_T$ Mobile App

In parallel with the Desktop App, the SPONSOR$_T$ Mobile App is aimed at visualizing personalized solutions and, within the permitted extent, at interacting with them. Specifically, when an organization manager is satisfied with the best solution found so far (or, eventually, the optimal solution is found), it is sent to the volunteers which can visualize it. Figure 8a, for example, shows three activities which have been assigned to a specific volunteer. In addition, volunteers can slightly modify the generated solution (as shown, for example, in Fig. 8b). In particular, volunteers can notify, in case, some delay in performing any of the assigned activities. This delay is communicated both to organization manager and to the other volunteers which share the activity time span (in other words, with volunteers in the same work shift). Furthermore, in case of need, volunteers can communicate their impossibility to perform an assigned task. In the latter case, the SPONSOR$_T$ system, besides communicating this information to the interested people, can propose a list of substitutes, sorted according to their relevance in performing the uncovered task, to the organization manager which can choose a replacement.

7 Conclusions and Future Works

The SpONSOR$_T$ platform has been developed in order to answer to specific needs of the Televita association. Nevertheless, it has been conceived in order to meet the needs of any organization where a support in managing the fruitful match-making between activities and human resources is needed. The ultimate goal is foreseen as the ability to assign the individuals to those tasks for which they are more suitable, in order to make volunteers feeling more useful. This is supposed to reduce the number of drop-outs. Furthermore, organization time is supposed to be strongly reduced while the solution quality is highly improved. Managing a volunteering association requires high adaptability. It is not uncommon, indeed, that some volunteer arrives late or is away. The SpONSOR$_T$ solution can be used to find a proper substitute in the short time, suggesting to the association managers viable alternatives in case of unforeseen events.

In the next future, we are going to evaluate the system with real users. This phase aims to test the system's robustness and, potentially, to collect feedback as a result of a more intensive use of the software in order to provide further improvements to the SpONSOR$_T$ system. With regards to the technical aspects, for example, with the increase of problem size (i.e., more volunteers and activities to perform), the standard solvers' heuristics might be not predictive enough resulting in some performance degradation. In this regard, we plan to introduce some domain specific heuristics with the aim of improving the performance of the resolution process. In addition, the search algorithm will be reviewed and different optimization techniques, ranging from those based on Large Neighbourhood Search to those relying on Genetic Algorithms strategies, will be also investigated with the aim of finding most efficient algorithms to solve the core problem. Furthermore, by including the overall workload of the volunteers, some multi-objective strategies, based on the Pareto frontier, can be adopted with the aim of producing fairer solutions. Additionally, it is necessary to say that we decided not to interfere too much with the normal management of the organization by using in the proposed approach the questionnaire customized by Televita, instead of standardized instruments which are commonly used for assessing individual differences. For this reason, it is foreseen in the planned assessment with real users the evaluation of volunteers' personality through standard questionnaires.

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ReMoVES Remote Monitoring Validation Engineering System: New Way of Care

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Abstract Customization of the rehabilitation program and patient monitoring involve gathering user and process-related information during the rehabilitation, which is then used to appropriately adapt procedures and services in order to satisfactorily enhance the user's experience. User satisfaction is the ultimate aim of customization along with clinical effectiveness. Case-based reasoning will help in further improving the rehabilitation process by either exploiting temporal profile evolution of the same patient or retrieving and processing information related to similar patients. To this end, thinking to a personalized and remote monitoring service available at patient's home could be a solution to extend the possibility of treatment to a wider population, in an easy and comfortable way, at a good price. The aim of this study is to present REmote MOnitoring Validation Engineering System (ReMoVES) platform: the proposed system addresses the problem of continuity of care in a smart and economical way within the rehabilitation field. The proposed solution has been favourably accepted by patients, who showed interest and involvement during tests conducted at rehabilitation facilities, as well as by therapists who have found ReMoVES a useful tool for assessing and monitoring the patient.

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1 Introduction

Over the last years, the impact of telemedicine is still growing thanks to the adoption of the concept of "continuity of care" by the Health Community. Operators have access to all patients' information, regardless of where they are located, and this helps to improve access to health services for end users [1].

Along with the societal changes, health-care sector is facing a quick and smart evolution, both in Europe and in the rest of the world. Some of the big issues, such as ageing population, chronic diseases, and spread of disabilities as stroke and all degenerative diseases have a great impact on health care strategies and care solutions. Thanks to the new technology solutions, the patient is more and more attentive and aware of his state of health, trying to maintain the highest quality of life level [2].

The digital innovation that has involved people's daily life, plays a fundamental role in the field of medical rehabilitation and many medical clinics start to include it as a fundamental therapeutic and commercial service. Nowadays, there are a lot of gaming consoles available to execute fitness exercises. The Nintendo Wii is a device used in a number of rehabilitation programs, to help the recovery of patients in more enjoyable way [3]. Although commonly used, commercial games are not developed for people with disabilities, and this causes to the patient a lack of motivation while failing to achieve the goals because they are too difficult. Furthermore, the user-system interaction, not designed for people with disabilities, implies a particularly active involvement of the patient that puts him in difficulty.

A comprehensive meta-analysis study about the clinical findings related to video-gaming activity for upper extremity rehabilitation after stroke is reported at Stroke Engine website [4]. Eleven randomized clinical trials (RCT) and one well designed quasi-experimental study have investigated the effect of upper limb rehabilitation using commercially available video game consoles.

In general, a few treatments have proved effective for:

- motivation and enjoyment
- increased physical activity
- purposeful active movements
- movement acceleration
- affected upper extremity intensity
- Wolf-Motor Function Test (WMFT)
- Brunnstrom Stages (hand and upper extremity)
- Functional Independence Measure (FIM).

The best outcome for upper extremity after stroke is presented in the work by Sin and Lee [5]. In such a case Range of Motion (ROM) improvements were achieved for shoulder flexion, extension, abduction, and elbow flexion. Fugl-Meyer Assessment—Upper Extremity score was improved along with Box and Block Test performances.

Starting from the assumption that treatments that provide feedback, increase practice with multiple repetitions, and motivate patients are essential to rehabilitation post stroke, paper [6] aimed to determine whether playing commercially available, general purpose video games results in improved balance and mobility post stroke. Chronic hemiparesis patients were randomly assigned to a gaming group or normal activity control group. Small positive effects of Active Video Gaming versus traditional therapy were observed. In conclusion, authors suggest that specifically designed games should be designed. Therapist assistance in making optimum movement choices is recommended to achieve more significant improvements.

For a wide review of the application of Kinect in elderly care and stroke rehabilitation the reader is referred to paper [7].

In this scenario, we are disclosing the REmote MOnitoring Validation Engineering System (ReMoVES) platform [8]: the proposed system addresses the problem of continuity of care in a smart and economical way. It can help patients with neurological, post-stroke and orthopedic diseases in recovering physical, psychological and social functions; such system will not only improve the quality of life and accelerate the recovery process for patients, but also aims at rationalizing and help the workforce required monitoring and coaching individual patients at rehabilitation centres. This solution spins off from the European Project Rehab@Home (FP7 n.306113) and addresses in an innovative way the theme of user's participation in a technology conception as well as the general access to technology at a large public thanks to the possibility to spread the care and rehabilitation service at an extremely low cost [9].

2 Objectives and Constraints

The main objective of ReMoVES is to transform the patient's home in a place where physical and cognitive rehabilitation processes can be performed in a safe and comfortable way. The patient will be in contact with experts in the rehabilitation centre providing guidance and feedback and will also enjoy the participation in the rehabilitation program, to increase inclusion and motivation [10, 11].

ReMoVES just relies on an inexpensive set of devices to track the user during the rehabilitation process; moreover, the whole IT infrastructure is a fully cloud-oriented service. Being a scalable and low cost system, it helps in giving the possibility of recovering to low income and disadvantaged families and patients, as well as a decentralized and widespread rehabilitation system.

The tele-rehabilitation is attracting an increasing amount of interest and on this wave, ReMoVES is going to provide a paradigm-shifting experience with respect to the existing solutions. Relying on the fact that the effectiveness of the tele-rehabilitation using serious-games or virtual reality is supported by scientific evidence [12, 13], the ReMoVES system focuses on acceptance studies, accessibility and employment of easy interfaces to deliver the best user experience. Every design choice is made to guarantee the enjoyment of the platform by the final user even if not accustomed to the technology.

ReMoVES promotes itself as an assistive technology to support daily activities for physical and cognitive rehabilitation. It enables active and healthy ageing through an effective and engaging rehabilitation process, which helps social inclusion and community building.

During the tele-rehabilitation activity, it is very important to monitor the emotional involvement of the patient, in order to increase inclusion and motivation. The focus that it has been made is on a sleek infrastructure with integrated sensors. This infrastructure can collect relevant physical and medical parameters of a patients' status for check-ups and relapse prevention.

ReMoVES provides analyses coming from devices designed to track full-body movements or hand gestures in the 3D-space and a wearable device that measures some physiological parameters of the user. In fact, the human engagement and emotions during therapy can be expressed through responses like accelerations and decelerations of the Heart Rate (HR) or variation of the Electro Dermal Activity (EDA). For this reason, these physiological signals are acquired by the wearable device to monitor relevant changes during different phases of a rehabilitation session [14]. During the tele-rehabilitation process the user is guided by simple interfaces in order to accomplish the required tasks assigned by the therapist: generally, they consist of simple movements or cognitive actions with an immediate visual feedback through serious-games. The patient will also enjoy the participation in a sort of virtual gym, to increase inclusion and motivation. ReMoVES goals are:

- propose a set of exercises with a personalized, serious-games based rehabilitation program;
- training for both the patient and his/her family members to the execution of exercises by means of user-friendly devices;
- acquisition and processing of relevant physical and physiological data using suitable sensors and proper software applications;
- promotion of social inclusion and community building.

From the therapist perspective, ReMoVES is an easy access tool, available via web from any personal device (mobile or PC), from which it can be set up the correct list of activities that a patient can carry on autonomously. The therapist is then able to see all the upgrades made by the patient and to receive feedback on the biophysical situation, such as the HR and EDA variations. The outcomes received are easy to read and can help the assessment of the therapy avoiding the daily meeting with a therapist, but helping in keeping the contacts for the time necessary for recovery after the hospitalization time.

3 Technical Description

The ReMoVES platform employs three off-the-shelf devices for motion tracking and biophysical data acquisition which are turned on during the execution of functional exercises. On the back-end a cloud architecture has been deployed to provide web-services and data processing.

The idea behind the proposed architecture consists in providing a personal rehabilitation program that is performed at home by the patient itself, while, from any internet connected device, the therapist can track the performances and effectiveness of the training. In detail, the built-in algorithms aim to provide a clear and concise report to the therapist, in order to facilitate the interpretation of the evolution of therapy.

The following technologies are deployed by ReMoVES platform:

Serious-games are digital games that have been developed exclusively for ReMoVES platform in collaboration with physiotherapists and physiatrists: the serious-games encourage the patient to carry out functional exercises in complete autonomy along with the traditional motion rehabilitation.

Microsoft Kinect V2 is a motion sensing input device based upon a high resolution colour camera and an infrared emitter for depth analysis, that can 3D-track simultaneously up to 25 fundamental joints of the framed human body. It offers a wide field of view ($70° \times 60°$) and recognition up to 4.5m far from the device.

Leap Motion is a device explicitly targeted at hand gesture recognition and computes the position of the fingertips and the hand orientation. Its interaction zone is limited to a semi-sphere of radius 0.60m around the device.

Microsoft Band 2 is a physiological sensor used for the acquisition of the two signals chosen as measure of involvement during the rehabilitation program: Heart Rate (HR) and Electrodermal Activity (EDA). It offers these key features: real time reading of the data stream and access to the device through Software Development Kit (SDK). Moreover it includes other sensors that could be used for future improvement of the system: accelerometer, gyroscope, barometer, GPS, skin temperature sensor, ambient light and UV sensor. Finally it is reasonably inexpensive.

Cloud back-end has been developed using state-of-the-art techniques to provide scalable, secure and efficient data processing and storage. The architecture of this component is not the subject of this paper, but it plays a fundamental role since the feature extraction processes takes place on it.

4 Exercising Through Serious Games

The ReMoVES platform services are currently used as integration to the traditional rehabilitation program. The system includes a set of exercises from where the therapist can choose the most useful.

These activities are presented to the patient as serious-games: they are digital games that have been developed exclusively for ReMoVES platform in collaboration with physiotherapists and physiatrists.

The system currently includes 10 different exercises that can be tweaked according to the patient requirement: level, duration, movement pattern, speed and other parameters can be set for a total of 60 game variations.

BreathBall This activity helps the patient relax and focus on his/her breathing. It is not an interactive game. The patient is leaded to breath with a regular rhythm by following a "breath ball" displayed on the monitor. The ball changes its size simulating inspiration and expiration: when it grows, the patient should inhale, then exhale when it shrinks. The BreathBall exercise makes the subject comfortable and brings back his/her heartbeat to a basal value before the actual rehabilitation session.

ShelfCans This serious game introduces the patient to a virtual environment similar to a kitchen. With the arm movement the patient grabs one of the colourful drink cans appearing in the middle of the screen and drags it to the corresponding shelf. This game is appealing because requires the user to be attentive to drop off the drink cans in the correct shelf according to its colour (Fig. 1a).

OwlNest The patient is encouraged to reach on-screen target with the arm motion (Reaching Task) in order to collect high in-game score. Many colourful owls appear randomly in any position of the screen for a given time-frame: the user should carry them in the nest before they disappear (Fig. 1b).

FlappyCloud This is a functional exercise for lower limb. The leg Abduction-Adduction movement reflects the position of a cloud object in the game: the patient should make it move forward without hitting some obstacles (Fig. 1c).

HotAir This is an activity to improve control of the patient's body balance. The user can control the direction of a hot-air balloon, floating in the sky with the balance shift: in-game score are collected when it is leaded towards the bonus targets (Fig. 1d).

EquilibriumPaint This serious game is an interactive version of the Sit to Stand exercise, typically used in traditional rehabilitation to evaluate the patient performances. The user should stand up and sit down repeatedly to collect in-game score, while his/her trunk must remain erect: an erroneous lateral shift causes the fall of the cans of paint leaning on an unstable wooden beam (Fig. 1e).

WineBottle This exercise mimics a real world scenario: pouring liquids from a bottle. With the Pronation-Supination movement of the hand, the patient should control the rotation of a bottle of wine appearing on the screen. He must fill a glass over and over again to collect as many points as possible (Fig. 1f).

EndlessZig In this activity the patient drives a marble along a zigzag path appearing on the screen. Going out of the boundaries causes score loss; similarly some bonus gems appears on the path. The patient controls the marble movement with Radial-Ulnar deviation (Fig. 1g).

CityCar In this game the patient drives a car along a road randomly generated. The user should steer in presence of curves and cross-

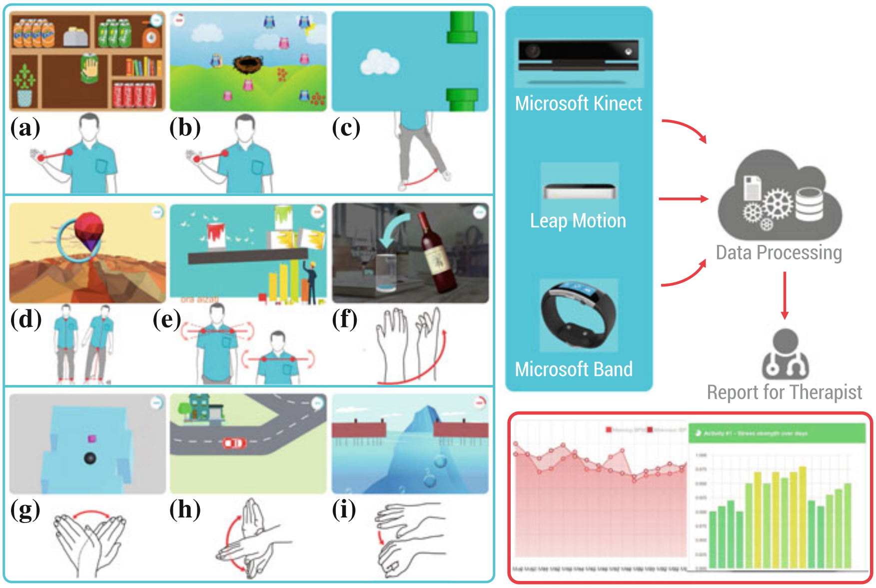

Fig. 1 Summary of ReMoVES architecture and list of serious games and their corresponding movement: **a** ShelfCans for arm Flexion-Extension and Abduction-Adduction. **b** OwlNest for arm Flexion-Extension and Abduction-Adduction. **c** FlappyCloud for leg Abduction-Adduction. **d** HotAir for Balance Shift. **e** EquilibriumPaint for Sit to Stand. **f** WineBottle for hand Pronation-Supination. **g** EndlessZig for hand Radial-Ulnar Deviation. **h** CityCar for Flexion-Extension. **i** FloatingTrap for Grasping

roads with the movement of Flexion/Extension of the wrist. The penalties are introduced when the user goes off track (Fig. 1h).

FloatingTrap In this serious game the patient is leaded to open his hand and make a fist alternatively. This exercise requires a good level of concentration: in fact, the user moves a floating raft on the left or on the right according to the finger Flexion/Extension in order to avoid some objects in the scene (Fig. 1i).

5 Movements and Therapy Application

The serious-games presented in Sect. 4 have been developed to deliver a pleasant experience even to patients that are not familiar with technology or digital games. In addition to this, a great effort has been put in the design of the functional exercises that the patient must carry on during the rehabilitation process accomplished with ReMoVES platform. In this section the fundamentals body movements that are tracked, fulfilling the requirements proposed by the physiotherapists and physiatrists are explicated.

5.1 Upper Limb

The serious-games that address upper limb movements are ShelfCans and OwlNest, where the motion tracking is achieved with Microsoft Kinect V2. The patient interacting with digital games is encouraged to reach on-screen target with the arm motion (Reaching Task) in order to collect high in-game score. The main movements at the shoulder joint (glenohumeral joint) tracked during the execution of functional exercises are Flexion-Extension and Abduction-Adduction; the hand position in the 3D space is traced (Fig. 1a, b). Moreover, to detect some erroneous strategies adopted by the patients to reach in-games targets, supplementary body joints are tracked with Microsoft Kinect. The calculation of the angle at the elbow joint is an index of correct execution of the movement: when the measure of this angle remains nearly constant during the whole exercise the patient is rotating both shoulder and arm in a rigid movement, instead of moving just the arm. The data analysis of hand position in the coronal plane allows detecting and measuring a spatial neglect in hemiplegic patients who ignore a part of the in-game space.

5.2 Lower Limb

Currently, the FlappyCloud is the only serious-game included in the ReMoVES platform that is developed around a functional exercise for Lower Limb. The user must accomplish the Abduction-Adduction movement with his impaired leg while he is standing (Fig. 1c). The therapist can suggest to the patient to hold to a physical support like the back of a chair in order to prevent falls or equilibrium instability. The elevation of the leg and additional body joints position are tracked with the Microsoft Kinect V2 to detect the balance status of the user body: to correctly accomplish the exercise the patient must keep the trunk erected and straight.

5.3 Balance Shift

The Microsoft Kinect V2 can be exploited for the estimation of the oscillation of the Centre of Pressure on the mediolateral axis even without a real force platform (Fig. 1d). The serious-game that includes this features is HotAir. The ReMoVES platform verifies that the patient uses a correct strategy during balance shift exercise: the head and shoulders should always be aligned with the trunk.

5.4 Sit to Stand

Microsoft Kinect V2 is deployed in the EquilibriumPaint serious-game: the patient must stand up and sit down repeatedly (Sit to Stand) keeping the trunk as straight as possible (Fig. 1e). To analyze the correct execution of this exercise the ReMoVES platform evaluates the trunk tilt on both coronal and sagittal plane and detects erroneous shoulder twist.

5.5 Hand, Wrist and Fingers Movements

Leap Motion is deployed in this analysis: the digital games encourage the patient to control in-game objects with the hand, wrist and finger motion. The main movements tracked during the execution of functional exercises are: Pronation-Supination (Fig. 1f), Radial-Ulnar Deviation (Fig. 1g), Flexion-Extension (Fig. 1h), Grasping (Fig. 1i). A different serious game has been developed for each of these movements: WineBottle, EndlessZig, CityCar and FloatingTrap respectively. During the execution of the first three exercises the hand/wrist angle (corresponding to roll, yaw and pitch) reached by the patient is recorded, while in the last the finger extension is measured with a value between 0 and 1 respectively when the hand is open or when it is closed in a grabbing pose.

6 Data Processing

The motion and biophysical values originating from the serious games and the peripherals are stored in the database at the rate of 2 samples every second, along with a timestamp to identify when that event occurred.

For each serious game available on the ReMoVES platform, we defined a set of appropriate key indicators aiming to highlight the patient engagement and performance during the execution of the functional exercises. These indicators are the result of a processing phase on the raw data.

For each serious game, a reference model has been defined on the basis of the results achieved by healthy subjects during several and repeated trials. The core of data processing consists of the comparison between the patient performance and the model from healthy subjects, resulting in a percentage number for each of the key indicators. In the final step the general evaluation for the current session—based on weighted average of the key indicators percentages—is computed in order to deliver a report to the therapist (Fig. 2).

In the following a detailed example of the data processing phase referred to EquilibriumPaint exercise is provided. During this activity Microsoft Kinect obtains the

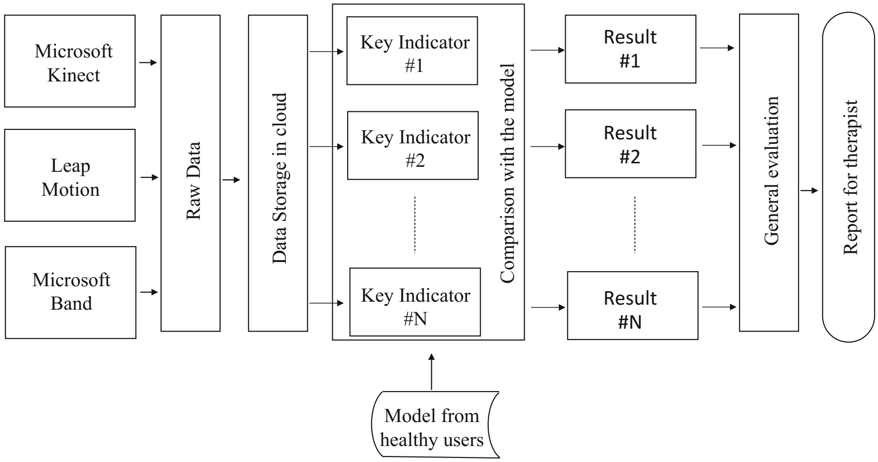

Fig. 2 Data Processing flow: raw data acquisition from sensors, key indicators definition and comparison with model from healthy users and final evaluation for the therapist

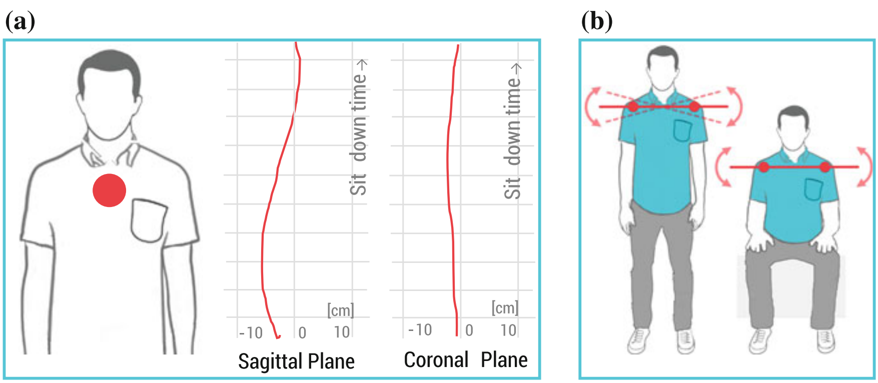

Fig. 3 **a** Trunk tilt on sagittal and coronal planes; **b** shoulder tilt detection

raw data from patient movements, tracking the main body joints positions in the three-dimensional space. From raw data, the following key indicators are extracted:

- **Score** related to in-game performance (e.g. missed targets or errors).
- **Repetitions** of the Sit to Stand movement performed during the entire duration of the exercise prescribed by the therapist (60, 120, 180 s).
- **Coronal shift**: verification of the correct strategy used by the patient to stand up, considering the trunk tilt on coronal plane (Fig. 3a). Even though the movement trajectory projected in the sagittal plane must show some forward/backward displacements, the correct coronal trajectory must be linear and constant around the zero value.

Table 1 Values of the key indicators of Equilibrium Paint activity carried out by two patients in comparison with the model from healthy subjects

	Key indicators								General evaluation
	Score		Repetitions		Coronal shift		Shoulder angle		Performance (%)
Healthy	6800	100.0%	12	100.0%	8.0 cm	100.0%	4.8°	100.0%	100.0
Patient #1	6550	96.3%	10	83.3%	9.8 cm	81.6%	7.2°	66.7%	81.2
Patient #2	4650	68.4%	7	58.3%	21.0 cm	38.1%	24.9°	19.3%	46.0

- **Shoulder tilt**: to accomplish the exercise correctly, the patient must stand up and sit down without twisting or tilting shoulders (Fig. 3b). A correct movement provides very small angles of inclination and therefore the average value must be around 0°.

First line in Table 1 shows, for each indicator, the average value as obtained from healthy subjects which represents the reference model. The key indicators values for patient 1 and 2 are reported in second and third line, respectively, along with a direct or an inverse percentage with respect to the corresponding healthy value. Specifically:

- The first patient underwent a hip operation for the installation of a prosthesis following a fracture. He/she performed the exercise with excellent results that are very close to the healthy model.
- The second patient was hit by a stroke with consequent hemiplegia to the left side of the body. He achieved good indicators while performing the exercise, with the exception of the Coronal Shift, almost three times larger than the reference model (low percentage score).

The last column provides the mean value of the four indicators percentages (in other activities the weighed average might be used instead) as a final evaluation to be reported to the therapist.

7 Preliminary Results

ReMoVES system is in testing phase at Complex Recovery and Rehabilitation Facility of La Colletta Hospital in Arenzano (Genova, Italy) and at Rehabilitation Center of Don Carlo Gnocchi Foundation in Fivizzano (Massa-Carrara, Italy).

Even though the system has been designed for home tele-rehabilitation, a preliminary testing phase in rehabilitation facilities has been necessary in order to understand, together with specialized team of therapists, if the exercises are appropriated and if the system is ready to be used by a patient, in complete autonomy. Up to this points research efforts have been focused on the extraction of significant features,

Table 2 Demographic patients characteristics

	Frequency	Percentage (%)
Gender		
Male	22	53.7
Female	19	46.3
Age		
30–39	1	2.4
40–49	4	9.8
50–59	4	9.8
60–69	9	22.0
70–79	16	39.0
80–89	7	17.0
Disease		
Stroke	8	19.5
Hemiparesis	11	26.8
Hip prosthesis	9	22.0
Knee prosthesis	2	4.9
Femur fracture	7	17.1
Tetraplegia	1	2.4
Parkinson	1	2.4
Other	2	4.9

according to the analysis method proposed above. This process requires the mutual collaboration between ReMoVES platform developers and therapists. Moreover, the feedback given by the patients plays a crucial role in this testing phase: the system has been tried by 41 participants (19 male, 22 female) aged between 30 and 86 who were hospitalized due to various causes (stroke, fractures, prostheses and Parkinson's disease).

Our test group was roughly made up by half post-stroke (11 hemiplegic and 8 with general diseases caused by stroke) and half orthopaedic patients, with the exception of one participant affected by Parkinson's Disease and a young tetraplegic man (upper limb was slightly involved) (Table 2).

In Table 3 an overview of the overall number of serious-games sessions accomplished is provided.

The most frequent exercise is the "BreathBall" since it is usually carried out before the actual rehabilitation session to induce relaxation. In addition to this, the therapists assign more frequently the functional exercises for upper limb and trunk (balance) rehabilitation: in these serious-games patients are guided to accomplish the correct movement and their cognitive domain is involved to stimulate their interest and interaction.

Table 3 Serious games activity summary and number of session repetitions

Activity name	Rehabilitation aim	Motion tracking device	Sessions
BreathBall	–	–	116
ShelfCans	Upper limb	Microsoft kinect	76
OwlNest	Upper limb	Microsoft kinect	69
FlappyCloud	Lower limb	Microsoft kinect	71
HotAir	Balance shift	Microsoft kinect	71
EquilibriumPaint	Sit to stand	Microsoft kinect	42
WineBottle	Hand	Leap motion	43
EndlessZig	Hand	Leap motion	42
City Car	Hand	Leap motion	39
FloatingTrap	Hand	Leap motion	35

8 Conclusions

By using simple low cost components an easy-to-use patient station is made available; very simple movements are required. Remote monitoring outcomes of rehabilitation exercises are edited in order to help the therapist in personalizing the plan of care for each patient through an adaptable web service system.

From the economic and social point of view, a good cost reduction for the extended care after hospitalization, along with the possibility of prevention of new events and a consequent reduction of expenses are evident.

On the other hand, remote monitoring allows a therapist to have more patients and to better follow them also after hospitalization. Referring to studies on adaptability, ReMoVES offers the possibility to engage people in their rehabilitation process and let them feel part of their own traitment. The major advantage in using sociable technologies in health care and then in rehabilitation is collaboration within the rehabilitation community, taking into account all the stakeholders.

ReMoVES can finally be considered a flexible system adaptable to various necessities in communication and interaction of all the participants, it really promotes well-being and affordable rehabilitation for many patients, including people with a lower income or particular life styles as well as people living in rural areas that could better afford the therapy.

It gives the therapist the possibility to more efficiently monitor their patients and to the clinics the possibility to support the patients even after their hospitalization, opening new possibilities to follow their recovering time.

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OPENCARE: Emergent Technologies for the Care of Older Adults in Residential Facilities

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Abstract The residential care sector is assuming in Italy an increasingly prominent role, as a consequence of the rapid growth in demand for long-term care caused by the rapid ageing of the population. This pressure is determining a clearly recognized need for innovative solutions to tackle with long term health related issues. This paper presents a recently kicked-off research and development project, named OPENCARE, that aims to improve efficiency and efficacy of care processes in the residential facilities. Following a participatory design approach, many aspects of innovations are detected, in particular by providing a transparent access to the health and status data related to the residents, not only to the care staff for routine management, but also to families and relatives.

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1 Background

The residential care sector is becoming increasingly relevant, as a consequence of the demographic ageing and the changes in the families' composition. As an example, in Italy the combined impact of denuclearization, pulverization and stretching processes of families has resulted in the convergence of Italian families from an *archipelago* like structure—multi-generation groups including several relative families—to an *atoll* like structure, with mononuclear, or denuclearized, and single-generation families [1]. As a consequence of a missing familiar support, there are almost 12,300 facilities, where approximately 385,000 frail people are hosted, out of which 72% are dependent older subjects [2]. As a consequence, the residential care system is turning into a complex scenario where the quality of care is heavily dependent on staff availability, especially as the functional and clinical conditions of the residents are increasingly worsening. However, due to the lack of private and public funding, the ratio between care staff and residents is often inadequate. Legal disputes between families and care providers, and episodes of elder abuse and neglect in care facilities are often reported by the mass-media.

The size of the phenomenon is confirmed by the recent establishment of a Special Task Force by the Ministry of Health, aimed at monitoring the quality of care in facilities across Italy.

Based on the previous motivations, this paper presents a recently kicked-off research and development project, named OPENCARE, that aims to improve efficiency and efficacy of care processes in the residential facilities, by providing a transparent access to the health and status data related to the residents, not only to the care staff for routine management, but also to families and relatives. Such a project builds upon previous experiences developed by the involved researchers, mainly focused on dementia patients monitoring and caregivers support [3, 4], and on home-based monitoring [5, 6].

2 The OPENCARE Project

The main objective of OPENCARE is to realize a new model to ensure transparency, effectiveness and efficiency of care processes within the residential facilities, through the use of a modular platform integrated with a distributed smart environment.

In order to achieve this main objective, OPENCARE identifies 4 different specific objectives aimed at:

- the realization of a modular, flexible and easy-to-use information management platform and related user interfaces;
- the development and experimental test of a smart environment able to integrate a set of so-called Macro-Smart-Objects (MSO) (i.e. a Smart Bed that integrates evolved, contactless and innovative sensors, capable of providing information concerning heart rate and respiratory activity, thanks to the processing of data from different

sensors, as accelerometers or microphones), Systems for Air Quality Monitoring and Evolved Carts for medication delivery and hygienic aids, equipped with a tablet that adapts the contents displayed according to the nearest user, by using automatic user proximity recognition.
- the design of a set of data analysis models leveraging the amount of data collected by the single sensors, to provide both long-term monitoring and promptly management of potential risks for the residents and the care staff;
- an integrated trial of the proposed solution and a related industrial partnership model for marketing OPENCARE services at a national and international level.

Compared to the existing solutions on the market, OPENCARE shows many aspects of innovations. Firstly, it intends to give a single and practical response to the complexity related to the management of residential structures instead of handling specific individual aspects. This innovation is the direct benefit of the participatory design technique applied in the process of drafting the project itself. This method had easily match all the OPENCARE functionalities with the real economical and structural situation of the existing buildings.

Secondly, the modular platform enables facilities to choose and require solutions in one integrated system. This advantage will determine two important benefit: from one side a lower cost will be guarantee; from the other side, new additional features will be available in the intelligent environment since modules will be able to communicate each other. Such a benefit is not available on the market at the present as integrated system capable of responding to all the emerging problems. Especially, many of the existing solutions already on the market ignore important issue (for example, the concept of transparency in respect of the family caregiver) or face one issue at time instead of whole process.

3 The OPENCARE Solutions

From the technical point of view, OPENCARE will implement innovative solutions in the following four areas:

(1) A new integrated platform. An innovative platform will be developed, to collect, elaborate and process data generated by MSOs, with the aim to be merged with users' data, in order to support the care staff. In fact, the platform will monitor the residents' health status and it will help the staff managing their personalized pharmacological therapy, diet, and care plan. A schematic representation of the integrated platform is shown in Fig. 1. Data collected and processed within the platform will enable a plain and transparent interaction model involving the patient's relatives, who will have access to the information, to check the status of their dearest ones, and get updates about their evolving conditions.

2) New sensors and MSO application. The project will develop innovative sensors that are not commercially available today. The bed solution will integrate both audio sensors and accelerometers, arranged as arrays of sensors, to generate

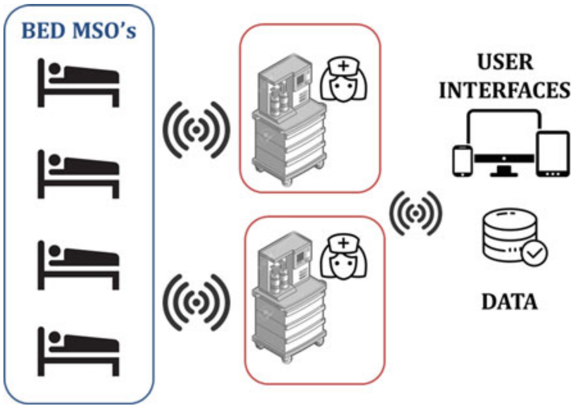

Fig. 1 The OPENCARE integrated platform main components

information about the presence in bed of the resident, their respiratory and heart activity (through audio tracks analysis). Due to the expected big amount and complexity of the generated raw data, they will be pre-processed by means of appropriate algorithms designed to analyze both kind of data, to remove artifacts and noise, and to be executed on embedded boards. A second innovative sensor will be designed and prototyped, aimed to detect the presence of urea particles in the air, thus suggesting the need to monitor the resident's hygiene. A third proximity sensor will be used on the smart carts in order to recognize the resident in the bed closest to the cart. This will simplify the drugs delivery and care management by the staff, by providing a reliable identification of the resident. In fact, a double identification technology based on radio frequency, through NFC (Near Field Communication) tag, will be used, in conjunction with computer vision techniques to minimize the probability of error during the face recognition process. The carts used for medication administration will be equipped with a video-based system too, able to detect the delivered drugs and minimize the risk of medication errors.

(3) Adaptive and user friendly interfaces for the system will be developed, to easily guide the users engaging with the system. The study, development and analysis of these interfaces will be carried out in compliance with the ISO 9241-210 [7] and it will be conducted by a multidisciplinary team skilled in the Human Computer Interaction (HCI).

(4) Innovative Management Model. OPENCARE will design and experiment an innovative management model based on algorithms for the automatic analysis of the data coming from the platform and the intelligent ambient [8]. The model represents the core revolution of the project since it is able to change the traditional care management process according to a proactive rather than a reactive approach. In this way, the risk prediction becomes the focus of the entire workflow. Moreover, using the massive amount of data collected through the sensing technologies, it will be possible to design advanced algorithms that are able to

learn and track the specific features of each monitored resident, and automatically detect any perturbation that can lead to a decrease in health conditions or quality of life.

4 The Participatory Design Approach

The design of Health Information Technologies for the complex needs of long term care is becoming an high priority due to the rapid ageing phenomena worldwide. The improvement of quality of care as well as the reduction of cost still significant represent challenges for both designers and health care professionals [9]. The innovation of future care technologies "*lay stress on the importance of end-user involvement at all stages of development, of stakeholder engagement, and of the need for early development of prototypes to be trialed extensively in actual working situations*" [10]. The participatory design (PD) is an approach where all stakeholders are involved in the design process. This approach starts from the early stage of the project idea until its conclusion [11]. The PD approach is a flexible process that requires three basic stages: (1) the initial exploration of work is the first phase that enables designers to meet the users and work with them in a cooperative way; (2) the discovery process is the second phase and it is aimed at prioritizing the technical development in respect to the users' goals and value; (3) the prototyping phase is the phase where designers and users iteratively shape technological artifacts to fit the solutions into daily activities of the target. In the specific case of the OPENCARE project the definition of the design concept was developed providing insights from the involvement of 5 companies, 3 care service providers, two universities and one research centers. The active involvement of all stakeholders from the outset represents a strategic path to match the needs of future beneficiaries with the proposed technology. As a matter of facts, the system should be adopted by those facilities committed to improve the quality of care and gaining a competitive advantage compared to the traditional providers. The adoption of the OPENCARE model could enable these institutions to act as a transparent and efficient care providers as well as to reduce errors and risks and to offer a proactive participation to guests and family members.

In this respect, the first participatory design phase of the OPENCARE development was the definition of the users' need framework and the elicitation of system's goals [12].

Firstly, the consortium cooperated to define the target of the OPENCARE solution that was described as follows:

- Older adults, as primary end-users that will use OPENCARE and benefit from technology innovation during their living into the facility;
- Nurses and family members as secondary end-users that will interact with OPENCARE using smart beds, carts for drugs delivery and hygienic aids (nurses) or retrieving information (family members) about the health status of guests.

– Healthcare professionals as tertiary end users of the innovative model that will allow them to get involved in the whole care process.

Secondly, the partnership established the match between the users ‘needs and the system functionalities. Five perspectives resulted from this activity (Table 1).

5 Discussion and Conclusion

The growth in the number of people over 80 years with the increased level of clients entering residential facilities is occurring at a time of significant change within local authorities and health authorities. In light of the increasing number of older people in our population, there is a clearly recognized need for innovative solutions able to tackle with long term health related issues. This demography change combined with the market development towards structured older adult’s services with a growing call of technologies makes Italy an important market opportunity for technology companies targeting the elderly sector. Coming from this background, the ambition of the OPENCARE project is to improve efficiency and efficacy of care processes in the residential facilities, by providing a transparent access to the health and status data related to the residents, not only to the care staff for routine management, but also to families and relatives. The participatory design approach concurred to develop the framework for the understanding of Health Information Technologies in the nursing homes. This resulting framework has been used to formalize hypotheses about the real effect of this kind of innovation in the long term care sector since there is an important gap in the literature: if overall, the literature suggests that health IT has to potential to improve overall healthcare quality, safety, and satisfaction while delivering some cost savings, most of these studies have not taken place in long-term care [13]. In the light of this gap, the OPENCARE system will be developed and tested in a limited area of each pilot facility. This challenge will contribute to open the healthcare technologies development to a broader spectrum of professionals since few studies reported clinicians’ views about home health care technology or their direct engagement into the design and development process of such artifacts. The test will be performed taking into account the previous experiences developed by the involved researchers [3–6, 14, 15]. The limited area of each pilot facility area will be equipped with at least 2 smart beds and 3 carts. The trial will run for 10 months during which guests, nurses and managers of facilities will benefit from the tested solutions. The following outcomes will be analyzed: satisfaction, usability and acceptance, impact on the whole care process and cost benefit analysis. The ambition of the authors is that trough this test, the project will contribute to the research in the nursing homes setting as well as to the effect of Health Information Technology on quality of long term care.

Table 1 The match between users' needs and system functionalities

Target perspective	Need	System match
Residents	Nutrition aids	Managing data on diet
	Mobility aids	Monitoring mobility actions
		Monitoring pressure ulcers and infections
	Hygiene and cleanliness aids	Monitoring depression
		Access to specialized assistance/reducing transfers
	Easily communication	Adherence to treatment, preventing adverse drugs events
	Integration with telemedicine systems	Security (e.g. Falls, wandering, etc)
	Medication support	
Family Members	Decrease of burden and anxiety	Easily available electronic information
	Preventing social isolation and depression	Efficiently communication
	Proactive participation in the social life of facilities	Transparent facilities
Nurses	More time to spend in clinical and care activities	Eliminating paperwork
	Reducing users complaints/time saving	Efficient communication with family members
		Events logs availability
	Audit and review	
	Reducing stress related to continuous monitoring activities/support of an intelligent virtual assistant	Intelligent and pervasive system
Care facilities	Greater security	Alert system
	Minor controversy with guests and family members	Transparency
	Lower burden, illness and injury for nurses	Availability of electronic workloads
		Integration with telemedicine systems
	Reducing transfers for specialized assistance	Detailed information on the care process
	Effective management control, quality of care and accountability	
Public care system	Guests and families satisfaction	Improvement of the quality of life
	Minor controversies with users and families	Improvement of the quality of care
	Cost reduction	Telemedicine services

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Part IV
Health and Medical Support Methodologies and Technologies

A Wearable Device to Support the Pull Test in Parkinson Disease

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Abstract The Pull Test is a common practice to assess the postural instability of patients with Parkinson Disease. Postural instability is a serious issue for elderly and people with neurological disease, which can cause falls. The implementation of the Pull Test consists in observing the user response after providing a tug to the patients' shoulders, in order to displace the center of gravity from its neutral position. The validity of the test can be compromised by a nonstandard backward tug provided to the patient. The solution proposed in this paper consists of a low cost multisensor system allowing an objective estimation of the input solicitation. Moreover, the system provides supplementary information on the user postural instability, by means of a set of features extracted from the user stabilogram, which are useful to assess the user response. A wide set of experiments have been performed to assess the system capability to provide a rough classification between stable and unstable behaviors. Results obtained demonstrate the validity of the approach proposed.

1 Introduction

Today almost 10% of people worldwide are over 60 and in the next 30 years this incidence will be doubled [1]. Statistics from the World Health Organization (WHO) reveals that the world's population is rapidly ageing: the number of people aged 60 years or older will rise from 900 million to 2 billion between 2015 and 2050 [1]. Only in Italy people aged over 60 years will rise from more than 22% to more than 33% between 2015 and 2065 [2].

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Assuring an Active Ageing is hence becoming a major challenge for the society thus involving efforts from different actors supporting a new model of welfare, such as health and social services, clinicians, users associations and technology drivers.

Assistive technologies can play a fundamental role in this framework. There are many aspects where elderly may require support, such as safe mobility [3–6], avoiding slips and falls, nutrition and social participation and integration [7]. Among these, falls represent a serious issue which can have catastrophic consequences. Around 30% of people over 65 fall at least once a year and 20% of this falls requires medical attention [7–14] and may lead to loss of autonomy.

Usually, falls are a consequence of postural instability, which is a disorder that affects the spatial orientation and gives an erroneous perception of the body movement as respect to the surrounding environment. It is estimated that about 20–30% of the population in general suffer of postural instability [15]. This is a consequence of many diseases, among which ear diseases, high blood pressure, diabetes, psychiatric disorders and neurodegenerative disease. As an example, postural instability is also one of the main symptoms of Parkinson's disease along with rigidity, tremor and bradykinesia [16, 17]. Several solutions have been developed for the automatic fall detection and classification [18–22].

Assistive technology can be very effective also for the assessment of postural instability both during laboratory tests and real time monitoring [23].

Many systems for the assessment of postural instability are available in the literature, such as inertial devices [24–27], instrumented platforms [28], instrumented insoles [29] and vision systems [30–33]. As an example, a multicomponent force platform able to measure the Antero-Posterior and Medio-Lateral displacement of the Center Of Pressure (COP) is presented in [28]. A portable device equipped with 4 strain-gauge transducers is presented in [30]. Biomechanics force platforms are indeed adopted for the statistical study on the relationship between age and fall risk [31].Visual systems allow monitoring the Medio-Lateral and the Anterior-Posterior movements by using dedicated markers [32]. This technology initially used for the gait analysis, has been successfully adopted in sports therapy, neuroscience, validation and control computer vision, and robotics. Instrumented insoles represent another interesting solution [33] to measure the COP under the feet plant which can be correlated to the user postural stability.

Above solutions require structured environments or complex installation, which make them suitable to perform assessment in dedicated laboratories, while cannot be adopted neither for personal use (real time postural sway monitoring) nor to perform assessment tests (e.g. the Pull Test (PT)) in unstructured environments.

Inertial unit based systems can be used to characterize both postural sway during stance and anticipatory postural adjustments prior to movement [24, 26, 34]. If compared to other systems, these solutions are wearable, very cheap and do not require structured environments. In general, inertial wearable systems have a high degree of acceptability [27]. Inertial unit based techniques for the stability assessment includes the use of accelerometers, gyroscopes and magnetometers. In [24] the relationship between the displacement amplitude of COP and the capability to maintain equilibrium is investigated. In [26] a tri-axial accelerometer is proposed to evaluate patients with neurological disorder, by comparing responses of different neurological disorders to healthy subjects.

In the framework of wearable and low cost postural sway detectors, the possibility to improve the information achieved during traditional procedures for the assessment of neurological diseases severity, such as the PT, is really strategic. In [35, 36] preliminary experimental results achieved by a inertial module developed to support neurologists during the PT are presented. In particular, the system proposed helps in assessing if the strength of the backward tug provided to the patient belongs to a pre-defined range, which otherwise can compromise the validity of the test, and it provides useful information to assess the user response to the imposed stimulus. A methodology for the signal processing to perform the classification between stable and unstable behaviors is proposed in [37].

In this paper, a customized solution to support neurologists during the Pull Test is presented. The system is aimed to provide both a real time feedback on the strength of the backward tug applied to the patient at the beginning of the test and a set of information useful for a further comprehension of the user response to the test stimulus. As far as we know, this is the first example of a device aimed to support the development and the assessment of the Pull Test.

2 The System Developed to Support the Pull Test

2.1 The Pull Test Protocol

The Unified Parkinson's Disease Rating Scale (UPDRS), developed by the Movement Disorder Society [38], defines the clinical maneuvers to be performed with the aim to clinically assess the motor aspects of patients with Parkinson's disease, including postural instability: the Pull Test [39]. The Pull Test is used to assess the recovering of a standing patient due to a moderate backwards tug. In order to prevent a fall, healthy people react by a quick backwards step. Patients with Parkinson may not recover and tumble backwards.

In particular, as defined in the UPDRS, the PT protocol consists in pulling on shoulders of a patient erect with eyes open and feet slightly apart and observing the patient response. The following evaluation rating [38] is used: (0) normal; (1) retropulsion, but the patient recovers unaided; (2) absence of postural response and would fall if not caught by examiner; (3) very unstable, tends to lose balance spontaneously; (4) unable to stand without assistance.

The basic implementation of the PT does not require complex or structured environments, as in case of approaches based on instrumented platforms and vision systems, which is a unique feature of this kind of clinical assessment.

Despite the widespread use of such test, due to the intrinsic variability in its execution, recommendations have been made for improving its accuracy in assessing postural instability [39, 40].

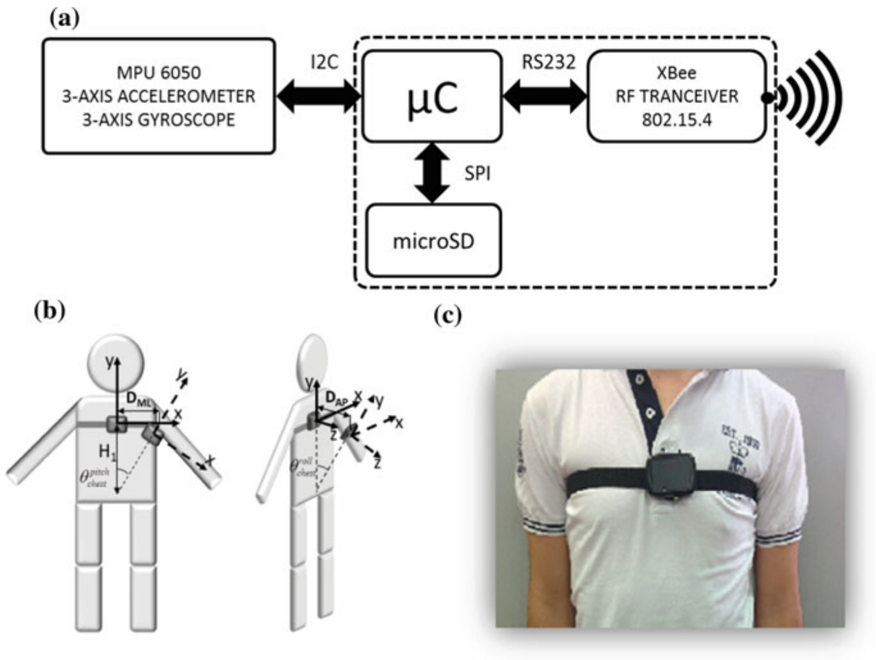

Fig. 1 **a** The schematization of the multisensor node, **b** the adopted reference system and **c** a real view of the device (2018, IEEE)

Moreover, although a restricted number of wearable devices have been developed, signals achieved during the PT need a customized pre-processing which requires a dedicated approach [37].

2.2 *The Backward Tug Assessment*

One of the main issue in performing the Pull Test is the evaluation of the imposed tug strength. Actually, the tug should belong to a predefined interval in order to guarantee the reliability and the repeatability of the test, as well as the coherence between the input stimulus and the evaluation of the user response, especially when the test has to be supplied to the same patient after a certain period of time to assess the disease evolution. To such aim a wearable device, to be positioned on the user chest, has been developed.

In order to provide information on the applied tug, the device uses an inertial unit to monitor the acceleration along the longitudinal axis (see Fig. 1) and a tool developed in NI LabVIEW®, which provides a real time assessment of the validity of the performed test.

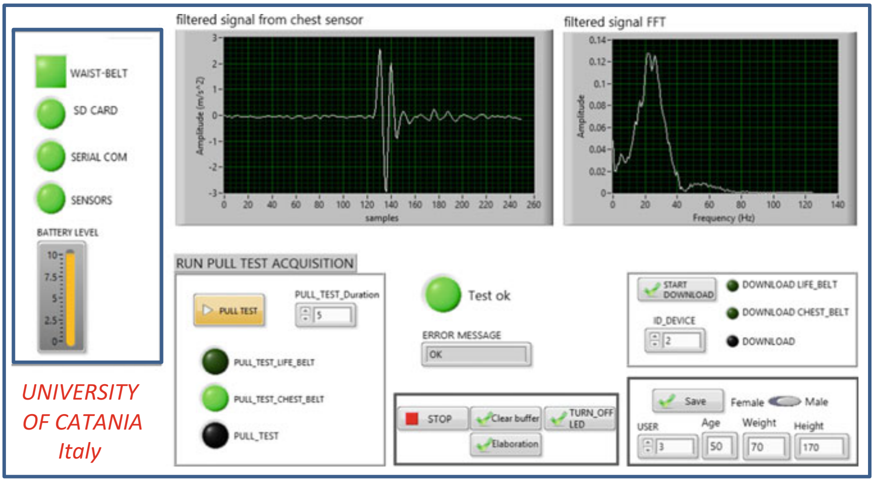

Fig. 2 The dedicated graphic user interface (2018, IEEE)

A schematization and a real view of the multisensor node are shown in Fig. 1. Each node is equipped with the InvenSense MPU6050 device, which includes a tri-axial accelerometer and a tri-axial gyroscope. The MPU6050, operated at 3.3 V, includes three simultaneous 16–bit analog-to-digital converters (ADCs), a user-programmable accelerometer full-scale range of ±2 g, ±4 g, ±8 g, and ±16 g, with an operating current of 500 µA. The chest node is also equipped with a microcontroller architecture exploiting an Atmel ATMega328P, a high speed micro-SD card and a XBee RF Module Series S1 Pro (802.15.4) to implement the communication between the multisensor system and the gateway realized by a PC and a XBee RF Module Series S1 Pro (802.15.4) transceiver connected by a USB-to-Serial converter. The sampling time is set to 20 ms per each measurement channel. The micro-SD card allows for storing rough signals provided by the inertial sensors during the test phase independently from the test duration. The communication between the microcontroller and the inertial unit is performed by I2C protocol at 400 kHz, while communications with the micro-SD card and the transceiver take place by serial protocols. The node is powered by a rechargeable 3.7 V 500 mAh LiPo battery, which is capable to operate the unit for more than 5 h. Devices are equipped with adjustable belts to fit patients with different body characteristics [37].

The solution described allows for monitoring whether the strength of the backwards tug belongs to the allowed interval. In such case the test is validated, otherwise the neurologist is requested to repeat the test.

Figure 2 shows one panel of the User Interface developed, which provides information on the test success and allows to download signals provided by the sensor unit and recorded on the embedded memory card.

2.3 The Postural Instability Assessment

Without compromising the test simplicity, it would be of strategic interest to improve the piece of information concerning the user response to the applied tug, especially in terms of a features set characterizing the postural instability of the patient. To such aim, standard approaches above described, such as instrumented platforms and vision systems, are not suitable since these solutions require structured environments.

Coping with such needs, the idea presented in [35, 36], and further developed through this paper, is to exploit the inertial unit embedded in the chest unit to extract a set of features, which are useful to provide the neurologist with supplementary information to properly assess the patient response to the applied tug, especially in terms of postural instability. Different variables and indexes presented in the literature, for the sake of the postural instability evaluation, have been investigated and a dedicated NI LabVIEW® tool was developed to extract such features from signals provided by the sensing unit. In particular, the possibility to use the theory of the COP applied to the projection of the user body's center of mass during the PT was investigated. To this aim inertial data from the chest positioned unit were used to reconstruct the trajectories of the movements of the user body during the test. As first, acceleration time series are low-pass filtered with a cutting frequency of 10 Hz to remove the higher frequency oscillations. Coherently with the reference system shown in Fig. 1, the angular displacements, θ_{chest}^{roll} and θ_{chest}^{pitch} are estimated by the filtered acceleration [35, 36]. The above angular displacements are used to estimate the average Antero-Posterior (AP) and Medio-Lateral (ML) displacements, D_{AP} and D_{ML}, of the chest and consequently the stabilogram plot [28] obtained by plotting D_{AP} versus D_{ML}.

The following quantities are then extracted from the stabilogram:

- $D_{chest}^{AP,range}$ $D_{chest}^{ML,range}$: the range of variation of the antero-posterior and medio-lateral displacements estimated at the chest, obtained from the stabilogram plot as the difference between the maximum and the minimum displacement;
- A_{chest}^{rect}: the surface area of the rectangle enclosing the stabilogram. The rectangular area represents the area that includes all the user movement paths. This is one of the most important parameter connected to the postural instability because it offers a direct feedback on the entity of the motion;
- D_{chest}^{RMS}: the root mean square (RMS) values of distances between two adjacent points of the stabilogram;
- MV_{chest}: the mean velocity of the displacement timeseries;
- $P_{chest}^{average}$: the average power of the displacement timeseries evaluated by the Power Spectral Density (PSD) of the displacement. This provides information about the rate of change of the displacement, with respect to time, without any reference to the direction of the movement;
- $f_{chest}^{average}$: the mean frequency of the displacement timeseries computed by exploiting the frequency vector of the PSD;
- the coordinates $\left(\Delta t, \langle\Delta r^2\rangle\right)$ of the Critical Point (CP) defined by the intersection of the two lines fitted to the two regions of the stabilogram-diffusion plot [28].

Here $\langle \Delta r^2 \rangle$ represents the mean square displacements between all pairs of points of the stabilogram plot separated in time by the time interval Δt;

- the short-term and long-term slopes: defined as the slopes of the two lines fitted to the two regions of the stabilogram-diffusion plot [28].

3 Experimental Results

Features introduced in Sect. 2.3 have been estimated for a large set of experiments involving 59 users. For the sake of convenience, during the development phase, tests were performed with users in good health simulating postural instability. In particular 22 users simulated postural instability during the PT. During the test the operator, positioned behind the user, provided a backward tug to the user shoulder. For the sake of safety the operator remained behind the user during the whole test to recover from injuries.

Users simulating postural instability reproduced typical behaviors observed in patients with different levels of real instabilities, such as a number of backward steps (retropulsion) to recover after the applied tug, or an accentuated body movement avoiding the fall.

As first, each test has been validated by comparing the acceleration applied through the backward tug with the predefined interval [35].

Data recorded for each test, have been downloaded from the memory card of the sensing unit through the NI LabVIEW® tool. Features above mentioned have been then estimated by processing the data through dedicated algorithms implemented in the NI LabVIEW® tool. Such features have been then analyzed in order to investigate the possibility to perform a classification between stable and unstable behaviors.

As an example, Fig. 3 shows results obtained for the following features: $D_{chest}^{AP,range}$, $D_{chest}^{ML,range}$, A_{chest}^{rect} and MV_{chest} [35]. The plots in Fig. 3 show the values of the previous features for the 59 users involved in the tests. As it can be observed, for the most of investigated cases, it is possible to properly classify stable behaviors from unstable cases. For convenience two different markers have been used to distinguish between users which have simulated a postural instability and users without postural instability.

4 Conclusions

In this paper, the possibility to improve the information achieved by the neurologists during the Pull Test for the assessment of neurological diseases severity, is discussed. In particular, a wearable inertial module, placed on the user's chest, is proposed to both assessing if the strength of the backward tug provided to the patient belongs to a pre-defined range, which otherwise can compromise the validity of the test, and to provide useful information to assess the user response to the imposed stimulus.

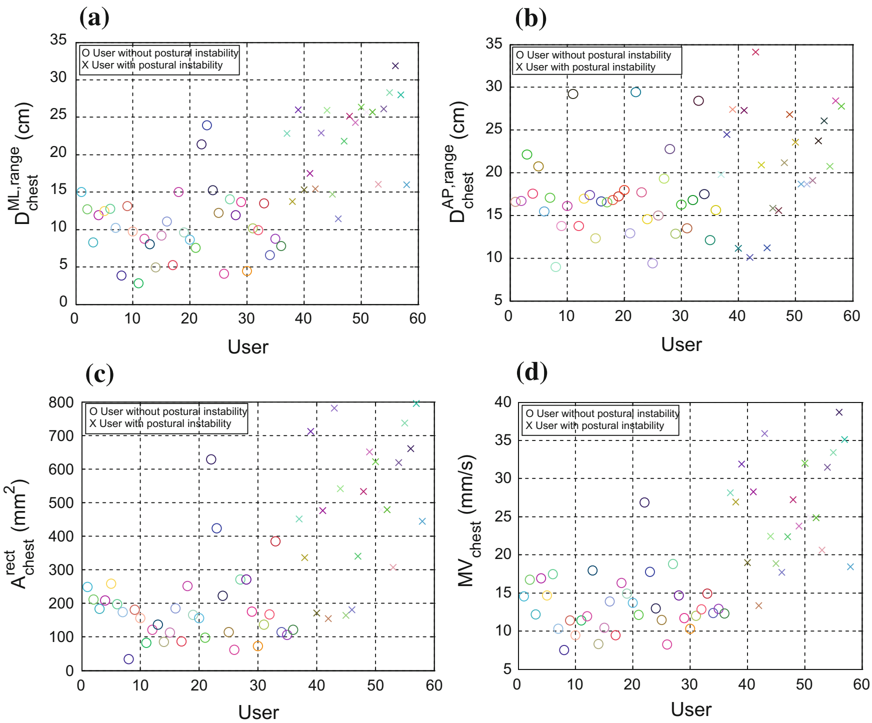

Fig. 3 Features extracted from users' response. **a** The medio-lateral displacement; **b** the antero-posterior displacement; **c** the surface area of the rectangle enclosing the stabilogram; **d** the mean velocity (2018, IEEE)

In particular, different parameters presented in the literature for the sake of the postural instability evaluation, were investigated in case of the Pull Test, with a large set of experiments in order to extract a set of features useful for the classification between stable and unstable behavior.

Results presented in Sect. 3 demonstrated that some of the investigated parameters are suitable for the classification between patients showing a stable or unstable response. In fact as it emerges from Fig. 3, a clustering of this two classes of user's response has been observed thus suggesting the possibility to adopt, for example, a threshold based classificator.

Further efforts will be dedicated to the development of a suitable advanced classification algorithm as well as to investigate the possibility to extend the proposed methodology for the postural instability monitoring of patients during Activities of Daily Living (ADL).

Actually, it must be considered that using the device in the real-world could bring to slight different results, which may require the refining of the post-processing strategies. To such aim, in collaboration with the neurologist at the University of

Catania-Italy, tests on real patients will be performed in order to achieve a wider amount of real behaviors which can be used to assess the proposed methodology.

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Study of the Usability of an Adaptive Smart Home Interface for People with Alzheimer's Disease

Francesca Gullà, Roberto Menghi and Michele Germani

Abstract Research on information technologies has seen in the last 20 years a very fast growth showing an increase of attention to the development of solution able to satisfy people with different characteristics and needs. Today, one of the main research topics aims at the definition of technologies and tools to support elderly people independent living. In this context, the present paper proposes a new home automation system able to support people with the early-stage dementia in kitchen management. This system is managed through an adaptive interface, which guides the user in kitchen activities, provides information on the functioning of all devices in the kitchen specifically, allows to set and control all household appliances in a simple and intuitive way and gives information, adapting to the end-user's capabilities and needs. Although this preliminary evaluation only included a small number of participants, the results showed that the introduction of a new smart home system can be useful to individuals suffering early-stage dementia to facilitate independent living and remain longer in their own homes.

1 Introduction

The number of older people (aged 65 and above), in a today's society is increasing; consequently, the amount of chronic disease is also rising [1, 2]. One of the most prevalent types of chronic disease within the older population is dementia [3]. Dementia is a general term for a decline in mental ability severe enough to interfere with daily life. The most common form of dementia is Alzheimer's disease (AD) which is responsible for an estimated 60–80% of all dementia cases [4]. Older adults impaired

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with dementia and AD are diagnosed with a loss of brain function which degrades the ability to think cognitively, communicate, make reasonable decisions, behave in a lucid manner, and recall memory [5]. As dementia mainly affects the older adult population, it is expected that people are not very experienced with computer and do not use it in their everyday living. This makes the technology an unlikely solution to suggest to people with AD. However, research has shown that technology instruments such as tablet or smartphones, help stimulate those with dementia [1, 6, 7].

In this context, through proper training between individuals and technological device, technology can improve the life quality for individuals suffering from cognitively debilitating disease [8]. Innovative devices such as iPads which are easy to use, cannot only help determine stage of dementia, but also provide stimulation to improve cognitive functioning [8]. In particular, the simplicity of the tablet, as well as its accessibility through its touchscreen function that allows direct input, and consequently support human-computer interaction in a more intuitive and accessible way can be user- friendly to even the most inexperienced [9]. Lim et al. [10] claim that the use of tablet in people with AD could assist in daily living. They explore the usability of tablet computers as a source of leisure for people with dementia. The results show that the participants with dementia were able to engage and use the tablet computer independently. This trial provides significant insights to introducing new technology within the early-stage dementia context. Users' needs must be considered on a case-by-case basis to successfully facilitate the uptake of tablet computers in the dementia context. Zmily et al. [11] explore the use of modern technology to enable people with AD to improve their abilities and to perform activities of daily living promoting independence and participation in social activities. In particular, they developed an integrated app, ADcope, that includes several modules that targeted individuals with AD, using mobile devices. They found that people with early stages of AD used mobile devices successfully without any prior experience in using such devices.

Modern technologies could so have an important role to satisfy main needs of users with dementia. However, one of the main problems of the developers is relating to the user interface usability. This topic is further complicated since dementia affects every individual differently and each person has his own specific set of conditions, disabilities and needs [12].

In this context, this research works aims to provide an adaptive smart environment, able to support people with the early-stage dementia in kitchen management. This smart system allows to manage the appliances and kitchen subsystems to optimize and improve the usability for different usable context. The system is managed through an adaptive tablet interface, which gives information on the features and usability of all kitchen available devices, allows to set and control all household appliances in a simple and intuitive way, and in any how adapting itself to the end-user's capabilities and needs.

2 The Adaptive Smart Home

The system consists of several devices (that is oven, dishwasher and the fridge) furnished with smart functions [13, 14]. All the household appliances can communicate with home automation system, providing information about status, programming and controlling operations. The network is realized through wireless technology and it supplies communication from/to the gateway and from/to any appliance or device. The hub of system is the gateway, which manages all the information. It connects the smart devices of the kitchen to the modem, to make them available outside the home automation network through the internet. It permits local application bundles and applications of devices of Home Network (i.e. tv, personal computer, tablet and smartphone) to access to storage data of home automation platform and to interact with all kitchen's devices.

The home automation platform is the 'core' of smart kitchen that organizes and elaborates all the data collected by the devices and operates events. It is a platform in a cloud service that gives network storage service and can be accessed from the gateway or other logic network application (i.e., Local Cloud Service Logics that can process the raw data sent by the gateway and store new data).

Finally, a web-based adaptive user interface has been developed to control and manage a smart environment, and in particular a smart kitchen. It is an application developed in cloud services, which manages the interface visualization and user interaction with the system.

The interface architecture is based on 3 main units, continuously communicating between each other: the Database Management System (DBMS), the Application Core and the User Interface (UI). The DBMS is designed to process and provide all information about user profile and context data; this unit is in charge to collect the data arising from the different inputs of the system. The Application Core represents the brain of the entire application and it is composed of two adaptive mechanisms: Adaptable and Adaptive Engine. The first one is based on user features and takes as input the collected information in the DBMS (User Features Profile) to adapt the graphical interface features, such as text, size and type of font. The second one is based on the user-system interaction and takes as input the collected information in the DBMS (User Use Profile and Context Data) to adapt the dynamic features such as preferences based on history of user's interaction, information contents, icons, and layout. Finally, the User Interface enables the control of the smart home devices. The User interface is based on graphic features (e.g. color text and buttons dimension) uniquely relate to a disorder, and contents that concern the quantity and type of information that the interface gives to the user [15, 16].

The interface supports the following functional areas:

- User interaction-appliance support: the system provides the ability to access the appliance control enabling the latter to set up, launch and monitor a given program;
- Environmental Comfort.

To support the end-user to manage a smart environment, the interface has been designed according to Inclusive Design approach [17] and Web Content Accessibility

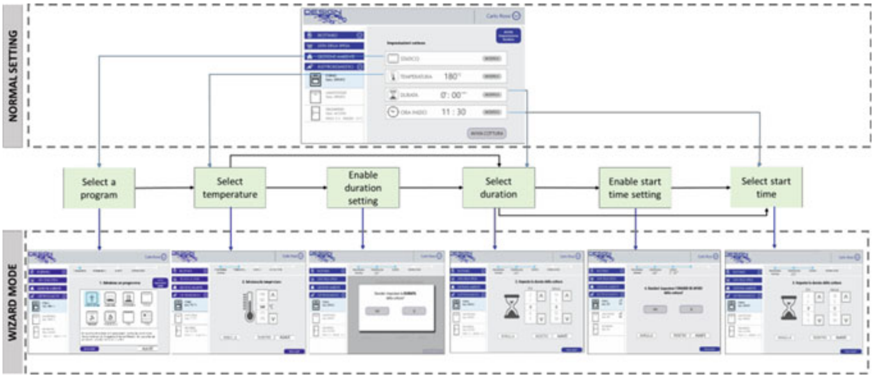

Fig. 1 Oven setting menu interface (top: Normal UI, below: Wizard UI)

Guidelines [18]. In particular, to accommodate different user needs, different interface versions were realized each providing the same information, yet in a different format. Two different user interfaces were developed: Normal Setting and Wizard Mode.

The first one was designed to resemble the most common setting menu [14, 19], where information are displayed on a single web page. All configuration options are displayed on the homepage and the settings can be changed by tapping on the button and accessing the setup window. The value can be changed and then, return to the main page.

The Wizard interface was designed to accomplish the task and minimizing the amount of information that the user should understand and manage. The information was given through a setting driven process. The UI was provided with a progress bar placed horizontally at the top of the page, which allowed the user to keep track of the progress state achieved. Based on the adaptation mechanism, the most suitable settings are suggested. Furthermore, on each screen additional help information is shown for a better choice understanding. In addition, some pop-up elements were inserted as confirmation controls to help the user in programming specific tasks (e.g., enable duration setting and enable start time setting). Moreover, during interaction with the interface, the user can change the information presentation mode by tapping on the proper button.

Figure 1 shows an example of Oven Setting Menu Interface.

3 Methods

In this study, we evaluate the usability of the proposed System. The following section describes in detail the selected participants, apparatus, study procedure, and the collected measures.

Participants. For the purpose of the study, volunteer subjects were recruited in facilities of the local municipality. The participants were primarily seniors, with early stages of AD. In total the sample was composed of 8 participants, 3 males and 5 females, with a mean age of 73.0 years old (SD = 3.6).

To be enrolled, the following inclusion criteria were fixed:

- Age 65 and older with high school education;
- Mini Mental State Examination [20] (MMSE) score between 22 and 28: early and mild impaired patients who retained the physical and functional ability to participate in a cognitive or motor stimulation program. Users with minor cognitive disabilities who live mostly independently but nevertheless need assistance with more complicated tasks or to learn new things will be selected.
- Familiarity with touchscreen devices (e.g. smartphone, tablet);
- Intermediate level of expertise in cooking.

Experimental Setting. The experiment took place in the kitchen of the usability lab, which was set up to serve research purposes. The lab was equipped with the interconnected smart appliances (i.e. oven, dishwasher, fridge), a table and a chair. On a large table, participants had at their disposal the tablet with the Application. The setting was maintained the same for all participants.

Equipment. The Application was presented on a Samsung Galaxy Tab A (10.1″). The whole interaction with the pilot application was recorded by means of dedicated cameras.

Procedure. On the day of the test, participants were first welcomed in one of the laboratory facilities and were debriefed regarding the overall activity and the goals of the experiment. Before the experiment began and with the support of a psychologist, participants were also asked to redo the MMSE to ensure that all users are comply with the established inclusion criteria. They were then asked to carefully read the informed consent and to sign it in only when the contents were clear, the experimenter explicitly told them that they could refer to the him to clarify any doubt before, during and after the experiment. The experimenter then walked the participant to the kitchen lab, where s/he was illustrated how the kitchen was set up. At this point participants received an explanation of how the application was structured and how to operate it.

Participants were asked to perform three tasks: (1) Oven setting, (2) Temperature fridge setting and (3) Environment Management.

The first task, consists of four mini-tasks: (a) select the cooking program (e.g. static, ventilated, grill, etc.), (b) select the program temperature, (c) select the program duration and (d) start the cooking program. The second task consists of one mini-task: set the temperature of the refrigerator. The third task consists of two mini-tasks: (a) set the environment indoor temperature and (b) set the environment interior lighting.

The experiment was conducted by using the user interface both in Wizard and Normal mode. During the entire interaction, users were encouraged to express their thoughts, feelings and opinions aloud (Thinking Aloud technique) while the experimenter was taken annotation of the performance, errors and user attitudes [21]. The experimental session was completed when the user has completed the three tasks.

4 Results

In the present section, we present the results of the experiment related of people with early stage of dementia. The following objective parameters have been collected for each task: task completion (C), errors number made by user during the interaction (E), number of support requests made by user to the experimenter (Sr) and time in second of completed tasks.

By analysing the results, shown in Table 1, we can observe that the Oven Setting (Task1) is the most complex task to be independently completed. In detail, in the Normal mode, only 3 of 8 users involved are able to complete the task independently. In fact, most users often recur to the aid of the experimenter (Sr = 5.5; SD = 2.9), with an average error E = 5.1 (SD = 2.6). Instead, in the Wizard Mode, five users complete the task independently. The errors number (E = 2.9; SD = 1.8) and the support requests number (Sr = 2.4; SD = 1.1) are considerably decreased compared to the Normal version. Regarding the Fridge Temperature Setting (Task 2), in the Normal mode, the results show that only one user was unable to complete independently task. During the task execution, an average number of errors equal to E = 3.0 (SD = 0.7) and an average support requests equal to Sr = 2.1 (SD = 0.4) have been found. On the contrary, in the Wizard mode, all users have successfully completed the assigned tasks.

Finally, for the Environment management (Task 3) the results show that the task was completed successfully by 6 users with an average number of errors E = 2.9 (SD = 1.5) and an average support requests Sr = 2.6 (SD = 1.8), in Normal mode. Instead, in the Wizard mode, all users have completed the task independently, with an average error E = 1.3 (SD = 0.7). The overall task duration was compared between the two conditions. As can be observed in Fig. 2b, the completion times for each task in the Wizard mode are generally lower compared to the Normal mode (Fig. 3).

At the end of the session, users ware also asked to answer to the SUS questionnaire [22]. The SUS analysis results show that the interfaces are considered very usable for

Table 1 Results of user performance

		Task 1	Task 2	Task 3
Normal mode	Task completion (C)	37.5%	87.5%	75.0%
	Error number (E)	5.1	3.0	2.9
	Support requests number (Sr)	5.5	2.1	2.6
	Time completion (s)	468.75	126.00	118.50
Wizard mode	Task completion (C)	62.5%	100%	100%
	Error number	2.9	0.4	1.3
	Support requests number	2.4	0.1	0.3
	Time completion (s)	397.50	117.75	93.75

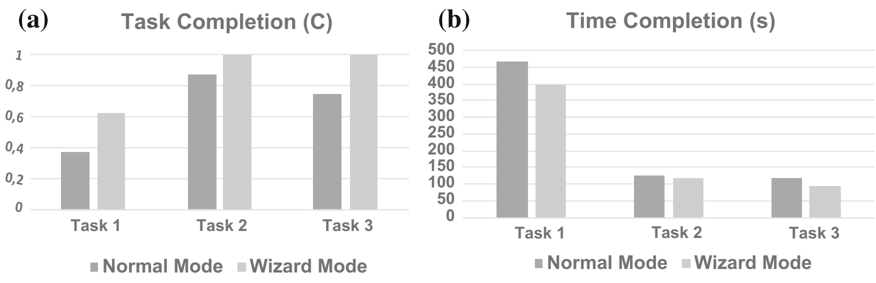

Fig. 2 Comparison between Wizard and Normal mode: (**a**) task completion (**b**) time completion

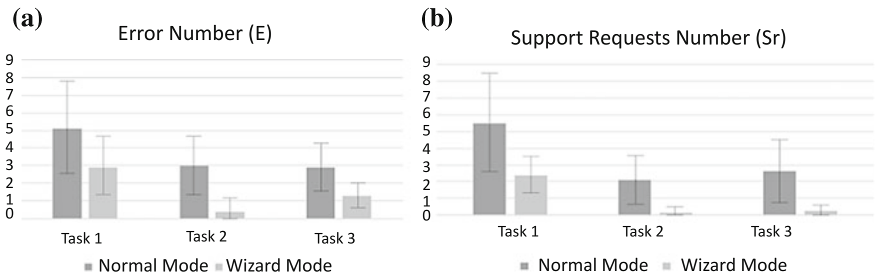

Fig. 3 Comparison between Wizard and Normal mode: (**a**) error number and (**b**) support request number

Table 2 Result of usability evaluation through SUS score

	Normal mode	Wizard mode
Average SUS score	77.5	84.5

all involved users. The Wizard Interface has obtained a higher score (SUS = 84.5) given by the greater amount of information available in this mode (Table 2).

5 Discussion and Conclusion

In the present work, we reported a preliminary usability study of an adaptive smart home interface designed and developed to support people with the early-stage dementia in kitchen management. Despite the interesting results, the limitation of this exploratory study was the small number of participants that do not allow a final statement about the technology adopted [23, 24]. In fact, it is important to note that the recruitment of the patients with early-stages of AD is very challenging.

The obtained results and feedback from the test session provide significant insights for the introduction of a new smart home system within the early-stage dementia context. Our findings show that the Wizard interface provides significantly support in the independent performance of the household tasks to the user with AD, both in terms of performance and time. In particular, the results show that in the most complex activities, such as the oven setting, users have found benefit in the setting driven process due to a decrease in cognitive load and the availability of more information. The greater clearness of the information given in the Wizard Mode allows to reduce the Time Completion of the task. Indeed, in the interaction with the Normal mode, some users have been confused by the many options displayed on the oven main menu. Instead, in the simplest tasks, such as fridge temperature setting and environment management, users have not found significant improvements. Moreover, during the use of the Wizard interface the number of errors and help request made by the users are lower than the Normal mode. Concluding, in the Wizard mode, participants were less dependent on the experimenter support.

These findings suggest that the system could be useful to help and guide people to remain independent in their own home environment for daily life activities. The introduction of an adaptive smart home system may then take into account the cognitive disabilities through its ability to adapt according to user needs. Future works will be focus on the integration and implementation of this system in real-life contexts with persons with early-stage and mild dementia.

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DAPHNE: A Novel e-Health System for the Diagnosis and the Treatment of Parkinson's Disease

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Abstract Parkinson's Disease (PD) is a neurodegenerative disorder that affects millions of people worldwide. A standardised objective tool for PD diagnosis and management is still missing and the adopted monitoring approaches are suboptimal. The development of a technological solution implementing e-health systems is investigated in various research projects. In this paper we propose DAPHNE system, aimed to implement innovative and sustainable services for the early diagnosis, for the therapy and for the management of PD by using wearable devices, information and communication technologies (ICTs), such as mobile Health (mHealth) apps and Internet of things (IoT) protocols. To such a degree, DAPHNE successfully proposes an Ambient Assisted Living (AAL) solution that supports the clinicians in early and differential diagnosis, promotes a precision medicine approach by enabling an at-home monitoring service optimised according the patient's needs, stimulates the self-management of patients and caregivers in the care path, significantly reduces healthcare costs in terms of diagnostic examinations/hospitalisation and, as major breakthrough, permits a PD diagnosis up to 7 years earlier than current methods, so maximising the drug therapy efficacy.

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Keywords Parkinson's disease · Wearable sensors · Integrated care · e-Health AAL

1 Introduction

The progressive aging of the worldwide population results in increasing of neurodegenerative diseases as Parkinson's Disease (PD). The estimated annual cost is €13.9 billion in the EU [1] and the number of patients is forecast to double by 2030 [2]. Idiopathic PD is a complex disorder of unknown cause, depending from both genetic and environmental factors [3] and characterized by a typical asymmetric onset. Pathology shows deficiency of pigmented cells in the pars compacta of the substantia nigra leading dramatically towards a critical lack of dopamine in the forebrain that manifests in motor symptoms. The cardinal motor symptoms of PD are tremor, bradykinesia, rigidity and postural instability [4] but also other impairments, known as non-motor symptoms, are manifested like olfactory disturbances, fatigue, pain, autonomic dysfunction, sleep fragmentation, depression, and dementia [5]. The disease is difficult to be promptly detected and treated as it shows a wide variability in the clinical expression as well as in the somatic symptoms progression. To date, a definitive and universally accepted test for the PD diagnosis is still missing, therefore the pathology is mainly assessed upon clinical criteria [6] and, despite the difficulties due to the complexity of the pathology, recent studies are increasingly focusing in redefining such PD diagnosis criteria [7]. Effectively, traditional PD diagnosis is based on clinical criteria [8] and a semi-quantitative assessment of motor tasks defined in the motor section of the Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS section III) [9]. Neurologists measure disease severity assigning MDS-UPDRS scores. Instead, disease progression is assessed with Hoehn and Yahr scale [10] which ranges from stage 1 (mild) to 5 (severe). The evaluation of these scales is mainly subjective, leading also to high inter-rater variability across different neurologists or different medical centers, as well as high intrarater over the time.

Since traditional diagnostic methods and monitoring approaches are still sub-optimal for PD management, it is widely accepted the use of smart technological solutions that can help clinicians in early diagnosis, differential diagnosis and quantification of symptoms over the time for an optimized disease monitoring. Recent advances in wearable devices, communication technologies and data mining allow to develop integrated e-health systems able to provide novel therapeutic and monitoring possibilities for patients with PD (PwPD). Specifically e-health systems allow to: (i) increase the efficiency in healthcare avoiding unnecessary diagnostic or therapeutic intervention, decreasing also costs and supporting clinical decision making; (ii) enhance the quality of healthcare by augmenting the contacts between patients and clinicians and sharing information between different providers; (iii) empower patients to actively manage their health and to adopt healthy behaviors [11].

For these reasons, e-health is becoming increasingly important to provide high level quality of care for EU citizen and different projects have been recently funded by EC within the healthcare domain. Specifically four projects address PD: (i) REMPARK (2011–2015) aimed to develop a Personal Health System with closed loop detection for the management of PD; (ii) PD_manager (2015–2018) aims to provide each patient of specific therapeutic treatments and to develop a home-care-focused rehabilitation system; (iii) NoTremor (2014–2016) aimed to develop specifically per each patient virtual, physiological and computational neuromuscular models of the coupled brain and neuromuscular systems in order to predict how PD develops; (iv) NeuroTREMOR (2012–2015) aimed at validating a novel system for the understanding of tremors, giving support to diagnosis and remote tremor management.

Recently, e-health systems focused on PD treatment were proposed so as to enhance the home and self-monitoring of this pathology. A first example is ParkNosis, a mobile Health (mHealth) application, able to collect data from motor tests and from questionnaires to be filled via the app by the patients and to supply a rapid feedback about their current condition through a smartphone or a smartwatch. However, the tests implemented were related to the hands only, so the diagnosis cannot be completed since lower limbs, posture, rigidity and other symptoms were not taken into account [12]. The PERFORM project instead, via a modified mouse equipped with three pressure sensors and an accelerometer sensor acquires data relatively to the tremor of the user. A Web-based home monitoring portal allows the patients to access to their personal medical information and medical history and facilitates the interaction between the patient and the doctors. Also in this case, the analysis of tremor cannot be considered exhaustive for a complete assessment of PD [13]. Zhao et al. [14] proposed the use of smart glasses as an assistive technology to facilitate daily living activities, through the development of apps for physiotherapy, relaxation and speech therapy or providing cues that may support gait. However, glasses are not very comfortable for every subject and they do not allow to acquire data for accurate motor assessment of PD symptoms. Finally, Cancela et al. [15] within PD_manager project, proposes the development of a mHealth platform for the monitoring and management of both motor and non-motor symptoms in PD. Presently, the methodology definition for the assessment of dyskinesia, bradykinesia, gait and posture is ongoing, as well as the experimentation, so the results can be discussed only later. Nevertheless, the protocol described does not consider all the items typically analyzed during PD neurological assessment, but only finger tapping and alternate finger tapping, so a complete evaluation of PwPD does not seem feasible.

In this paper we describe the DAPHNE system, which aims to implement innovative and sustainable services for the early diagnosis, the therapy and the management of Parkinson's Disease by using wearable devices, information and communication technologies (ICTs) and m-Health technologies and promotes home monitoring, engagement and self-management of patients and caregivers in the care path.

The technological system can support the clinical staff during the pathology progression, from the beginning of the disease, favoring the correct diagnosis and monitoring the treatment over the time. The idea is to provide the clinicians with sensor devices and smart interfaces able to objectively and quantitatively measure the motion performance of the patients in order to: (i) identify a deflection in motor capabilities that allows to detect the disease in the prodromal stage. In this way, the neurologist can diagnose PD when small cortical areas are involved in the degeneration process that accompanies the pathology and can provide timely interventions with neuroprotective therapies that slow the disease progression, resulting in better quality of life both for patients and their caregivers; (ii) accurately quantify the disease assessment in PwPD and the response to pharmacological therapies, allowing a continuous and ubiquitous monitoring, developing a personalized care path based. This approach will al-low to address PD pathology during the whole progress and to apply the principles of the novel precision medicine concept for healthcare systems, whose main goal is to provide the best available care for each individual. For this purpose, a massive data and knowledge sharing between all the parts involved in the project is needed to ensure an adequate reciprocal benefit [16]. As efficient PD tool for the monitoring, the management and the early diagnosis of the disease, DAPHNE naturally qualifies as Ambient Assisted Living (AAL) solution for the integrated care [17, 18].

DAPHNE is a 24 months research project that has been approved and funded by REGIONE TOSCANA public authority. At the moment of the preparation of this paper the project was in its 12th month of living period.

2 Materials and Methods

2.1 Clinical Hypotheses

The idea of developing a system for the PD care is based on practical clinical hypotheses suggested by clinicians' experiences:

- Hypothesis 1: Subclinical latent phase—there is a latency time in PD between the beginning of the neurodegenerative process and the appearance of the typical motor symptoms that generally lead the clinician to the diagnosis. This latency is about 5–7 years [19, 20], so the diagnosis is expressed when disease is already widely spread.
- Hypothesis 2: Idiopathic Hyposmia (IH)—Hyposmia is a PD co-morbidity in more than 95% of PwPD [21]. Further in healthy subjects IH is associated with an increased risk of developing PD of at least 10% [22].
- Hypothesis 3: Pharmacological benefits—Pharmacological therapies are essential to slow the disease progression rate and to reduce the effects of its typical symptoms [23] so they are periodically assigned and modulated by clinicians according to the status of patients. Particularly, neuroprotective therapies give the best benefits when administered in the early stages of the disease.
- Hypothesis 4: Monitoring of PD patients' activities—Advanced PD patients show severe motor and cognitive impairments, so an appropriate assistive monitoring system is required.

Since PD is a progressive degenerative disorder, it is reasonable to suppose that subjects show a gradual worsening of motor skills over the time. Such phenomenon can be promptly identified by an accurate instrumentation. According to the hypotheses, subjects with IH are supposedly a convenient reference group for a pre-frailty state for the testing of the instrumentations and of the procedures to be adopted for the early diagnose of PD. The demonstration of a subclinical motor decline and of its subsequent improvement, induced via a pharmacological therapy (i.e., levodopa drug) promptly administered, is a reliable and low cost PD diagnose procedure that, furthermore, can justify the execution of an expensive and invasive diagnostic test (i.e., SPECT-DaTSCAN [24], a nuclear medicine tomographic imaging technique). In this way PD diagnosis could be anticipated of 5–7 years compared to date. Moreover, an adequate ICT instrumentation able to objectively assess the motor performance and to easily interact with patients can support doctors in monitoring and adequately change the treatment when required so as to optimise and personalise pharmacological therapies. Finally, a remote telemedicine system can also provide to patients with severe disorders and or in the most advanced stages of PD a valuable health-assistance instrument by monitoring their physiological signals and their activity patterns, by reminding them therapy to be followed and by easily connect them with clinicians.

2.2 Clinical Objectives and Services

PwPD require different services (differential diagnosis, therapy and monitoring) according to their own impairments meant to efficiently help them throughout the pathology progression, starting with an early diagnosis. According to precision medicine approach, it is important to study cohorts of patients with specific disorders and to provide adequate solutions for each of them. In this context, DAPHNE involves subjects with IH, de novo patients (untreated patients) and PD patients with various levels of severity and for each group specifically provides various services.

Subjects with IH are subjected to a yearly screening program in hospital that comprises neurological, motor and olfactory assessments. In fact, at least 10% of hyposmia affected subjects are expected to develop PD within a range of few years, hence a slow deflection in motion performance can trigger a PD early diagnose.

De Novo patients present an early mild PD non pharmacologically treated yet. For this group of patients, it is important to test the response to levodopa, which is the drug mainly used for PD treatment. This is a sub-acute test consisting in administering in-creasing doses of levodopa for approximately half a month. A motion analysis is per-formed at the very beginning (basal condition-no drug used) and at the end (maximum levodopa dose administered) of such period in order to assess the patient response to the drug treatment. Subsequently, for an equivalent period of time, the dose is progressively decreased and the assessment of the motion is performed again 10 days after the end of the medication intake. Such procedure enables the evaluation of the effect of levodopa on motor performances since this drug is efficacious for

PD but not for Parkinsonism disorders, hence a positive response can support the PD diagnosis. De Novo patients periodically repeat the biomechanical analysis in hospital during the first year and in case the diagnosis is confirmed they can start the personalised treatment.

Patients already PD diagnosed need to be periodically assessed by the neurologist. The latter can visit PwPD either in a hospital environment or remotely via DAPHNE allowing patients to stay at home. The typology of parameters to be monitored as well as the requests for the biomechanical and neurological assessment can vary on the basis of the pathology stage, according to the clinician's evaluation, who via DAPHNE can individually modulate the therapy observing the patient's response to drugs. PwPD benefit in turn of the system continuously being updated about the pathology progression and the pharmacological treatment response.

Regardless of the patient status, DAPHNE provides valuable mHealth and telemedicine services through mobile and web-based apps that include behavioural and healthy lifestyle guidance, drug therapy reminder, personal diary and medical appointment agenda, a direct and constant contact with the clinical staff upon patient request, an objective and quantitative assessment of PwPD throughout his care path.

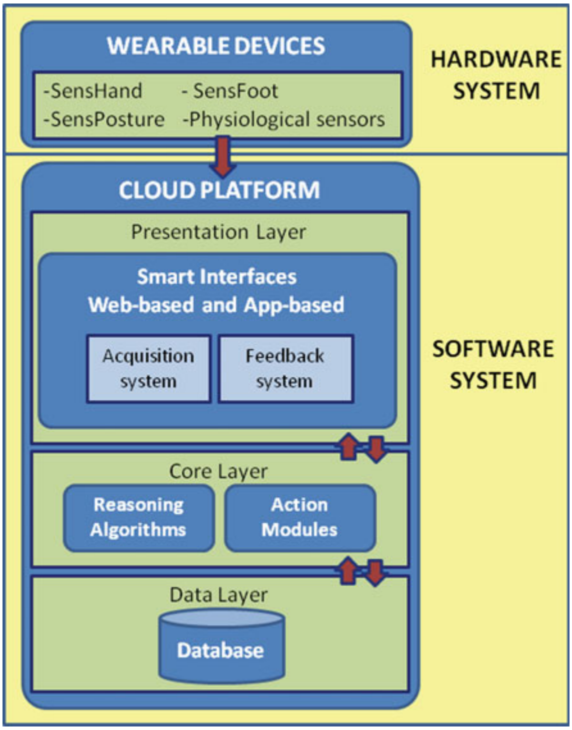
3 Results and Discussion

In order to provide the described services, DAPHNE foresees the development of adequate technological solutions in terms of hardware, firmware and software. In particular, web and mobile apps supported by a Cloud platform are being developed as core of the entire project. The overall system concept is reported in Fig. 1: (i) an hardware part consisting of a set of wearable sensors; (ii) a multifaceted cloud-based software that in turn contemplates a presentation layer, a core layer and a data layer. In the following sections we describe each of this system component.

3.1 Hardware: Sensorized Wearable Devices

The DAPHNE hardware architecture is composed by a set of wearable, comfortable and no obtrusive devices. In particular, two systems, based on inertial sensors and called SensHand and SensFoot [25–28], were developed for the motion assessment of PwPD by means of a fine upper and lower limbs posture and motor analysis. An analogous device was developed for chest posture evaluation. The project also considers to integrate sensors for the monitoring of physiological parameters such as Hearth Rate Variability (HRV), pulse oximetry and Galvanic Skin Response (GSR) in the hardware infrastructure of the SensHand part. The devices developed are low-cost, low-power, non-invasive, small in size, lightweight, wireless and easy to use. They are supplied by rechargeable LiPo batteries and they allow to collect data at 100 Hz sampling frequency.

Fig. 1 The DAPHNE system architecture



SensHand (Fig. 2) is a network composed by four sensor units developed for hand motion assessment. Each unit integrates an inertial measurement unit (IMU) equipped with the STM32F103RET6 microcontroller (ARM 32-bit Cortex™-M3 CPU, STMicroelectronics, Italy) and the LSM9DS1 iNEMO inertial module (3-axis gyroscope, 3-axis accelerometer and 3-axis magnetometer). In particular, the module placed on the wrist is the coordinator of the system and it is equipped with the SPBT2632C1 (STMicroelectronics, Italy) 3.0 Bluetooth serial device for wireless communication towards a control station. The other modules are integrated in silicone covers and placed on the distal phalanges of the thumb, index and middle fingers. Modules coordination and internal data synchronisation are implemented through the CAN-bus standard.

SensFoot (Fig. 2) consists of a single IMU for the assessment of the lower limbs motor performance and it integrates similarly a 3-axis gyroscope, 3-axis accelerometer and a 3-axis accelerometer. The device is equipped with the SPBT2632C1A 3.0 Bluetooth module which wirelessly transmits data acquired to remote personal computer for analysis. The device is placed on the dorsum of subject's foot within an elastic band to ensure a firm bound between foot and sensor.

SensPosture is technologically analogous to SensFoot, but it is integrated in a brooch or a chest strap, in order to monitor the posture of PwPD during their common daily activities. Furthermore, the device is equipped with a vibration or auditory

Fig. 2 DAPHNE hardware components SensHand on the left and SensFoot on the right

feedback, to alert if anomalous postures are detected by the inertial sensors and to provide support to correct the same.

The DAPHNE hardware infrastructure is managed by an appropriate embedded firmware developed both for sensor data collection and the establishment of a wireless sensor network based on a Bluetooth Piconet necessary for the concurrently upper and lower limbs motor analysis. Sensor fusion algorithms, digital filtering and real-time methods for sensors calibration were also implemented and embedded in the Flash memory of each one of the microcontrollers integrated in the devices.

3.2 Software: Cloud Platform Layers

The Cloud platform is structured in three different layers, as pointed out in Fig. 1.

Presentation Layer. Computer or mobile interfaces are accessible by both patients and doctors. This aspect implements instruments such as Java Server Pages. Smart interfaces based on a web-application approach were developed to provide an easy, fast and pervasive management of the data acquired for the pathology assessment and its monitoring. Furthermore, the interfaces functionalities and access rights are tailored on the base of the different end-users involved (e.g., patients, caregivers, clinicians, researchers). In particular, a smart interface for sensor data collection during the biomechanical tests at the hospital were integrated in the clinical staff web- application. Such interface (Fig. 3) allows the storage in a local and on-line database of both the patient's personal info and the data transmitted directly by the inertial sensors during a guided and automated procedure. During the execution of the motor tests, feedbacks are appearing on the screen regarding the proper sampling frequency as well as the correctness of the data acquired through accurate data loss

Fig. 3 DAPHNE clinical interface. Such interface is composed by: un upper part in which is possible to control linked sensorized wearable devices status (Interface Connection); an Info section in which patient personal data can be inserted; a Biomechanical Test Set acting as control panel to choose which task the patient is asked to perform; a lower section in which feedbacks about the test results and the saving path can be controlled; a section in which feedback about the frequency at which devices are acquiring can be checked; a task timer; a Data Loss section sending an alert in case the test is failing; a MDS-UPDRS section in which the assigned score is shown

recognition functions. Other functionalities such as the real-time calibration of the wearable sensors and the firmware upgrade of the devices were also implemented. The web- application allows the automated extraction of measurement indices by means of the reasoning algorithms that assigns the MDS-UPDRS score to the patient under examination. A simplified version of the smart interface is being developed for the patient's web-application so as to allow the execution of the biomechanical tests directly at home by also supplying video tutorials and real-time feedbacks on the accuracy of the motor tasks executed. The patient will also be given the opportunity to access to the sections dedicated to the management of its drugs and its appointments. In particular, a calendar section in which reminders about planned tests, visits, drugs administering hourly timetable, medical fulfilments tracking is in preparation.

Core Layer. This section is responsible of the data treatment through the formulation of reasoning algorithms able to aggregate data and supply a quantitative and qualitative measure of the disease parameters. Data to be processed are acquired by the sensors and by means of dedicated application programming interfaces (API)

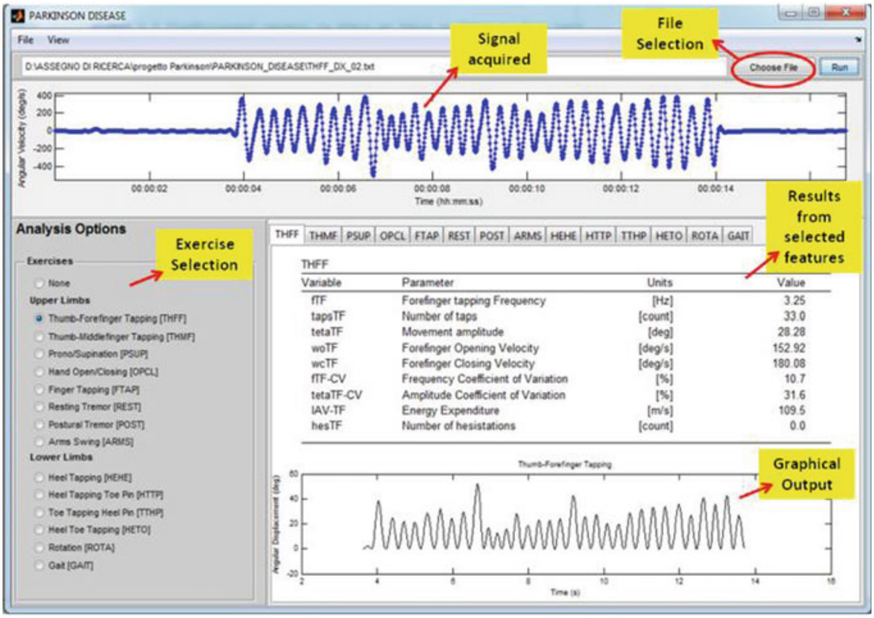


Fig. 4 Algorithm interface for algorithm debug and raw-acquired data assessment purposes

supplied to the cloud. The Core-Layer will exploit a server structure, i.e. a software platform such as Apache Tomcat able to execute web applications. The reasoning algorithm was developed in Matlab®R2012a and automatically analyses the data acquired during motor examination of PwPD. The button Test-Assessment inserted into the interface aforementioned (Fig. 3) calls such algorithm. At the current stage of the project the algorithm still has to be included into the cloud infrastructure, hence the interface is simply interacting with a locally stored Matlab script and the data analysis is executed offline. Furthermore, the algorithm, when run into a Matlab environment for debug or further development purposes, is provided of its own interface (Fig. 4) that allows to choose the file to analyse, select the type of exercise and visualize the results in terms of spatio-temporal and/or frequency features. Graphical outputs are shown to allow to infer the results obtained by the patients. The data can be also exported in excel files for data storage or further analysis.

Data Layer. This layer is responsible for the implementation of a database aimed to collect and insure the data persistence through the definition of the storage, of the access and of the management modalities considering an open source approach such as MySQL and JDBC. The Data-Layer allows the PD and clinical staff to access the results of the biomechanical tests performed and evaluate the therapeutic treatment to be adopted and to track the disease course.

3.3 Data Security

The communication with the devices or software external to the Cloud platform are possible by means of secure connection systems using transmission protocols for application layers such as HTTPS. The implementation of the platform exploits the Infrastructure as a Service (IaaS) Cloud Computing paradigm defined as the ensemble of technologies that allow the data storage and elaboration thanks to the exploitation of hardware/software resources distributed on client-server architectures. The Cloud platform is implemented upon a Google Cloud Platform service. Data travelling between customer devices and Google are encrypted by default using HTTPS/TLS (Transport Layer Security) protocols and, as well known, Google Cloud Platform meets rigorous privacy and compliance standards (e.g., SSAE16/ISAE 3402 Type II and ISO 27001 for the systems, applications, people, technology, processes and data centres) that ensure a high level of data safety and privacy (i.e., ISO 27018 Cloud Privacy for protection of personally identifiable information and ISO 27017 Cloud Security for information security controls). Google Inc. is certified under the EU-U.S. Privacy Shield Framework and it satisfies the security requirements of the EU Data Protection Directive.

3.4 Preliminary Results

The first version of the proposed system already allowed to acquire data from PwPD, healthy subjects of controls and subjects with IH. The system is patented [29] and ethical committee approvals are already obtained. The preliminary results of this study are reported in [25–28], showing that the system is able to differentiate between the groups investigated with good performance in terms of accuracy and to satisfyingly correlate on clinical scales scores. In terms of technology specifically developed during the project, SensHand, SensFoot, SensPosture (Fig. 2), the presented user interface prototype (Fig. 3) and the reasoning algorithm (Fig. 4) have been already tested on a small group of patients and are currently under validation. The realisation of the cloud, with the transposition of the interface and the reasoning algorithm in it, is still under development.

3.5 Clinical Impact

The main clinical impact of DAPHNE system derives from the possibility to objectively and quantitatively measure the motion performance of PD patients and subjects at risk for developing the pathology through the wearable inertial sensors developed and the relative processing algorithms implemented. DAPHNE acquires data relatively to both upper and lower limbs movement during the execution of a structured protocol of basic body exercises. The final goal is to provide clinicians of a quantitative evaluation of the MDS-UPDRS III, assigning objective scores that specify the severity of the pathology. The ability to finely assess a patient, concretely, allows the clinicians to diagnose PD already in the prodromal phase, when slow deflections in motion are imperceptible upon visual examination. The early diagnosis of PD permits to anticipate the beginning of a pharmacological therapy up to 7 years before the current practices, also with neuroprotective drugs, widely increasing their efficacy [30]. A slow in the disease progression rate promotes a delay in symptoms manifestation with high benefit in terms of quality of life for PD patients.

The objective assessment of PD support the clinicians also during the periodical differential diagnosis and it provides precise information about the response to a specific pharmacological therapy. In this way the neurologist can adequately vary the treatment on the basis of individual characteristics, promoting personalized care paths.

Furthermore, the objectivity of the measurements, as well as the opportunity to store in a cloud database all the data acquired of each patient, can induce a wide reduction both for intrarater and interrater variability that currently affect PD assessment.

Moreover, the remote system allows to move some examinations directly to patients' houses. This is particularly important for those patients in advanced disease stages that manifest severe impairments including motor fluctuations during the day. These patients can acquire their motor performance when critical events occur and the clinician can remotely observe the results, timely intervening if needed. The remote system can be used also by mild/mid PD patients to periodically monitor their performance and possibly increase these subjects' empowerment and engagement in the care path.

Finally, the availability in clinical practice of DAPHNE system can drastically reduce the number of invasive and expensive exams based on imaging techniques (i.e., SPECT-DaTSCAN), which are currently used to objectively confirm the diagnosis.

Conclusively, DAPHNE allows the definition of a novel methodology and protocols for objective PD diagnosis, as well as a smart remote system for assistance and monitoring of the disease over the time, and enhances the PD management, the relationship between patients and clinicians and the engagement of the patients in the PD treatment.

3.6 Economic Impact

From an economic point of view DAPHNE can concretely deliver an important impact effectively contributing in cutting the costs that both SSN (Sistema Sanitario Nazionale) and PwPD themselves have to face. In fact, due to the exploitation of a remote health-assistance system, SSN can beneficiate of a significant reduction of costs in term of hospitalisation, human resources to be deployed to assist PwPD, utilisation of diagnostic instrumentation such as SPECT-DaTSCAN and assistance

Table 1 Percentage of PwPD in Tuscany region per HY and frequency of the neurological visits

Severity	Number of PwPD in Tuscany	Percentage of PwPD per HY (%)	Minimum number of neurological visits per year
HY1	2250	15	3
HY2	5250	35	3
HY3	3750	25	5
HY4	3000	20	5
HY5	750	5	0
De-Novo	478.27		10

Table 2 Costs items of the technological kit

Technologies and services	Cost (€) for applications
System of wearable devices for hand	900
System for wearable devices for foot	420
Wearable commercial devices	900
Software (algorithms, apps, end-users' interfaces)	300
Integration system (gateway)	160
Cloud service	250
Total	2980

to be provided in the most severe stages of the disease. Furthermore, also PwPD themselves can beneficiate of a reduction of transportation costs to be sustained along with a reduction of losses due to the unproductivity that hospitalisation causes [31]. According to de Lau [32], in 2006 the volume of people to be assisted solely in Tuscany (Italy) region was nearly equal to 16 thousand cases, of which roughly 500 cases are de novo patients. The distribution according to the HY stages of these PwPD are reported in Table 1 [33]. On a year basis, according to a study carried out in 2011 by Von Campenhausen [34], SSN spends in Italy an average of 8340 € per each PwPD. Interestingly, DAPHNE, by providing a complete technological kit (wearable devices, smart end-users-interfaces and Cloud service) both to the health districts and to patients assisted, successfully enables an early diagnose of PD and provides an at-home health assistance instrument, thus effectively reducing PD management costs. The estimated costs of a certificated DAPHNE kit is about 2980 € justified by the items presented in Table 2. Taking into account the costs related to the provision of at least 5 technological kits to ideally all of the 12 health districts present to date in the Tuscany Region, DAPHNE can lead SSN to save ~350 K€ solely in Tuscany (Table 3). Such values were calculated without considering the cost of drugs to be used.

Further savings arises since DAPHNE is expected to slow the disease progression rate by providing an early objective diagnosis of the PD, namely up to 7 years before

Table 3 DAPHNE economic impact

Severity	Current PwPD total annual cost (€)	Current SSN total annual cost (€)	DAPHNE PwPD total annual cost (€)	DAPHNE PwPD annual reduction/increase (€)	DAPHNE SSN total annual cost (€)	DAPHNE SSN total annual reduction/increase (€)
HY1	67.5 K	128.25 K	67.5 K	0	135 K	+7 K
HY2	283.5 K	1.34 M	283.5 K	0	1.35 M	+7 K
HY3	401.2 K	2.12 M	453.4 K	+52 K	2.40 M	+283 K
HY4	150 K	5.93 M	138 K	−12 K	5.47 M	−468 K
HY5	0	3.74 M	0	0	3.56 M	−187 K
De-Novo	224.6 K	0	224.6 K	0	7 K	+7 K
Total	1.13 M	13.27 M	1.16 M	+40 K	12.92 M	−350 K (−2.9%)

Table 4 Expected annual cost saving in Italy with 10% reduction of used SPECT-DaTSCAN

SSN current total annual cost (€) in Italy	Expected SSN annual cost (€) with DAPHNE	Economic saving (€) with DAPHNE
~204.17 M	~198.23 M	~6 M

the current practices, therefore decreasing the number of patients in stages HY5 and HY4 respectively of the 5 and 8%. Hence, DAPHNE favours a displacement of PwPD in the less costly stages HY 1-3 [35].

Moreover, other savings stems from an expected reduction of the utilisation of the invasive and expensive SPECT-DaTSCAN tests, presently the only certified instrumentation for the diagnose of PD. A single run of such test costs around 1000 €. Roughly 230,000 SPECT-DaTSCAN exams are executed every year in Italy. DAPHNE is expected to reduce of at least the 10% the number of needed executions of such test and thus allowing a reduction of nearly €6 million (Table 4).

3.7 Technological Impact

ICTs improvement has continuously been providing new services and useful instruments in several fields. Largely developed upon the constant spread of web/cloud platforms and the diffusion of smart and mobile devices, mHealth technologies are nowadays more and more requested and employed [36]. Such widespread of mHealth applications is also positively welcome by physicians who believe this trend helps in reducing the number of required medical interventions whilst provides a valuable remote health assistance instrument in both normal and emergency conditions [37]. mHealth technologies are in turn encompassed in the much larger concept of e-Health that pursues the preservation of high quality healthcare and cost-saving strategies at once [38]. The forecasted market value for telecare was predicted to triple from $9.8 billion (2010) to $27.3 billion (2016) and according to Cisco Customer Experience Report for Healthcare conducted by InsightExpress [39] the digital impact on customer experience lead to a 70% of users who find comfortable the communication with doctors via texting, email, video instead of seeing them in person (19% prefer a video chat consulting with doctor, 20% prefer an online consultation via instant message with a doctor, 21% prefer an email consultation with a doctor, 23% prefer telephone consultation with a doctor, 20% prefer text message consultation with a doctor). e-health is nonetheless affected by the evolution of ICT itself, and thus an advanced at home health service is required to qualify as the Internet of Things (IoT) technology, or rather the instrumentation the system is made of is required to directly connect with internet and or other objects also implementing IoT protocols so as to learn and evolve itself [13, 40, 41].

DAPHNE addresses all these aspects just mentioned since provides an at-home e-Health service [42, 43] to be used by both clinicians and patients, or equivalently their caregivers, which is accessible via mHealth apps or web-based interfaces by means of a pc browser. Beside all the aspects already mentioned about the possibilities within DAPHNE, importantly, the system also provides a long-term scan of subject body movements allowing the sensorized wearable system to progressively learn the major subject movement peculiarities (IoT) so as to obtain a valuable long term monitoring instrument that enormously helps doctors in providing appropriate therapies. As such, DAPHNE is a valuable AAL solution for the integrated care.

Eventually, it is important to mention that DAPHNE paves the way for the development of an actual business model and of commercial opportunities for the technological solutions developed in it.

Nevertheless the system needs to overcome the following barriers for the achievement of the expected results: (i) the validation of the clinical methodology; (ii) the elderly people's acceptability of technological solutions provided since this can reduced the patients' self-empowerment instead of increasing it; (iii) legal, ethical and social issues.

4 Conclusion

In this paper, we reported on an innovative system, DAPHNE, aimed at providing early diagnosis of Parkinson's disease along with an effective remotely-connected therapy assistance and disease stage-monitoring instrument by using mHealth and ICT technologies. DAPHNE main goal consists in providing a smart cloud-based platform that elaborates data received via internet by wearable devices (SensHand, SensFoot, SensPosture), which quantitatively measure the movement/posture of upper and lower limbs. In such regard, the system naturally classifies as IoT technology being the used wearable devices capable of both directly connect to a web data-processing interface, tailored for such purpose and in turn controlled by the cloud platform, and remotely get their firmware updated. Furthermore, the project naturally pursues a precision medicine approach by supplying specific at home health-assistance instruments according to the class of patient treated, namely IH affected, de novo or PD in different HY stages. In fact, by facilitating the exchange of information between doctors, patients and caregivers, DAPHNE enables neurologists to continuously monitor patients and specifically adapt ministered therapies. Considering all these aspects, DAPHNE is expected to deliver a significant impact from different points of view: (i) clinically, by optimizing the service in terms of timeliness, flexibility and human resources; (ii) socially, allowing patients to stay in their homes rather than being hospitalized, a crucial aspect for the maintaining of a high quality of life largely considered fundamental to diminish the disease advance; (iii) economically, by reducing the cost SSN has to sustain for the hospitalization, for the management of patients in terms of personalized care services and adherence to the clinical prescriptions, for the assistance provided to patients in the most severe stages of the disease and for the diagnostic examinations. Thus, DAPHNE provides an important AAL solution for the integrated care. Moreover, such service paves the way for the development of an actual business model and of commercial opportunities for the technological solutions developed in it. As major breakthrough, the implementation of DAPHNE can contribute to anticipate up to 7 years the current PD diagnose so tremendously enhancing the effectiveness of drug therapies.

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MARIO Project: Experimentation in the Hospital Setting

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Abstract In the EU funded MARIO project, specific technological tools are adopted for the patient with dementia (PWD). At this stage of the project, the experimentation phase is under way, and the first two trials were completed as shown below: the first

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trial was performed in November 2016, and second trial was performed in April 2017. The current implemented and assessed applications (apps) are My Music app, My News app, My Games app, My Calendar app, My Family and Friends app, and Comprehensive Geriatric Assessment (CGA) app. The aim of the present study was to provide a preliminary analysis of the acceptability and efficacy of MARIO companion robot on clinical, cognitive, neuropsychiatric, affective and social aspects, resilience capacity, quality of life in PWD, and burden level of the caregivers. Thirteen patients [5 patients (M = 3; F = 2) in first trial, and 8 patients (M = 6; F = 2) in second trial] were screened for eligibility and all were included. At admission and at discharge, the following tests were administered: Mini-Mental State Examination (MMSE), Clinical Dementia Rating (CDR), Clock Drawing Test (CDT), Frontal Assessment Battery (FAB), Hachinski Ischemic Scale (HIS), Neuropsychiatric Inventory (NPI), Geriatric Depression Scale (GDS), Hamilton Rating Scale for Depression (HDRS-21), Multidimensional Scale of Perceived Social Support (MSPSS), Social Dysfunction Rating Scale (SDRS), Brief Resilience Scale (BRS), Quality of Life in Alzheimer's Disease (QOL-AD), Caregiver Burden Inventory (CBI), Tinetti Balance Assessment (TBA), and Comprehensive Geriatric Assessment (CGA) was carried out. A questionnaire based on the Al-mere Acceptance model was used to evaluate the acceptance of the MARIO robot. During the first trial, My Music, My Games and My News apps were used. At discharge, no significant improvement was shown through the above questionnaires. During the second trial, My Music, My Games, My News, My Calendar, My Family and Friends, and CGA apps were used. At discharge, significant

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improvements were observed in the following parameters: NPI ($p = 0.027$), GDS-15 ($p = 0.042$), and BRS ($p = 0.041$), CBI ($p = 0.046$). Instead, the number of medications is increased at discharge ($p = 0.038$). The mean of hospitalization days is 5.6 ± 3.9 (range = 3–13 days). The Almere Model Questionnaire suggested, a higher acceptance level was shown in first and second trial.

Keywords Building resilience for loneliness and dementia
Comprehensive geriatric assessment · Caring service robots · Acceptability
Quality of life · Quality of care · Safety

1 Introduction

In the EU funded MARIO project [1], specific technological tools are adopted that try to create real feelings and affections making it easier for the patient with dementia (PWD) to accept assistance from a robot and, in specific situations, with the presence of a human supporting the operations made by the machine.

In this stage of the project, the experimentation phase is under way, and the first two trials were completed as shown below: first trial was performed in November 2016, and second trial was performed in April 2017.

Currently implemented and assessed applications are the following:

– My Music app: the effect of music on neuropsychiatric symptoms in patients with dementia has been shown [2–4], in particular for anxiety and agitation[2]. Reducing these symptoms is fundamental to independent living and for the quality of life of people. My Music app is focused on allowing PWD to listen to and remember their favourite songs.
– My News app: the aim of this app is to allow PWD to keep in touch with daily news. Moreover, My News app allows the people to select which news they wish to read or hear MARIO read, through vocal or touchscreen selection of the news categories or directly through titles.
– My Games app: the aim of this app is to carry out cognitive stimulation and entertain the PWD. Cognitive stimulation is encouraged by the game “Simon”. This is an electronic game of memory skill invented by Baer and Morrison [5]; the device creates a series of tones and lights and requires a user to repeat the series (if the user succeeds the series becomes progressively longer and more complex). In comparison, the entertainment function is facilitated by the provision of the following games such as: card games (as Briscola, Scopa, and Tressette), chess and ping-pong.
– My Calendar app: the aim of this app is to improve the temporal orientation of the PWD, and to remind them of their daily appointments.
– My Family and Friends app: this app was developed to keep the PWD in contact with their relatives and friends in order to reduce their isolation and improve their socialization.

– CGA app: in older people, especially those with multimorbidity, the Comprehensive Geriatric Assessment (CGA) approach is recommended and validated worldwide. One of the aims of the MARIO project from a clinical point of view is to develop an innovative robotic module to perform an automated CGA using systems capable to explore different health domains that allow the determination of the current health status of the PWD through the use of a Multidimensional Prognostic Index (MPI) [6]. The app therefore may support the reduction of adverse outcomes thus prolonging independence.

This paper addresses the impact of the apps described above, when they were delivered by MARIO. We also explored the impact of robot embodiment and how this affected the interactions between PWD and the robot [7–10].

The aim of the present study is to provide a preliminary analysis of the acceptability and efficacy of MARIO companion robot on clinical, cognitive, neuropsychiatric, affective and social aspects, resilience capacity, quality of life in dementia patients, and burden level of the caregivers.

2 Materials and Methods

This study fulfilled the Declaration of Helsinki, guidelines for Good Clinical Practice, and the Strengthening the Reporting of Observational Studies in Epidemiology guidelines [11]. The approval of the study for experiments using human subjects was obtained from the local ethics committee on human experimentation. Written informed consent for research was obtained from each PWD or from relatives or a legal representative. PWD were consecutively recruited in the Department of Geriatrics, Casa Sollievo della Sofferenza Hospital (San Giovanni Rotondo, Italy), and were screened for eligibility.

Thirteen patients [5 patients (M = 3; F = 2) in the first trial, and 8 patients (M = 6; F = 2) in the second trial] were screened for eligibility according to the inclusion/exclusion criteria shown below and included in the trials.

Inclusion criteria were: (1) patients with diagnosis of dementia according to the criteria of the National Institute on Aging-Alzheimer's Association (NIAAA) [12] and the Diagnostic and Statistical Manual of Mental Disorders—Fifth Edition (DMS-5) [13]; (2) presence of mild cognitive impairment evaluated by Mini Mental State Examination (MMSE $\geq$ 18) [14], and (3) the ability to provide an informed consent or availability of a proxy for informed consent. Exclusion criteria were: patients with serious comorbidity, tumors and other diseases that could be causally related to cognitive impairment (ascertained blood infections, vitamin B12 deficiency, anaemia, disorders of the thyroid, kidneys or liver), history of alcohol or drug abuse, head trauma, psychoactive substance use and other causes of memory impairment.

The MARIO robot was shown to all patients and the applications were demonstrated. After preliminary training, the PWD interacted with MARIO during their hospitalization.

In the first trial (November 2016), we invited PWD to use the following apps: My Music, My Games and My News. The participants interacted with MARIO 60 min per day (min/die) in mean (respectively, a mean of 41 min/die for My Music app, a mean of 19 min/die for My Games app, and 0 min/die for My News app) for a mean of 7.6 ± 4.3 hospitalization days (range = 3–12 days).

In the second trial (April 2017), we invited PWD to use the following apps: My Music, My Games, My News, My Calendar, My Family and Friends, and CGA. The patients interacted with MARIO 78 min/die in mean (respectively, a mean of 27 min/die for My Music app, a mean of 19 min/die for My Games app, 7 min/die for My News app, 4 min/die for My Family and Friends app, 3 min/die for My Calendar app, and 21 min/die for CGA app) for a mean of 5.6 ± 3.9 hospitalization days (range = 3–13 days).

At admission and at discharge, the following parameters, explained in details in the text, were collected by a systematic interview, clinical evaluation and review of records from a psychologist: demographic data, clinical and medication history and a complete multidimensional and cognitive-affective assessment.

2.1 Diagnosis of Dementia, and Cognitive-Neuropsychiatric-Affective Assessment

Dementia was diagnosed by the Diagnostic and Statistical Manual of Mental Disorders—5 Edition (DMS 5) criteria [13]. Diagnoses of possible/probable Alzheimer's disease were made according to the NIAAA criteria 12 and supported by neuroimaging evidence (CT scan and/or NMR).

In all PWD, cognitive status was screened by means of the MMSE [14], Clinical Dementia Rating (CDR) [15], Clock Drawing Test (CDT) [16], Frontal Assessment Battery (FAB) [17] and Hachinski Ischemic Scale (HIS) [18].

Neuropsychiatric symptoms were evaluated with the Neuropsychiatric Inventory (NPI) [19] including the following 12 domains: delusions, hallucinations, agitation/aggression, depression mood, anxiety, euphoria, apathy, disinhibition, irritability/lability, aberrant motor activity, sleep disturbance and eating disorder. Affective status was evaluated using the Geriatric Depression Scale (GDS) [20] and Hamilton Rating Scale for Depression (HDRS-21) [21].

2.2 Evaluation of Social Aspects and Resilience

In all PWDs, social aspects were assessed by the Multidimensional Scale of Perceived Social Support (MSPSS) [22] and a Social Dysfunction Rating Scale (SDRS) [23]. The Brief Resilience Scale (BRS) [24] was used to assess the ability to bounce back or recover from stress.

2.3 Quality of Life and Caregiver Burden Level Assessment

The Quality of Life in Alzheimer's Disease (QOL-AD) [25], a 13-item measure test, was used to obtain a rating of the persons quality of life from both the PWD and the caregiver. Moreover all caregivers were administered the Caregiver Burden Inventory (CBI) [26].

2.4 Clinical Assessment

The Tinetti Balance Assessment (TBA) tool was used to evaluate mobility and stability of the PWD.

A CGA was carried out evaluating the following domains: functional status with activities of daily living (ADL) index [27], and by instrumental activities of daily living (IADL) scale [28]; cognitive status with the Short Portable Mental Status Questionnaire (SPMSQ) [29]; comorbidity with the Cumulative Illness Rating Scale (CIRS) [30]; nutritional status with the Mini Nutritional Assessment (MNA) [31]; the risk to develop pressure sores with the Exton-Smith Scale (ESS) [32]; the number of drugs used by patients and the co-habitational status.

2.5 Acceptability and Usability Assessment

Almere Model Questionnaire [33] was used to evaluate the acceptance of the MARIO robot. This questionnaire was specifically developed to test the acceptance of assistive social technologies by older users.

The questionnaire was administered to the PWD and a questionnaire was performed by person who supervised the trial session (MARIO Questionnaire) designed to find out the perceptions about companion robots, especially what the PWD would like the robot to do for them, and how robot can improve their clinical status by using the apps.

2.6 Statistical Analysis

All the analyses were made with the SPSS Version 20 software package (SPSS Inc., Chicago, IL). For dichotomous variables, differences between the groups were tested using the Fisher exact test. This analysis was made using the 2-Way Contingency Table Analysis available at the Interactive Statistical Calculation Pages (http://statpages.org/). For continuous variables, normal distribution was verified by the Shapiro–Wilk normality test and the 1-sample Kolmogorov–Smirnov test. For normally distributed variables, differences among the groups were tested by the Welch 2-sample t test or analysis of variance under general linear model. For non-normally distributed variables, differences among the groups were tested by the Wilcoxon rank sum test with continuity correction or the Kruskal–Wallis rank sum test. Test results in which the *p* value was smaller than the type 1 error rate of 0.05 were declared significant.

3 Results

3.1 First Trial Outcomes

The characteristic outcomes of first trial are shown in Table 1. The average age of the PWD was 74.20 ± 10.06 years (range = 66–86 years). The patients had a mean educational level of 9.00 ± 6.21 years (range = 4–18 years), a MMSE mean score of 19.66 ± 1.67 (range = 18–22), a CDT mean score of 2.80 ± 1.92 (range = 1–6), and a CDR = 1 (mild cognitive impairment).

At admission, the PWD had not shown executive dysfunction in FAB mean score (13.00 ± 1.22, range = 12–15). However, they had shown the presence of neuropsychiatric symptoms (NPI mean score: 24.40 ± 10.24, range = 12–40), and depression (GDS-15 mean score: 5.80 ± 1.64, range = 4–8; HRSD-21 mean score: 9.80 ± 3.96, range = 6–15).

The PWD received high support from family, friends and significant others, (MSPSS mean total score: 71.20 ± 14.96, range = 51–84), and they perceived very mild negative aspects of themselves social adjustment (SDRS mean total score: 28.20 ± 4.60, range = 21–33). The PWD demonstrated a good ability to bounce back (BRS mean total score: 16.80 ± 1.79, range = 4–18).

The PWD quality of life was at a fair level (QoL-AD mean total score: 32.40 ± 5.13, range = 28–38), the caregiver's quality of life was at a fair level (QoL-AD mean total score: 39.60 ± 11.84, range = 20–49), and the caregiver burden was at low level (CBI mean total score: 18.00 ± 6.93, range = 14–30).

The PWD demonstrated a moderate risk of fall in TBA (8.80 ± 4.92, range = 0–11), and a mild impairment in the all domains of CGA: ADL mean score (4.20 ± 2.49, range = 0–6), IADL mean score (4.80 ± 3.56, range = 0–8), SPMSQ mean score (2.60 ± 1.67, range = 0–4), CIRS mean score (2.20 ± 1.30, range = 1–4), MNA mean score (23.00 ± 6.04, range = 13–28), ESS mean score (17.00 ± 3.74, range = 11–20), and mean number of medications (5.60 ± 2.51, range = 4–10).

At discharge, no significantly improvement was shown (Table 1).

According to the Almere Model Questionnaire (Table 2), a higher acceptance level was shown in the following domains: Attitude (80%), Facilitating condition (100%), Intention to use (60%), Perceived adaptivity (60%), Perceived enjoyment (100%), Perceived sociability (80%), Perceived usefulness (80%), Social Influence (60%), Trust (60%), and Use/Usage (60%).

Table 1 Characteristics of the patients with dementia that had used MARIO robot during the first trial

	All		
	(n = 5)		
Gender—Males/Females	3/2		
Males (%)	60.00		
Age—Mean ± SD	74.20 ± 10.06		
Educational level—Mean ± SD	9.00 ± 6.21		
Hospitalization days—Mean ± SD	7.60 ± 4.30		
Time of interaction with MARIO (min/die)—Mean ± SD	60.00 ± 0.00		
My Music app (min/die)—Mean ± SD	41.00 ± 5.48		
My Games app (min/die)—Mean ± SD	19.00 ± 5.48		
My News app (min/die)—Mean ± SD	0		
	Admission	**Discharge**	***P* value**
MMSE—Mean ± SD	19.66 ± 1.67	19.42 ± 1.83	0.317
CDR—Mean ± SD	1.00 ± 0.00	1.00 ± 0.00	–
CDT—Mean ± SD	2.80 ± 1.92	2.80 ± 1.92	–
FAB—Mean ± SD	13.00 ± 1.22	13.00 ± 1.22	–
NPI—Mean ± SD	24.40 ± 10.24	24.80 ± 10.35	0.317
GDS-15—Mean ± SD	5.80 ± 1.64	5.40 ± 0.89	0.414
HRSD-21—Mean ± SD	9.80 ± 3.96	8.60 ± 2.70	0.655
MSPSS—Mean ± SD	71.20 ± 14.96	71.20 ± 14.96	–
SDRS—Mean ± SD	28.20 ± 4.60	28.20 ± 4.60	–
BRS—Mean ± SD	16.80 ± 1.79	16.80 ± 1.79	–
QoL-AD—Mean ± SD	32.40 ± 5.13	34.00 ± 5.34	0.180
QoL-Family—Mean ± SD	39.60 ± 11.84	39.60 ± 11.84	–
CBI—Mean ± SD	18.00 ± 6.93	18.00 ± 6.93	–
TBA—Mean ± SD	8.80 ± 4.92	8.80 ± 4.92	–
ADL—Mean ± SD	4.20 ± 2.49	4.20 ± 2.49	–
IADL—Mean ± SD	4.80 ± 3.56	4.80 ± 3.56	–
SPMSQ—Mean ± SD	2.60 ± 1.67	2.80 ± 1.79	0.317
CIRS—Mean ± SD	2.20 ± 1.30	2.20 ± 1.30	–
MNA—Mean ± SD	23.00 ± 6.04	22.80 ± 5.89	0.317
ESS—Mean ± SD	17.00 ± 3.74	17.00 ± 3.74	–
N of medication—Mean ± SD	5.60 ± 2.51	5.60 ± 2.51	–

Table 2 Distribution of Almere Model Questionnaire domains in patients with dementia during the first trial

Code	Construct	Definition	%
ANX	Anxiety	Evoking anxious or emotional reactions when using the system	0
ATT	Attitude	Positive or negative feelings about the appliance of the technology	80
FC	Facilitating condition	Objective factors in the environment that facilitate using the system	100
ITU	Intention to use	The outspoken Intention to Use the system over a longer period in time	60
PAD	Perceived adaptivity	The perceived ability of the system to be adaptive to the changing needs of the user	60
PENJ	Perceived enjoyment	Feelings of joy or pleasure associated by the user with the use of the system	100
PEOU	Perceived ease of use	The degree to which the user believes that using the system would be free of effort	40
PS	Perceived sociability	The perceived ability of the system to perform sociable behavior	80
PU	Perceived usefulness	The degree to which a person believes that using the system would enhance his or her daily activities	80
SI	Social influence	The user's perception of how people who are important to him think about him using the system	60
SP	Social presence	The experience of sensing a social entity when interacting with the system	40
TRUST	Trust	The belief that the system performs with personal integrity and reliability	60
USE	Use/Usage	The actual use of the system over a longer period in time	60

3.2 *Second Trial Outcomes*

The characteristic outcomes of the second trial are shown in Table 3. The average age of the participants was 80.50 ± 6.59 years (range = 70–89 years). The people with dementia had a mean educational level of 4.25 ± 1.75 years (range = 1–6 years), a MMSE mean score of 24.01 ± 2.37 (range = 19.5–27.4), a CDT mean score of 2.63 ± 1.85 (range = 1–6), and a CDR mean score of 0.63 ± 0.35 (range = 0–1).

At admission, the PWD had shown executive dysfunction in FAB score (12.75 ± 3.49, range = 6–17), mild neuropsychiatric symptoms (NPI mean score: 6.25 ± 7.59, range = 0–24) and mild depression (GDS-15 mean score: 3.75 ± 3.62, range = 0–8; HRSD-21 mean score: 5.00 ± 5.66, range = 0–12).

Table 3 Characteristics of the patients with dementia that had used MARIO robot during second trial

	All		
	(n = 8)		
Gender—Males/Females	6/2		
Males (%)	75.00		
Age—Mean ± SD	80.50±6.59		
Educational level—Mean ± SD	4.25±1.75		
Hospitalization days—Mean ± SD	5.63 ± 3.89		
Time of interaction with MARIO (min/die)—Mean ± SD	77.50 ± 39.91		
My Music app (min/die)—Mean ± SD	25.63 ± 4.96		
My Games app (min/die)—Mean ± SD	18.75 ± 15.53		
My News app (min/die)—Mean ± SD	6.87 ± 5.94		
My Calendar app (min/die)—Mean ± SD	3.75 ± 3.54		
My Family and Friends app (min/die)—Mean ± SD	3.13 ± 2.59		
CGA app (min/die)—Mean ± SD	20.63 ± 17.41		
	Admission	**Discharge**	***P* value**
MMSE—Mean ± SD	24.01 ± 2.37	24.39 ± 2.26	0.180
CDR—Mean ± SD	0.63 ± 0.35	0.50 ± 0.27	0.157
CDT—Mean ± SD	2.63 ± 1.85	2.50 ± 1.93	0.317
FAB—Mean ± SD	12.75 ± 3.49	12.75 ± 3.49	–
NPI—Mean ± SD	6.25 ± 7.59	2.00 ± 2.77	**0.027**
GDS-15—Mean ± SD	3.75 ± 3.62	1.63 ± 1.85	**0.042**
HRSD-21—Mean ± SD	5.00 ± 5.66	1.13 ± 2.42	0.068
MSPSS—Mean ± SD	79.00 ± 5.95	80.50 ± 5.43	0.317
SDRS—Mean ± SD	24.25 ± 1.75	24.50 ± 1.85	0.317
BRS—Mean ± SD	18.13 ± 1.64	20.63 ± 1.77	**0.041**
QoL-AD—Mean ± SD	33.50 ± 5.63	38.25 ± 3.81	0.066
QoL-family—Mean ± SD	37.25 ± 3.37	37.25 ± 3.37	–

(continued)

Table 3 (continued)

	All		
CBI—Mean ± SD	4.50 ± 5.09	3.50 ± 4.18	**0.046**
TBA—Mean ± SD	9.25 ± 0.46	9.25 ± 0.46	–
ADL—Mean ± SD	5.25 ± 1.17	5.25 ± 1.17	–
IADL—Mean ± SD	5.88 ± 3.04	6.13 ± 2.64	0.157
SPMSQ—Mean ± SD	1.25 ± 1.39	1.25 ± 1.39	–
CIRS—Mean ± SD	3.50 ± 1.07	3.50 ± 1.07	–
MNA—Mean ± SD	24.25 ± 2.32	24.50 ± 2.00	0.317
ESS—Mean ± SD	17.88 ± 2.48	17.88 ± 2.48	–
N of medication—Mean ± SD	5.00 ± 3.21	5.88 ± 2.99	**0.038**

The PWD received high support from family, friends and significant others, (MSPSS mean total score: 79.00 ± 5.95, range = 72–84), and they perceived very mild negative aspects of themselves social adjustment (SDRS mean total score: 24.25 ± 1.75, range = 21–26). The PWD had shown a good ability to bounce back (BRS mean total score: 18.13 ± 1.64, range = 17–22).

The PWD's quality of life was at a fair level (QoL-AD mean total score: 33.50 ± 5.63, range = 26–40), the caregiver's quality of life was at a fair level (QoL-AD mean total score: 37.25 ± 3.37, range = 29–39), and the caregiver burden was at very low level (CBI mean total score: 4.50 ± 5.09, range = 0–14).

The also shown a low risk of fall in TBA (9.25 ± 0.46, range = 9–10), and a mild impairment in the all domains of CGA: ADL mean score (5.25 ± 1.17, range = 3–6), IADL mean score (5.88 ± 3.04, range = 1–8), SPMSQ mean score (1.25 ± 1.39, range = 0–4), CIRS mean score (3.50 ± 1.07, range = 2-5), MNA mean score (24.25 ± 2.32, range = 21–28), ESS mean score (17.88 ± 2.48, range = 15–20), and mean number of medications (5.00 ± 3.21, range = 2–11).

As shown in Table 3, at discharge, significant improvements were observed in the following parameters: NPI (p = 0.027), GDS-15 (p = 0.042), and BRS (p = 0.041), CBI (p = 0.046). Instead, the number of medications is increased at discharge (p = 0.038).

The Almere Model Questionnaire (Table 4) results show a higher acceptance level in the following domains: Attitude (90%), Facilitating condition (100%), Intention to use (70%), Perceived adaptivity (80%), Perceived enjoyment (100%), Perceived sociability (80%), Perceived usefulness (90%), Social Influence (60%), Trust (60%), and Use/Usage (60%).

Table 4 Distribution of Almere Model Questionnaire domains in patients with dementia during the second trial

Code	Construct	Definition	%
ANX	Anxiety	Evoking anxious or emotional reactions when using the system	0
ATT	Attitude	Positive or negative feelings about the appliance of the technology	90
FC	Facilitating condition	Objective factors in the environment that facilitate using the system	100
ITU	Intention to use	The outspoken Intention to Use the system over a longer period in time	70
PAD	Perceived adaptivity	The perceived ability of the system to be adaptive to the changing needs of the user	80
PENJ	Perceived enjoiment	Feelings of joy or pleasure associated by the user with the use of the system	100
PEOU	Perceived Ease of use	The degree to which the user believes that using the system would be free of effort	30
PS	Perceived sociability	The perceived ability of the system to perform sociable behavior	80
PU	Perceived usefulness	The degree to which a person believes that using the system would enhance his or her daily activities	90
SI	Social influence	The user's perception of how people who are important to him think about him using the system	60
SP	Social presence	The experience of sensing a social entity when interacting with the system	20
TRUST	Trust	The belief that the system performs with personal integrity and reliability	60
USE	Use/Usage	The actual use of the system over a longer period in time	60

4 Conclusion

In the present preliminary study, using a small sample of PWD, it was found that after the first trial no significant improvement was shown through the administered questionnaires, whereas after the second trial, significant improvements were observed in neuropsychiatric and affective symptoms, resilience capability and caregiver burden level.

It highlights the importance of these preliminary data in order to improve the robotic platform and implement new applications, such as demonstrated from first trial to second trial.

Nowadays the PWD have a positive perception and a good acceptance of the robot, and are motivated to use it, as demonstrated to the Almere Model Questionnaire data in the two trials.

The project experimentation needs to be further developed in order to improve the working patterns of the system and to better integrate all of its elements with a particular attention to end-users and their needs, limits and requirements.

These two trials aimed mainly at drawing clear conclusions on the interaction between the user and the MARIO robot and on the acceptability level and efficacy of MARIO companion robot on clinical, cognitive, neuropsychiatric, affective and social aspects, resilience capacity, quality of life in dementia patients, and burden level of the caregivers.

These data, however, are of great importance since they not only give useful indicators to assess what has been accomplished up to now, but they also provide important guidelines in order to improve the system capabilities while specific experimentation stages focused on the clinical aspects are expected to be carried out in the next months. The significant differences between two trials about the outcomes are explained by the fact that in the first trial only three apps were implemented and the robot didn't have an optimal operation.

The work was achieved through a fruitful and continuous interaction among the different participants involved in the system development process and stakeholders, thus enabling the implementation of the platform, can be further and easily enriched in the future.

Finally, the collected and above mentioned data show a satisfactory integration between the PWD and the system along with a great level of acceptability of MARIO robot by the end-user, both the patients themselves and the caregivers or medical providers, those who, day by day, take care and assist their patients.

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Part V
Analysis, Modelling and Design of AAL Services

DayD: Smart System to Monitor Patients' Swallowing

Claudia Porfirione

Abstract Swallowing is a complex mechanism which requires the use of approximately fifty pairs of muscles and various nerves. The term "dysphagia" refers to a malfunctioning digestive system resulting in difficulty swallowing liquid and/or solid food. This disorder is very serious and frequent in diverse pathologies: treatment is extremely complex and requires a wide range of experts both in the diagnostic and healing phases. In fact, dysphagia exposes patients to several risks: aspiration of foodstuffs, malnutrition, dehydration, acute and chronic bronco-pulmonary complications, social life restrictions and impairment in their quality of life. In this paper, we describe a proof of concept for a new hardware and software smart system for patient swallowing monitoring designed using a user-centred approach and interdisciplinary team of clinicians, industrial designers and engineers to help patients with dysphagia go through their rehabilitation regimes at home in a safe and autonomous way. The intent is to provide an application and a device for healthcare professionals who deal with dysphagic patient management and also for the patient and caregiver. Through this interactive system, patient and doctor are in constant contact and the application informs the doctor or therapist etc., about the imminent risk factors in order to be able to act immediately and exclude further complications. This research tries to define a new category of wearable devices that are easy to use and useful for all involved in this pathology by describing the form and functions of its hardware and software.

Keywords Dysphagia · Wearable device · Tech support · Swallowing monitoring

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1 Introduction

Nowadays the field of healthcare is moving away from traditional medical treatment to the discovery and individuation of lifestyles that can help the frail in their own homes thanks to technological support. In the world of Design, the medical design sector is a particularly fertile ground for experimentation and in rapid growth as testified by the abundance of new systems of objects, services and, social and cultural models aimed at monitoring or maintaining health and well-being.

ICT technology offers support for the development of promising new prevention, treatment and rehabilitation systems above all when accompanied by interdisciplinary research (where Design plays a decisive role).

We are witnessing a change in the organising of health care: specialised inpatient treatment characterised by complex apparatus in contrast with home care that increasingly more consists of medical appliances which are often formulated in smart networks.

To this day the design of these new medical devices start off in design-ledengineering and only in the final phase are completed with input from Design experts. Since we are specifically interested in device design as a practice, one of the explicit project goals was to involve an interdisciplinary team throughout.

Viewing this project as lying on the intersection of Industrial Design, Medical and Engineering Research the team included academic researchers from each sector. To balance the engineering and technical development with a design-oriented focus, we included an industrial designer from the beginning of the DayD project, in addition to a hardware prototyping expert, and medical specialists.

The team, formed in 2016, is specifically composed of personnel specialised in treating dysphagia (ENT and speech therapists), electrical, electronic and biorobotic engineers and designers.

The design guidelines were shared with the various team members, and the iterative process allowed each member of the team to contribute using their field of expertise to impact the whole team.

The design of the DayD device went through numerous ergonomic versions during planning and the mechanical mechanism was influenced by the use of soft materials and medical requirements.

1.1 Literature Review on Dysphagia

Swallowing is a complex mechanism requiring the use of approximately fifty pairs of muscles and various nerves [1]. It is very difficult to find the description of swallowing disorders in the literature of epidemiological terms. While swallowing is a physiological mechanism, the onset of dysphagia is a symptom of an underlying condition, comorbidity and other coexisting factors. It is not a nosological entity in itself but a symptom of other pathological condition [2].

Moreover, there are various ways of reading dysphagia: subjective symptoms (selfevaluation questionnaires), screening, diagnostic procedures (phonetic and swallowing dynamics evaluation, etc.) and hospitalisation (aspiration problems and weight loss etc.).

It has been assessed that approximately ten million Americans seek medical advice about swallowing disorders every year [2]. Dysphagia is more related to old age but the number of children affected has increased, mostly due to the higher survival rate of premature or syndromic babies [3].

On account of the complexity of this condition, the multifactorial nature of the management of dysphagic patients is very difficult and requires the collaboration of a multidisciplinary team [4]. Seriousness may vary from difficulty in eating to limited ingestion and even to the impossibility of oral intake [5].

The presence of dysphagia in the adult population in acute care hospitals, rehabilitation centres for post-acute patients, residential facilities and at home is high and set to increase parallel to the prolonging lifetime and the evolution of re-animation techniques. In fact, prevalence and occurrence of neurodegenerative diseases which dysphagia is frequently associated with increases in old age (senile dementia, stroke and Parkinson's etc.).

However, the exact prevalence and occurrence of dysphagia is not known. Recent epidemiological data relative to Europe, and in particular to Italy, is not available in medical literature as shown in studies by Kuhlemeier [6], and Reilly [7].

The prevalence of over 65 dysphagic patients is between 30 and 40% [2]; particularly stroke patients 30%, Parkinson's 52–82% and Alzheimer 84% as identified in studies by Schindler [2].

Dysphagia incidence in hospitalised patients is higher in elderly (Table 1), having a substantial impact on morbidity, length of hospitalisation and healthcare costs [2].

The major complications of dysphagia are risks of the aspiration of foodstuffs of various forms and consistencies in the lower airways, malnutrition and dehydration. In particular, aspiration pneumonia with high mortality occurs in 50% of dysphagic patients creating a highly critical situation which is difficult to cope with on the national level also relative to difficulties in the implementation of monitoring and the necessity of suitable follow-up rehabilitation [8, 9].

Furthermore, greater attention has to be paid to the aspect linked to social restrictions and the consequent impairment in patients' quality of life [10]. The relationship between dysphagia and the reduction of psychological and social activity is becoming increasingly clear such as the manifestation of a reduction in self-esteem, confidence, capacity to work and enjoy leisure.

Table 1 Rate of dysphagia by sex, age, and race among hospitalized patients [2]

Patient Characteristic	Hospitalizations, No.	Dysphagia rate, No. (%)	SE
Total	77,540,204	271,983 (0.35)	0.01
Sex			
Male	31,976,946	128,783 (0.40)	0.02
Female	45,563,258	143,200 (0.31)	0.01
Age y			
<45	34,206,054	39,985 (0.12)	0.01
45–64	17,035,348	60,727 (0.36)	0.02
65–74	9,693,062	49,880 (0.51)	0.04
≥75	16,605,740	**121,391 (0.73)**	←
Race			
White	46,147,103	149,205 (0.32)	0.01
Black	9,213,321	29,229 (0.32)	0.03
Asian	1,302,353	4113 (0.32)	0.10
Other	2,012,462	4555 (0.23)	0.03
Unknown	18,864,965	84,881 (0.45)	0.02

1.2 Review of Existing Dysphagia Applications

After consulting an epidemiological study on swallowing disorders in collaboration with medical staff, research turned to mobile Applications present in the iOS App store and the Google Play store. The researchers used the key words "dysphagia" and "swallowing therapy". Fourteen relevant applications were identified: all launched between 2013 and 2017. Conversely, applications made for congresses or conferences were excluded (e.g.: ESSD Conference 2015, ESSD Conference 2017, Congress Dysphagia).

The importance of involving experienced clinicians in the development of health applications has been highlighted before [11]. Only seven applications have been developed and involve close collaboration between qualified medical staff (doctors, therapists or speech therapists).

This search reveals a lack of applications for swallowing exercises: few applications are intended to be used by patients outside of the clinic.

The functions developed in the Apps deal with the following themes:

- divulging information about issues connected with dysphagia and how swallowing works (with animated videos and tutorials)
- data collection and management on dysphagic patients
- motor exercises for rehabilitation
- advisory database on equipment, diet, medicine and useful techniques
- prediction of the probability of recovering functional oral intake (Predictive Swallowing Score) (Table 2)

Table 2 Existing dysphagia applications

Name/Price	Year	Description
FonoFAQ: Disfagia[b] 0 €	2013	Distribution of guidelines and FAQ
Aspiration Disorders[b] 5.49 €	2013	Student training on swallowing function
Dysphagia Checklist[a] 9.70 €	2014	Helps therapists to compile patients in easy to consult evaluation charts
iSwallow[b] 0 €	2015	Aimed at patients undergoing swallowing rehabilitation, provides reminders and instructions
Dysphagia2Go[b] 33.90 €	2015	Designed to help clinicians document observations from the chart review stage to oral mechanism exams and bedside assessments (geared towards clinicians)
SmallTalk Dysphagia[b] 0 €	2015	Provides a vocabulary of pictures and icons that talk in a natural human voice
Dysphagia[a,b] 10.99 €	2015	Educational tool that includes animations of normal swallowing physiology and examples of atypical swallowing physiologies
Dysphagia Therapy[b] 17.99 €	2015	Helps clinicians navigate their options to manage treatments and rehabilitation
Diversamente Buongustaio[a,b] 0 €	2015	Cookery book with recipes to help dysphagic patients to not give up the hedonistic aspect of food
Swallow Prompt[a,b] 1.09 €	2016	Helps people in managing their saliva with vibrations or beeps at set intervals
Disfagia[a,b] 0 €	2016	Collection of exercises and information on the theme of dysphagia
Mobile SLP Dysphagia[a,b] 10.99 €	2016	Therapy exercises for improving swallowing safety and increasing muscle strength, mobility, and motor memory
IDDSI[a,b] 0 €	2016	Gets access to the descriptors and look up the different IDDSI food texture and drink thickness tests
PRESS calc[a] 0 €	2017	Given some clinical characteristics, it provides estimates of the probability of recovering functional oral intake within a user-defined time period (up to 40 days)

[a]Available on Android
[b]Available for IOS

1.3 Review of Existing Dysphagia Devices: Patents and Market

The development of the project required a parallel survey on the existence of patents aimed at obtaining screening for dysphagia as well as devices for treating this pathology currently on the market; the survey was carried out in collaboration with the Institute Superiore Sant'Anna di Pisa.

The conducted patent research concentrated on the application and acquisition of parameters described in detail in the following paragraph (2 Objectives). Since it has been chosen to use marketed technology for the development of the appliance, the patent research assessed all the technologies and not the individual sensors.

The reviewed patents contained these words in the title or a combination of the following terms in the abstract: dysphagia, screening, telemedicine, physical parameter control, medical device, device, sensors, cough, fever, head posture, neck posture, calories, oxygen and carbon dioxide. The keyword research was carried out using the international database: https://worldwide.espacenet.com/. The patent research led to the detailed analysis of 35 patents, five of which were partially relevant but not noteworthy.

The result of the analysis confirmed concrete grounds for the team to develop a project for the device.

The part of the research conducted on appliances currently on the market for dysphagia is indicated below.

There are different types of dysphagia that require specific assessment, treatment and precaution with the subsequent use of suitable appliances.

Once the assessment is completed, doctors must decide whether the patient can eat orally. When this solution is not possible, an alternative nutrition option must be decided on, for instance the use of a nasogastric tube (NGT) or through percutaneous endoscopic gastrostomy (PEG). On the other hand, devices based on neuromuscular electric stimulation (NME) are sometimes used to re-educate dysphagic patients [12]. Several studies observed how transcutaneous neuromuscular electric stimulation can facilitate swallowing [13, 14].

All the above mentioned devices (NGT, PEG or NME) fall outside of the objectives relevant to the present research project which focuses on monitoring dysphagic patients.

The result of the fact-finding survey on state-of-the-art devices shed light on the substantial lack of a monitoring and swallowing care system able to collect data and send an alarm when there is an imminent risk of inhalation (Fig. 1).

Fig. 1 Some of the devices for dysphagia currently on the market, and a topic of this study

2 Objectives

The project, denominated DayD (Daily Dysphagia), aims to remotely monitor patients affected with dysphagia during mealtimes in order to report eventual anomalies which could cause suffocation to the doctor/speech therapist in real time. In this way, they can act immediately to undermine risk situations.

Furthermore, data collection and its processing allows the patient to be monitored over time, suitable care and therapy, and the detection of problematic, often very dangerous issues linked to this pathology in advance.

The smart system is aimed at both health workers who deal with handling dysphagic patients and the patients themselves or caregivers [15]. The intention is to supply effective daily aid which is practical and acceptable for the actual users.

The resolve of the research group is to increase the patients' level of confidence and autonomy consequently improving their quality of life [16].

The parameters that the system must be able to monitor are the following:

1. behaviour: alertness during meals, collaboration, attention, capacity to control physiological secretions;
2. motor skills: posture control, adoption of compensating postures or manoeuvres, fatigue;
3. coughing: presence and effectiveness;
4. oxygen saturation: assessing changes during meals or signs of possible inhalation (reduction of 2–3% alertness, 5% meal suspension);
5. variation of voice timbre (i.e. gurgling voice signalling inhalation [17–19]);

Table 3 Analysis chart of the monitoring parameters and sensor choice

Parameters	What to survey	How	Tool
1. Behaviour	Alertness-fatigue	Heartbeat-O_2	Pulse oximeter
2. Motor skills	Posture	Neck movement	Gyroscope
3. Coughing	Intensity-quantity	Decibel	Microphone
4. Oxygenation	Level	Oxygen	Oximeter
5. Voice	Timbre	Decibel	Microphone

3 DayD Project Concept

This paper puts forward the study and definition of a suitable and ergonomic design, able to integrate technical elements, useful to the detection of salient parameters while paying close attention to the psychological impact and acceptability of proposed solutions. For this purpose it has been chosen to adopt a UCD (User Centred Design) in every phase of development [20].

The first cognitive phase on the extent of the problem was fundamental for formulating the principle objective of the DayD project: obtaining information to evaluate and recognise the signs and symptoms of dysphagia in order to intervene quickly and efficiently, hence avoiding frequent, serious consequences.

Secondary objectives (no less important) resulted to be:

- allowing people living with this pathology to get together and eat meals safely at home and outside the home;
- helping people regain confidence and autonomy while caring for their loved ones/patients.

The first phase in designing the wearable device focuses on identifying suitable sensors able to monitor the five parameters and their correct anatomical positioning.

The iterative work of comparison and collaboration carried out with the research team identified only four sensors for the data collection requested by the medical health staff (summarize in Table 3).

In the following paragraphs, we present the DayD preliminary design process, including design considerations and choices made with regards to the device software and hardware.

3.1 General Design Considerations

In the following section we present the DayD design process, including physical appearance, material selection, layout, and gesture design [21]. We describe our design guidelines, the interdisciplinary design team, and the various stages of design prototyping up until the current prototype, the second in sequence.

Fig. 2 Some headphones for running available on the market

We designed DayD using a combined interaction and industrial design process. In the process, we explored a large number of forms and gesture capabilities, through a variety of techniques: pencil sketches; ergonomic studies; skeleton prototypes; CAD designs; and material exploration [22].

We actively involve users in our design process with focus groups separate sections, each of which includes caregivers, patients and healthcare providers.

DayD is designed as a small wearable appliance similar to Headphones for running (Fig. 2). In this way it is versatile and able to adapt to diverse lifestyles and different types of use which may vary depending on the habits, age and psychophysical conditions of the user. The appliance is designed to be geometrically and proportionally comfortable while paying maximum attention to hygiene (cleanability, resistance to sweat/water) and safety. This means that DayD can be worn permanently, like an earpiece, for constant monitoring. Thus, in the case of imminent suffocation the device can send an alert to inform the caregiver and doctor/therapist in order to intervene quickly.

3.2 Hardware Specifications

At the moment, screening tests for monitoring dysphagic patients can only be carried out in specialised medical studios. DayD allows the user to monitor the pathology in an autonomous way using a combination of three sensors (microphone, pulsometer and gyroscope). Moreover, the device memorises the patient's data and transfers it to the doctor for monitoring over time. In this way, doctors can remotely check the progression of the pathology and prescribe eventual treatment/therapy to be carried out.

The wearable device works in close cooperation with the DayD application which provides the system user interface (both doctor and patient). Considerable user feedback is supplied through the app: e.g., being in the wrong position during mealtimes (through a sound alert).

The activation of the hardware is effected through an internal accelerometer which activates the sensors as soon as the user puts the object on. The design entails the device to be recharged by induction using a small platform plugged into an electrical current.

During development the research group also took into consideration the possibility of the device being easily maintained by healthcare workers/family members to help the users face the extremely delicate situation [23].

3.2.1 Pencil Sketches

We started the design process with iterative rounds of pencil sketches and ergonomic studies: these suggested a number of simple forms.

The study arrived at the conclusion that a sporty-shaped device was more appropriate than other formats with standard electrodes that, even though simple and functional, looked more like medical devices and would be rejected by many users.

We went back and forth between the paper-based sketches and simple, quick-and-dirty ergonomic engineering studies, each informing the other of their progress. Figure 3 shows the result from this stage.

In the end the shape was perfected through various studies on sensor positioning and a review study on component size.

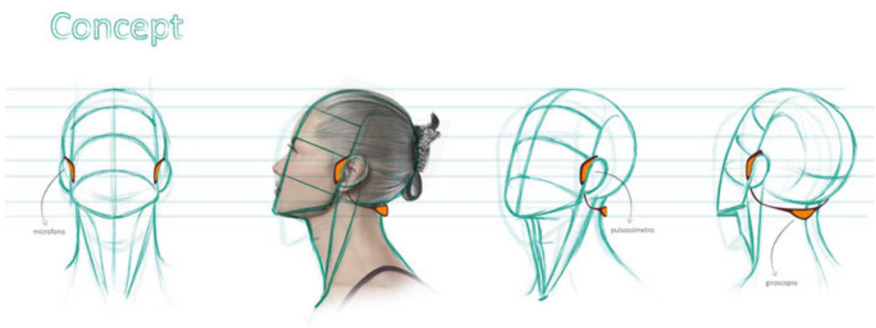

Fig. 3 Early pencil sketches

3.2.2 Materials

We wanted the materials to also reflect the versatile nature of the device as well as its strength. In addition, we were keen to evaluate the use of alternative materials in the design of DayD, beyond the classic plastics so often utilized. To that end, we collaborated with the research group to explore the integration of different materials with moving parts.

We worked with various kinds of different coloured bio-compatible materials and tested the relationship between neck movements and the flexibility of the material.

We explored the acceptability of the proposed solutions giving major importance to warm, pleasant materials.

Finally, we decided to propose a combination between soft structures (with hard centre) and parts with rigid, glossy surfaces.

3.3 Software Specifications

In the DayD project great significance was placed on identifying the optimal characteristics related to the system interfaces [24]. The importance of an approach centred on the person (Human Centred Robotic Design) in the project for ICT was motivated by the need to design advanced mechanisms for interaction, that are easy to use for all users, with particular reference to vulnerable users [25, 26].

The system is made up of five main sections, one of which can be utilised after the second access ("monitoring" section):

1. Patient's data
2. Tests
3. Protocol
4. Device configuration
5. Monitoring (Fig. 4)

The first time the DayD device is used specific calibration parameters are adjusted by medical staff according to the user's needs. In particular, the position of the neck while the patient is swallowing plays a fundamental part for correct homecare (section 4—Device configuration). In this section specific calibration levels of voice, coughing, heartbeat, temperature and oxygenation are adjusted. The first three sections are essentially compilation forms which help medical staff collect, update and manage the user's information.

The section "monitoring" collects data in real time on the patient's swallowing activity and organises it infographically over time to allow rapid and intuitive consultation.

The following table summarises the basic structure of the system (Fig. 5).

Fig. 4 Home interface

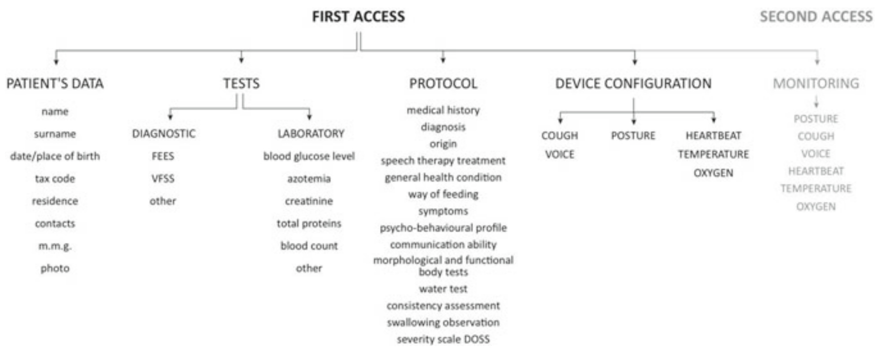

Fig. 5 Software structure

4 Next Steps

The project started in June 2016 and is currently in the phase of launching the first functional prototype which is aimed at testing the feasibility of the whole intelligence system especially sensor positioning and data collection and processing.

This prototype is not eligible for testing on patients. Therefore, the successive phase is intended to refine the design in such a way as to enhance acceptability and wearability in order to ensure the collection of quantitative and qualitative data thanks to feedback supplied by the users [27].

To sum up, the work on the development of the DayD project will continue with four short-term objectives:

(1) develop new iterations of the device using patient feedback;
(2) test the reliability on a normal population;
(3) test the usability of the device on patients with swallowing difficulties;
(4) test the clinical feasibility of a two-month monitoring program with patients;
(5) analyze signals obtained from the different sensors (signals processing from raw data to definition and extraction of most important features for dysphagic monitoring).

4.1 First Functional Prototype

The functional prototype (hardware) in use at the moment utilises the following economic and commercially easy to find electronic components:

(1) ARM SensorTile development kit of STMicroelectronics (to be used with STEVAL-STLKT01V1), very small (approx. 2 cm side) and equipped with a battery
(2) ODROID-C2 (64-bit quad-core single board computer)
(3) Pulsometer Beurer with bluetooth PO-60
(4) Adaptor USB Bluetooth 4.0 by Trust (Fig. 6)

5 Conclusions

The pervasive application of ICT technology and Ambient Assisted Living gives Design an opportunity to make its contribution in an incisive, innovative process in which competences and experiences rooted in many fields of Science merge together.

In this paper, we described a proof of concept for a new hardware-software mobile system for swallowing therapy at home. Motivated by the lack of such systems on the market and the need of this kind of unit for domestic access, our prototype is simple

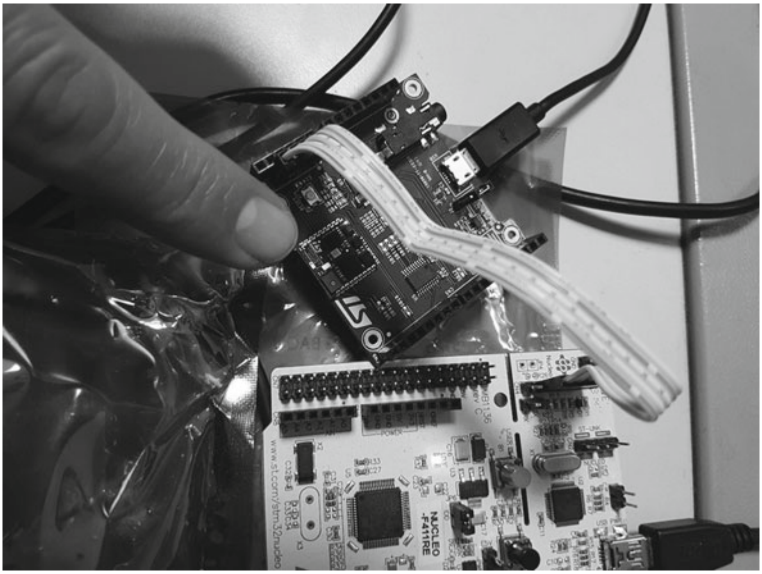

Fig. 6 First functional prototype

to develop, follows universal-design principles [28] and adopts a flexible approach to motivate patients and increase their involvement in use.

The developed design aims to belong to a new type of article whose structure is closer to that of an everyday object than a piece of medical apparatus. Interacting with the device means the users (patients or caregivers) can receive and consult information easily and quickly even though they are not doctors or technicians [29]. At the same time the device will be able to remotely collect and transmit scientific (also predictive) data to specialist medical staff in real time.

Although in its early stages, the future work on the DayD intelligent system will include incremental development guided by patients' feedback as well as usability, appealing design and clinical feasibility of the device.

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Age-Friendly City and Walkability: Data from Observations Towards Simulations

Andrea Gorrini, Luca Crociani, Giuseppe Vizzari and Stefania Bandini

Abstract The use of agent-based simulation systems can provide an innovative framework to support the design of age-friendly cities, focusing on walkability assessment. This is aimed at managing the complex interaction between elderly pedestrians and vehicles at zebra crossings, in which the compliance to traffic norms plays a fundamental role. The data of an observation performed at a non-signalized intersection are presented to provide useful insights for supporting the future development of agent-based models. Results focus on drivers' compliance to crossing pedestrians, describing potentially conflictual interactions among heterogeneous agents. The discussion closes with the potential applications of the collected data set for modelling the phenomenon.

1 Introduction and Related Work

Agent-based modelling and simulations of pedestrian circulation dynamics have been increasingly reported in the technical and scientific specialized literature. Scientific communities started to incorporate agent-based systems to improve the expressive-

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ness of traditional approaches and to simulate the complex behaviour of people and traffic in outdoor and indoor urban scenarios. The intrinsically dynamical properties of agent-based models offer a research framework to face the complexity of the future cities [8], offering new possibilities to incorporate and integrate the growing presence of autonomous entities/artefacts both physical (e.g. autonomous vehicles) and virtual (e.g. data coming from heterogeneous sources: social media, distributed sensors etc.).

The development of agent-based models and systems requires to check the quality, robustness and plausibility of the obtained simulations against real data, in order to tackle decision making problems related to urban mobility. Recent literature contains a wide range of methods and study cases supporting this view [1]. The aim of this paper is to present a real case of data collection performed to collect useful insights about pedestrian-vehicles interactions at non-signalized intersections, supporting the future development of a heterogeneous agent-based system to simulate the phenomenon.

From pioneering works, several models have been developed and applied for the simulation of pedestrian and vehicular dynamics, including both Cellular Automata and particles models [3]. These two approaches have, separately and independently, produced a significant impact, yet efforts characterized by an integrated model considering the simultaneous presence of vehicles and pedestrians are not as frequent or advanced. With the notable exception of [7], most efforts in this direction are relatively simplistic, narrow (i.e. targeting extremely specific situations), homogeneous for the simulated entities, and they are often not validated against real data [5, 13]. In this framework, we consider the possibility to model and simulate the complex aspect of drivers' compliance to pedestrian yielding rules in the context of interactions among heterogeneous agents, and its implications on self-organization dynamics.

2 Observation Results

The video-recorded observation was performed in 2015, at a zebra crossing in the city of Milan (Italy). The scenario of the observation has been selected by means of a preliminary analysis which was aimed at crossing the geo-referred information related to the socio-demographic characteristics of the inhabitants of Milan and the localisation of road traffic accidents. Results showed that the chosen residential area is characterised by a significant presence of elderly inhabitants and an high number of pedestrian/car accidents involving elderlies pedestrians in the past years. See [6] for a detailed description of the results of the observation.

A sample of No. 812 crossing episodes has been identified from the video (about one hour and ten minutes), considering only the cases in which one vehicle directly interacted with one or more adult and elderly pedestrians (see Fig. 1). At non-signalized intersections traffic laws require drivers to yield those pedestrians who are already occupying the zebra, but also those who are localized nearby or in correspondence of the curb waiting to cross. The level of compliance of drivers

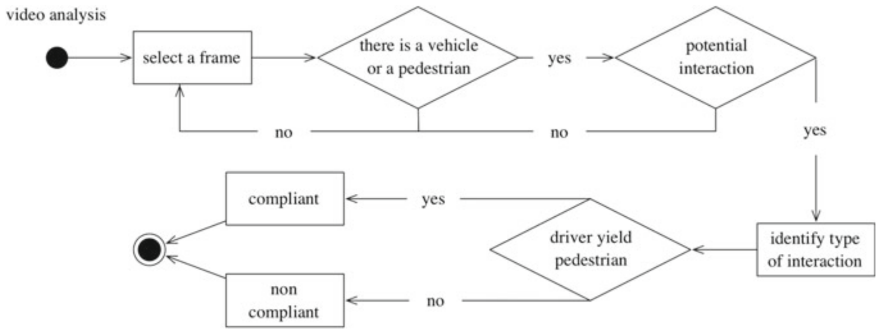

Fig. 1 The work flow for selecting the sample of crossing episodes from the video images

Table 1 Results about the drivers' compliance to the right-of-way of crossing pedestrians

Types of pedestrian/vehicle interaction	Compliant	Non-compliant
Ped. approaching/waiting/crossing from the near side-walk	191 (46.14%)	223 (53.86%)
Ped. approaching/waiting/crossing from the far side-walk	230 (57.69%)	168 (42.21%)

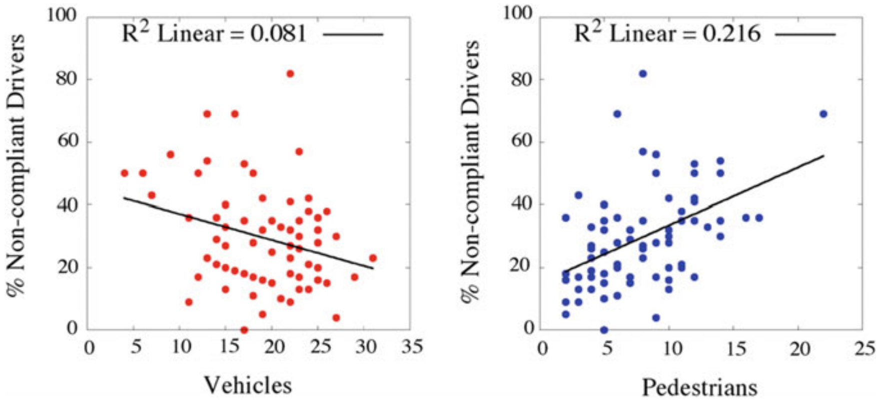

Fig. 2 The relation between non-compliant drivers and the number of vehicles (left) and crossing pedestrians (right) in the observed intersection. Each data refers to one minute of the video

to pedestrians' right-of-way have been estimated considering the position of crossing pedestrians with respect to the curb (i.e. pedestrian about 1.5 meter far from the curb, waiting at the curb, crossing on the zebra) and to the direction of travel of vehicles (i.e. pedestrian from the near or the far side-walk).

Preliminary analyses on results (see Table 1) showed that 48% of the total number of crossing episodes was characterized by non-compliant drivers with crossing pedestrians from the two side-walks. A multiple linear regression (see Fig. 2) was calculated to predict the percentage of non-compliant drivers per minute based on: (*i*) number of vehicles per minute (18.89 veh/min in average; $p = 0.007$, significant predictor) and (*ii*) number of crossing pedestrian per minute (8.01 ped/min in average; $p < 0.001$, significant predictor). A significant regression equation was found [$F(2,70) = 14.526$, $p < 0.001$], with R^2 of 0.293. This demonstrates that the non-compliance of drivers is negatively determined by traffic conditions and positively determined by pedestrian flows on zebra. Despite the low level of drivers' compliance, no accidents or risky situations have been observed, thanks to the self-organization of the system based on pedestrians' yielding/collaborative behaviour to approaching cars.

3 Discussion

The results showed in the previous section represent applicable insights towards the extension of a model for the analysis of pedestrian crossings [2, 4], considering potentially conflictual interactions among heterogeneous agents. As shown in Fig. 3a, the model is based on the integration of two independent models for the simulation of vehicles, moving in continuous lanes, and pedestrians, moving in a 2-dimensional discrete environment. The two environments are superimposed, and car-agents per-

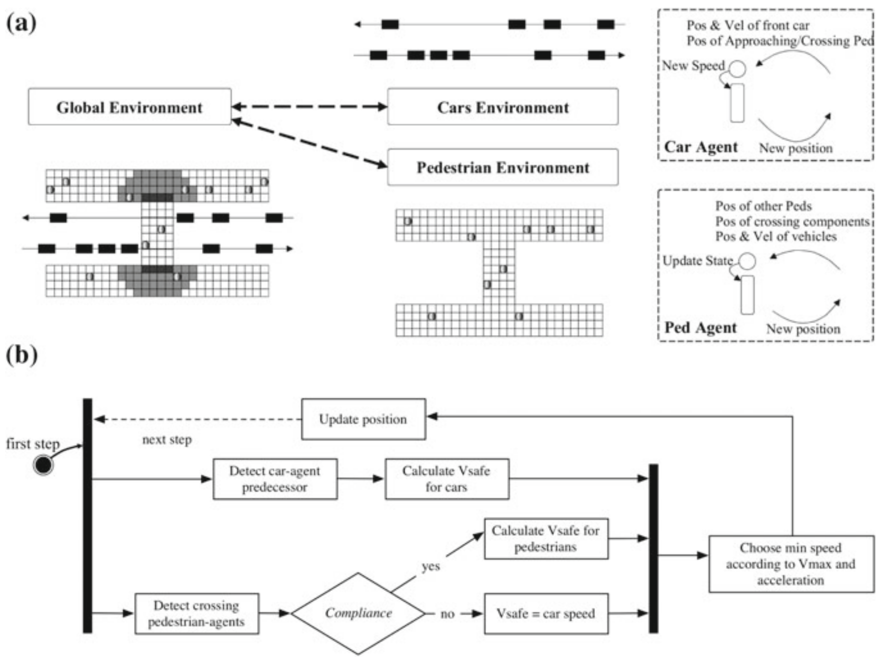

Fig. 3 A description of the environment and the two classes of agents (**a**). Car-agents life-cycle considering their possible non-compliance with respect to the presence of pedestrian-agents (**b**)

ceive pedestrian-agents while they are crossing or in the nearby of the curb (grey cells in Fig. 3a) and vice-versa. The interactions between them are described in Fig. 3b. Pedestrian-agents consider the speed and distance of cars to avoid collisions, giving way to non-compliant vehicles. The compliance of car-agents is mainly influenced by the necessary braking distance. On the other hand, according to a fixed probability that will be set on the collected data on compliance, car-agents can deliberately avoid to stop even if the braking distance is sufficient, requiring pedestrian-agents to yield.

The potential applications of such research are related to the possibility to test the effect of non-compliance on emergent observables like: near accident situations, exposure to accidents, traffic capacity of the road and Level of Service [9]. This is totally in line with the concept of "Age-friendly City" proposed by the World Health Organization [10]: a framework for urban development encouraging an active ageing of the population. The investigation of innovative solutions to enhance the level of walkability of urban areas for the elderly [11] is becoming, in fact, a mandatory requirement for the design of Age-friendly Cities. In addition, despite the specific context of the performed observation, this kind of research is also potentially relevant to test the effects of alternative traffic management solutions (e.g., traffic light systems, speed limits) and to complement studies on autonomous vehicles [12] in order to evaluate future transportation scenarios in Smart Cities.

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A Novel Model for Improving the Social Healthcare of the Italian Older People. Step 1: Sample Analysis

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Abstract The present research paper would propose a novel social healthcare model for Italian older people, having carried out an in-deep analysis of the current scenario. In fact, studying older people over 75 who live in the inner areas of the Marche region has allowed acquiring the knowledge of their main needs and characteristics. This paper aims to study such the sample considering that nowadays the society trend is characterized by an increasing number of older people in comparison with previous decades. Then, the improvement of the current social healthcare model becomes an important challenge, trying to support older people in being more autonomous and less isolated, escaping from the potential related depression. According to the survey results, the services that a novel social healthcare model should provide are suggested.

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1 Introduction

Nowadays, the current society is characterized by an older people care model that is inappropriate and insufficient for providing the right services and reaching the customers' full satisfaction.

Indeed, in a global society that stretches to get older [1], the need to improve the older people care becomes increasingly more relevant. This depends also on the fact that in Europe, during the last fifty years, the common family model has been changing [2]: from a patriarchal model where all the family components stay close in their city or town, or even live together in the same home, to a more distributed model, where normally sons live far away from their parents due to job opportunities.

According to this context, older people living alone need to have a more adequate assistance, not only from a healthcare point of view, but also from a social perspective. A healthcare perspective becomes fundamental: older people need more high-quality care to prevent diseases or to recover faster from them. Even a social point of view is very important in order to avoid the isolation of older people from society due to their cognitive or physical problems.

In the last years, also the technological evolution has supported the rising issue of older people healthcare [3, 4]. The IoT technologies diffusion has allowed the creation of tailored devices for monitoring the healthcare and different human parameters (the so-called smart objects), such as blood pressure, heart rate, glycaemia, and so on [5, 6]. Moreover, also the communication systems had been improved in order to guarantee the connection of people far from home. Along with these devices, also more invasive systems have been designed, such as assistance robots for the older people [7], in order to support them constantly along their daily activities.

This paper aims to propose a novel concept model for improving the social healthcare of Italian older people, to support these users in being more autonomous during their daily lives, involving both the activities inside the house such as wash up, get dressed, etc., and the activities outside like shopping, blood tests, etc. Moreover, the proposed novel concept model would improve the participation and social inclusion of older people to prevent all the cognitive and physical limitations due to depression [8], and every other diseases connected to the isolation of a person.

Before describing the concept model to support the older people, a deep analysis has been conducted by the authors on a sample of Italian older people living in a specific region, composed by several towns that are homogeneous in terms of: population typology, geographic conformation, decentralization of the healthcare system, and services provided by the public administration. This in-deep analysis has allowed realizing what are the main characteristics of the older people sample, and which is the starting point to define what might be the functionalities and services of the concept model for improving the social older people healthcare. The main tool used during this phase has been a detailed questionnaire drawn up by mayors and doctors of the targeted towns.

2 State of the Art

The novel concept model that results from this research work, after the analysis of a well-defined sample of Italian older people, intends to be a new approach to support and sustain the healthcare of such persons.

During the last years, in Europe, several examples of new models to foster older people in reaching their new needs due to the change of family model have been emerged. In order to understand how the present research paper is involved in the current context, it is necessary to investigate what are the main current social health-care models in Europe and in Italy (the country involved in the questionnaire carried out and presented by this paper).

2.1 The Current Social Healthcare Model in Europe

The growing attention for the social and health issues that has been expressed by Europe in the last ten years through, for example, financial programs such as Horizon 2020 [9] shows the emerging need to rethink the current social healthcare model according to novel needs and requirements coming from a changed population.

In fact, according to several researches conducted [10], the population trend until 2050 shows a relevant increase of older people. Moreover, in Europe it is expected an increase about 50% from 2000 to 2050 and among these a sudden rise of ultra-octogenarians people [11]. This highlights an evident need to improve the current healthcare model that cannot support such an older people increase with high-quality services.

Therefore, in the whole Europe different models to support the older people care has been created: e.g., in United Kingdom (UK), Netherlands, Portugal, and Spain.

For example, in Netherlands, the main purpose has been to support older people having cognitive discomfort and problems, and physical disabilities. There, care for older people is traditionally given in nursing homes and assisted living facilities, and the capacity planning for healthcare services has traditionally been done using a demand-based method. Currently, the above-mentioned approach remains too dogmatic and obsolete to fully answer to older people needs. For this reason, a novel model has been studied and proposed since 2009, where older people have been aggregated in neighborhood communities where each apartment has been designed for a particular need or requirement due to a specific physical or cognitive problem. Naturally, these communities have been monitored and supported by qualified staff and also through the adoption of new IoT technologies. Older people that choose to live in these communities have the advantage to remain at home and not in nursing houses [12].

2.2 Focus on the Italian Model: Main Issues

Nowadays, in Italy, older people are supported by a healthcare system based on the delivery of public services that, in several cases, are not so adequate compared to people needs. Moreover, the current care model is still based on family, where the members become caregivers of older people.

At present, this model is not so self-contained and optimal due to the fact that the traditional family is changing, and often sons and daughters are far away from their parents for pursuing jobs. This does not permit a good care of older people. Consequently, the present caregivers necessary appeal to people external to the family. The disadvantage of this new situation is that external caregivers are not always high-qualified, and they represent an expensive cost for the entire family.

From 2001 to 2015, this new caregiver role has increased about 50%, reaching in 2015 more than 880.000 caregivers [13]. Mostly, these caregivers are not Italian people and this aspect, which could be negligible in other cases, becomes a barrier here due to the language that hampers social relationships. In this way, social relationships are not fostered and older people are more and more isolated.

Another impactful aspect is linked to the geographical environment, because the older people more disadvantaged are those who live in towns in the inner Italian regions, where there are not hospitals and the care services delivered by municipals are not able to cover all the requested needs. These regions and towns risk suffering from depopulation, if the current model would not be adjusted.

Therefore, the present research paper has carried out an in-deep analysis of an older people community that lives in a specific area of the central Italy, where all these issues highlighted in the previous paragraphs exist. The analysis has been conducted over the whole population of older people over 75 living in that area, in order to investigate their lifestyle and their main needs and requirements about healthcare. The results of this first sample analysis allow designing an alternative healthcare model, able to provide tailored and high-qualified services.

3 Analysis of the Reference Sample

The study has been carried out to analyze the actual social healthcare model and identify the criticalities that adversely affect the quality of life of older people. The chosen reference sample is the older people over 75 who still live in their own homes.

The survey was conducted in seven municipalities of the inner areas of the Marche region (i.e., Falerone, Francavilla d'Ete, Massa Fermana, Mogliano, Montappone, Monte Vidon Corrado, Servigliano), which include a territory of 106.6 kmq and a population of 14,709 inhabitants. The area is mainly hilly and it has similar characteristics to several territories of central Italy (e.g. Toscana, Umbria, Emilia-Romagna, etc.): a territory with a widespread urbanization and far from social and economic flows. It is also distinguished by a high depopulation and an economy based on small and medium-sized enterprises. The reference area is characterized by a community with a high average age (47 years, +1.60 years in comparison with regional indicators), a high incidence of older people over 75 (+3.45% in comparison with regional indicators), and a lower number of people belonging to the segment of the active population (35–54 years) (−2.52%) [14].

3.1 Questionnaire

The survey was conducted from December 2016 to February 2017 and it involved local administrations and medical personnel. Through collaboration between technical and health experts, it was possible to get a detailed report of the actual social healthcare model. The questionnaires were completed by family doctors and mayors, with the support of municipal employees (i.e. general register office, social welfare office, technical office), who know well the context and interact with the older people community every day.

Data were collected through a questionnaire composed of 27 items grouped into four main domains: personal data, accessibility and mobility issues, social healthcare services, and health condition information. The survey consists of closed-ended questions organized in radio buttons. The first part of the questionnaire examines user personal data that include the year of birth, the family unit, and the proximity or absence of kin. The accessibility of the houses is assessed through questions on location and type of dwelling and queries about the presence of mobility aids (e.g. elevator). Moreover, user mobility is assessed with questions about the ownership and use of car. In the second part of the questionnaire, it has been analyzed what local social healthcare services (e.g. caregiver, home care, etc.) are required by older people and then it is possible to assess the state of health. The questions are related to cognitive problems, speech disorder and user independence status. In more detail, the state of autonomy has been analyzed according to the basic activities of daily living (ADL) scale [15] with the focus on bathing and showering, personal hygiene and grooming (including brushing/combing/styling hair), dressing, toilet hygiene (e.g. getting to the toilet, cleaning oneself, and getting back up), functional mobility, and self-feeding (not including cooking or chewing and swallowing).

3.2 Results

In this section, the main outcomes of the study are reported. In total 1259 individuals answered to the survey that means a response rate of 54%. It is a representative sample, which accurately reflects the members of the target population.

The sample is characterized as follows:

- The 55.5% of the respondents are females while 44% are males;
- The median age is 83 years and the oldest users are 103 years old;
- The respondents live in seven different villages of hilly Marche region.

The idea of independent living at home is a key aspect for older people, especially considering that the 22.4% of them live alone and the 29% live as a couple. Others have cohabitants younger than 75 years.

A greater proportion of respondents (66.2%) live in single-family homes in the center or district. The 64% has a multiple floor house, of which the 98% without elevator.

The 17.1% of people lives in an isolated house. Of these, more than half do not have a car. This could limit their accessibility to social activities.

Gender seems to play an important role in having a car. In fact, the 77.5% of men have one compared to 20.9% of women. Consequently, men are more likely to be more socially isolated when devoid of mean of transport, as highlighted in Table 1.

Only the 6.2% of respondents exploit voluntary associations services. It mainly refers to older people with chronic diseases, cognitive problems or disabilities, especially those who do not have a car.

Going into more detail of health conditions, the 10.5% of respondents need healthcare due to chronic diseases (e.g. renal insufficiency, diabetes, etc.).

The 24.3% of respondents manifests one or more cognitive problems. The most common are poor memory and orientation (Fig. 1), which display a direct relationship with age. The depression state is often related to chronic diseases or inability to perform basic tasks.

A quarter of respondents reported finding difficulty in at least one ADL, which makes them dependent on others.

In particular, observing the level of independence in ADL, it emerges:

- The 6% has a very little or little impairment (difficulty with 1–2 ADL);
- The 7% has a moderate impairment (difficulty with 3–4 ADL);
- The 11.6% has a severe impairment (difficulty with 5–6 ADL).

As shown in Fig. 2, the Katz Index of Independence in ADL increases with age. It is higher amongst individuals with chronic diseases and/or cognitive problems. No significant difference with gender.

Table 1 How the mean of transport availability influences the participation to social activities

Community centres	Users			
	Men		Women	
	Car: YES (%)	Car: NO (%)	Car: YES (%)	Car: NO (%)
Social	66.3	22.4	33.6	11.9
Religious	61.4	31.2	82.9	59.1

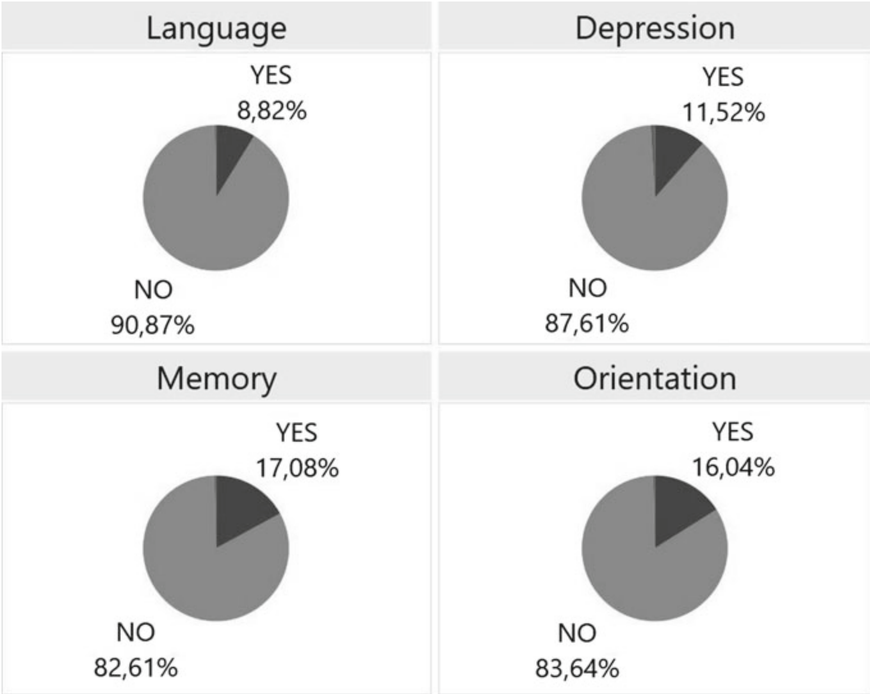

Fig. 1 Cognitive problems

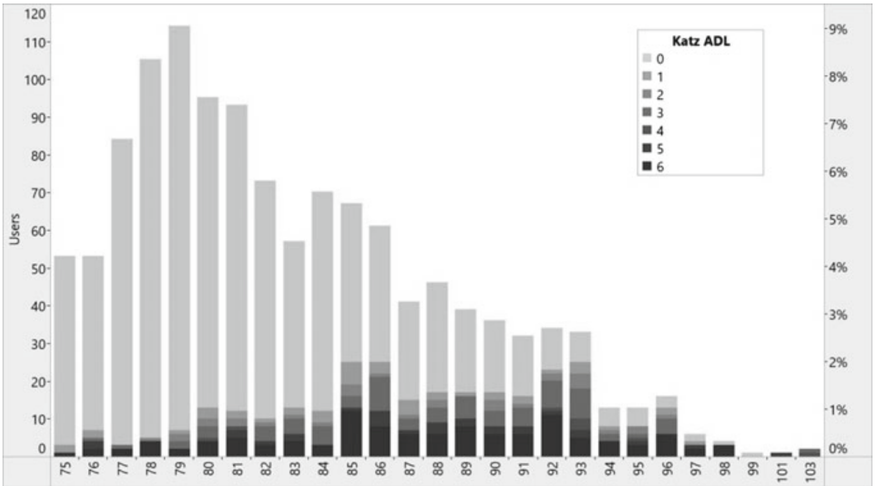

Fig. 2 Katz ADL in relation to age

Table 2 How the health conditions influences the participation to social activities

Community centres	Users			
	Healthy (%)	Impairments in ADLs (%)	Cognitive impairments (%)	Chronic diseases (%)
Social	41.4	6.8	12.1	9.1
Religious	73.2	24.6	34	18.9

According to the life expectancy trend, older people tend to stay healthy longer.

These results highlight that the majority of people are able to live independently within the community if provided of an adequate support.

The 12.1% of the respondents needs an informal caregiver who assists them at home. This percentage grows amongst older people with:

- Impairments (more than 40%);
- Chronic diseases (43.9%);
- Increased age.

Conversely, households do not affect the presence of informal caregivers. This can be understood in light of the fact that family takes care of its older people.

The health conditions affect the isolation and loneliness of older people as shown by a lower participation to community based services (Table 2).

The health and community services should be improved and promoted to increase the quality of life and face the social isolation.

Results also demonstrate a very poor use of technology to help older people maintaining their independence. Only the 22.7% of them has got internet at home and this percentage drops drastically (7%) considering older people who live alone or as a couple.

Moreover, nowadays, young people tend more and more to leave the parental home. Therefore, the demand of home help services and more skilled caregivers would increase.

4 Improving the Social Healthcare Model

The data analysis points out the characteristics of the target population and provides some relevant outcomes useful to improve the current welfare model: an integrated solution aimed to optimize the existing services in the area and to add new services in order to satisfy untreated needs can be defined. Primarily, the new welfare ecosystem should reduce the multiple access points of services in order to simplify the process, decreasing the degree of confusion, and to better valorize them. In addition, it could be a good opportunity for the companies to offer their services in a reliable and effective way.

This scenario involves two main actors:

1. *Stakeholders*: represented by older people, formal and informal caregivers, primary care physicians, which can request, book or manage services;
2. *Providers*: represented by public institutions (health system, civic authorities, public transport, etc.), private companies (technological, construction or services to individuals) and non-profit organizations able to provide services (both existing and innovative) in a structured and consistent way.

A rationale model that connects the above-mentioned stakeholders consists in a hub-configuration, where all services are categorized according to their objective in order to organize the proposed catalogue and to help users to find what he/she needs easily (Fig. 3).

The possible objectives of the organization for the "service hub" could be:

1. *Managing daily activities*: help in hiring caregivers, support on paperwork and utility payments, housework, gardening and so on;
2. *Health care*: management of medical examinations and tests booking, prevention and monitoring (heart, blood sugar, falls, diet, etc.), home health care, medical transportation;
3. *Social activities*: support in purchase of daily shopping, medicines and clothes, social events organization (cards tourney, dinner party, meetings, etc.), ordinary transportation to key sociality places (community centers, bar, social place, shops, etc.), creative labs for maintaining an active status (with kids, handicrafts, pet care);

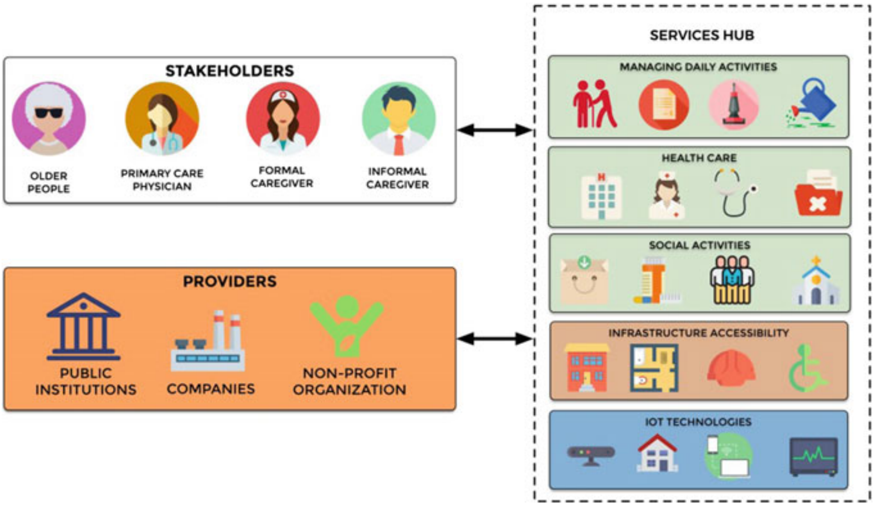

Fig. 3 Services hub and stakeholders involved

4. *Infrastructure accessibility*: support in building renovation and maintenance to increase a high degree of accessibility (kitchen furniture, bathroom and bedroom aids, lifts for people with handicap);
5. *IoT technologies*: connected devices introduced in house with the aim of continuous monitoring users in their daily life and with the possibilities of detection of issues about safety, security, health status, and domestic accidents.

This model allows solving the drawbacks reported in the analysis phase improving the accessibility to the services and reducing the architectural barriers, encouraging an active ageing and maintaining a certain degree of self-sufficiency. Moreover, the monitoring activities allow applying the prevention approach that have a key role in wellbeing of older people and to reduce the cost of national health system.

Because of this structure, this model is easily expandable, scalable, and exportable.

The modularity of hub configuration allows adding new services and new categories (if needed) making easy future expansions. Furthermore, the model can be implemented and managed by a software platform, optimizing the services process and the employment of human resources, making it a scalable solution. Finally, after a real application with users and an evaluation of an economic feasibility, the model export in larger regions can be performed, representing a virtuous ecosystem able to guarantee well-being conditions for older people and opportunities for depopulated areas of new business and new forms of attraction fostering the repopulation.

5 Conclusions

The paper aims to investigate the current social healthcare model in order to identify its inefficiencies. A survey has been carried out by focusing on older people over 75 who still live in their own homes in the hilly area of the Marche region. A sample of 1259 individuals has been analyzed in terms of socio demographic characteristics, home and services accessibility, participation to social activities, and health conditions. It has emerged a very poor use of technology, the necessity to improve the home help in terms of qualified informal caregivers, and the need of new services aimed to reduce the older people isolation, loneliness, and depression, which are often due to physical or cognitive impairments.

These outcomes suggest some opportunities to improve the current social healthcare model by means of a services hub able to:

- Increase the services accessibility and ensure that services supply meets the older people needs;
- Provide a reference point for older people and their family through traditional (office and phone) and smart (mobile application) channels;
- Improve and valorize the territorial point of interests, activities, etc.;
- Improve the quality of healthcare services.

Future works will focus on the development and experimentation of the proposed model in the above-mentioned areas. Nevertheless, its implementation in different geographic areas and scenarios will be investigated.

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Assisted Coaching for Older People: Initial Considerations

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Abstract In this paper, we introduce the concept of "assisted coaching" which consists in providing the patients (and the physicians acting as a coach) with some form of technology that support the required behavior change and in general the compliance with the program without replacing the physician in his/her role of a coach. In particular, we deployed two smartphone apps: (i) one to allow a questionnaire to be administered daily to the participants in order to provide more reliable data about the compliance of a patient to the program and (ii) one that implements a chat that allow patients to ask questions to the coach. The approach was initially evaluated in the contest of a weight reduction program in a clinical setting. The study was conducted as a pilot study and involved 10 older participants (over 62 years) and 4 younger participants as a comparison group. The result suggests that the general approach is interesting and appreciated by the patients, in particular the questionnaire app. Yet, the two specific apps need to be at least partially redesigned to better fit their needs and expectations.

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1 Introduction

Population aging is expected to cause a profound impact on the costs of health-care provision due to the prevalence of chronic diseases common in old age. A way to positively overcome this issue is associated to the use of ICT solutions to enable better management of chronic conditions and to support independent living. As a matter of fact, older adults often have complex health related conditions, essential self-management tasks and frequent medical examinations that can be facilitated with technologies [1]. In particular, the so-called mHealth which envision the provision of health-related support via mobile devices such as smartphones, possibly connected with specific mobile monitoring devices [2].

An example of that is the health coaching approach focused on educate the subject on specific health-related topics and subsequently support them in achieving their health-related goals [3]. In this case, new technologies open viable and effective way to monitor the patient's behavior [4, 5] and guarantee therapy adherence [6]. Personal mobile coaching services have been used with positive results as a way to lead seniors toward healthier life styles and therefore prevent or manage chronic conditions [7–9].

In this paper, we present a specific approach of mHealth to coaching that we call "assisted coaching": we explicitly aim at supporting the human coach by providing tools for the patients that help them to stay connected with the coach in a consistent, safe, reliable, though sustainable way from economic and organizational point of view.

Our approach is similar to the "semi-automated coaching" [10–13] and the so-called "blended coaching" [4]. It also contrasts with other approaches of replacing a human coach with an intelligent fully automated assistant (for example [6, 14, 15]). We choose to pursue this approach to address possible ethical and legal issues, as outlined by sociotechnical systems studies [16], as well as to account for the possible lack of empathy and social intelligence usually attributed to automated assistants [4].

2 The Assisted Coaching Apps

In this initial phase, the Assisted Coaching approach consists in the provision to the patients of two apps realized by an Italian IT company operating in the healthcare and social services market (GPI Group).

The first app is a tool to manage online questionnaires. Through a web-app, the coach can set up specific set of questions and schedule appropriate timing to deliver them to the patient. Then, again through a web-app, the coach can monitor when and how the patient replies to the questions and summarize the results. Upon the reception of a set of questions, the patient has a limited time to fill the questionnaire (as specified by the coach). See Fig. 1, left.

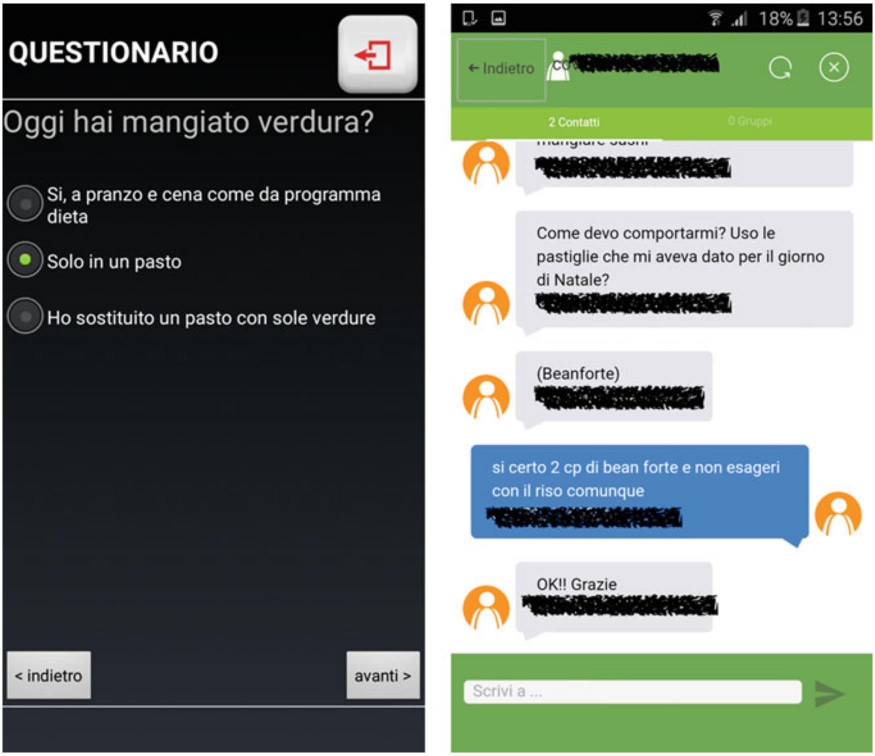

Fig. 1 Screenshots of the two mobile apps (the questionnaire app on the left and the chat app on the right)

The second app is an implementation of a chat (see Fig. 1, right). It looks similar to other similar app (WhatsApp, Telegram and so on) but it complains with the legal protocols for the privacy of clinical data in Italy. Furthermore, the coach can manage the online conversation in the same integrated web-app used for the questionnaire that also manage patients' clinical information, therapy diary and other information.

3 The Study

In order to investigate the feasibility of the "assisted coaching" approach and specifically the acceptance and the appropriation of the two apps, we assessed the service as part of an assisted coaching program for a weight reduction program. The participants were recruited among the patients of two clinical structures one located in Ancona (National Institute of Health and Science on Aging—I.N.R.C.A.) and one in Trento (Policura). Three professional dieticians (2 in Ancona and 1 in Trento) were recruited to prepare the content and to manage the study as coaches.

3.1 Methods and Participants

The study involved 10 older users with age ranging from 60 to 72. Six (6) were diabetics patients on a clinical protocol (recruited in Ancona) and 4 were followed by a dietician in a weight reduction program after a recommendation by their physician (recruited in Trento). As a comparison group, 4 adults (age ranging from 30 to 35) in a weight reduction program in the Trento's structure were also involved.

For technical reasons, the questionnaire app only (and not the chat app) was deployed in the Ancona cohort.

In all cases, the participants were selected among the patients already enrolled in a weight reduction program in their respective structure. The participants applied on a voluntary basis. The participants in the Trento cohort were compensate with a reduction of the fees for the program.

All participants were informed by the respective coach about the goal of the study (that is, assessing the two apps, not evaluating the weight reduction program) and about the possibility of leaving the study in any moment without the need to leave the program.

Before the starting the study, all participants received a face-to-face short training on the two apps (around 1 h). They were interviewed about their experience after the first week of the program in Ancona and after the second week in Trento. A reprise of the interviews were made after two weeks in Ancona and after eight weeks in Trento.

The interviews were organized as structured interview along the following dimensions:

- *Usability*: we inquired about the perceived efficacy (with respect to the coaching service as a whole and specifically with respect to each of the two apps); the perceived efficiency (again, with respect to the coaching service as a whole and with specifically respect to each of the two apps); satisfaction of using each app and learnability, that is how easy it is to learn (the latter was modified as memorability in the second interview).
- *Acceptability*: we interpreted it explicitly in terms of willingness to pay for using the apps in the context of a coaching program.
- *Ethical issues*: we included specifically privacy and impact on social relations.

For each item of the interview, we also asked the participant to provide a score on a Likert scale.

Furthermore, at the end of the study we held a focus group with all the three dieticians involved. In the focus group we aimed at discuss the same dimensions above to account for the professionals' point of view.

3.2 Results

The interviews were audio recorded and transcribed. A thematic analysis [17] was then undertook. This section addresses the key themes that emerged. When we report citations by the participants interviews, we indicate whether the participant was an older ("o") or a younger one ("y") and a two-digit number to unique identify him/her (that is, o03 is the participant identified as 03 who belongs to the group of older participants). Dieticians' quotes are identified with "d" prefix. All the citations have been translated from Italian.

From what concerns the scores of the Likert scale, since number of subjects is limited, they are not used for statistical analysis but rather as a support to the qualitative analysis.

3.2.1 General Considerations on Acceptability

In general, the participants appreciated the idea of assisted coaching program even if, as explained in the following, they also raised several concerns.

In particular, despite some technical and usability issues, the questionnaire app was appreciated as a tool to reflect on own behavior. The use of the questionnaire app was quite satisfying: although two of the older participants stop using it after four weeks, it was used nearly every day by the rest of the participants.

On the other hand, the use of the chat app raised several concerns because although it potentially opened a communication channel with the coach, the dieticians were only able to schedule few hours each week to reply by the web console to the questions posed through the chat. In this way, the potential benefits of this communication channel were available to the participants who complained about the lack of purpose for this type of support.

Still, the discussions about acceptability provided some evidence that the "assisted" approach has a value for which the participants have a willingness to pay. In some cases, the value was openly recognized (o02 "*Absolutely yes […] when you go to a dietician you pay. Therefore, replacing or integrating this service is something useful […]*") while some participants displayed an implicit (for example y04 "*[…] as usual, should it be free, it would be better! you know?*"). Nobody was explicitly negative for concerns related to the tools functionalities although few were concerned with cost in relation to the value: for example, the oldest participant: o03, 72-year-old, said that "*with nothing [in the sense of no money], you can't get anything […] I could use it at the beginning yet if I can do without it*" yet even her later on in the interview conceded that "*if they are essential things, you can spend on them* […]".

Indeed, some participants expressed the point that it is important to get an understanding of the approach before fully appreciating it: o02 "*if you don't know it, you can't understand how useful it might be, therefore autonomously choosing it is more difficult than [implicitly] having it as part of the program*".

This aspect, about the need to experience it before understanding, emerged several times in the interviews. Indeed, it is interesting to note that in general, the older participants tended to be more positive in the first interview (after 1 or 2 weeks of usage) and slightly less positive in the second (after 28 weeks) while the younger participants, on the contrary, tended to improve their opinion from the first to the last interview. For example, the efficacy of the services went from an average score of 3.75 to 3.5 for older people while it increased from 3.5 to 4.25 for younger ones. The similar pattern is apparent in almost all the dimensions (as noted above, this could not be taken as statistical evidence because of the limited sample). This aspect can be explained from the fact that older people are initially reassured by the simplicity of the tool while younger people might be initially more skeptical for the very same reason.

It is worth saying that while the questionnaire app was generally well understood and used regularly and constantly, the chat app was use much less (almost not at all). There are two reasons for that. First, the apps had some technical problems at the beginning of the study and the messages were not properly transmitted: this was not signaled and of course this contributed to the dissatisfaction with the service. Then, the dieticians were only able to answer messages from the chat on a specific time slot once a week: as explained below, this was considered insufficient by many participants.

3.2.2 Theme 1: Being Under Control/Reflect

One aspect that emerged in the interviews of all the older participants—and it also surfaced in the interviews of several younger participants—regards a specific effect of the questionnaire app which consists in letting the user to feel "under control" (by itself and/or by the coach). This aspect is always reported with a positive emphasis: for example, o02 "*Let's say I felt controlled […] and in this type of program, the fact that you are controlled has a sense.*"; o01 "*for sure, it keeps you in the game, therefore there has been a little bit more control*"; y05 "*You feel … I'd say … controlled in the sense that it reminds you something*").

The aspect of "control" is sometime explicitly associated with the opportunity to reflect on one's own behavior as a key aspect for a better compliance with the program: y05 "*it helps me […] to take the stock of the situation in that moment … to know that I did what it was important to do in order to have a regular life*").

The negative aspects related to this theme was mostly related to the lack of flexibility on the schedule and the modalities of the administration of the questionnaire (o01 "*it might have been simpler [with respect to the timing], in the sense that I could decide: now I've time and I do it [the questionnaire]*"). Of course, the bugs on both apps (that surfaced in particular during the initial days of the study) were detrimental to the user experience yet, almost all participants were able to properly contextualize the testing nature of the study and the technical problem did not have a major effect on the appreciation.

3.2.3 Theme 2: Personalization

Another aspect that surfaced from almost all the participant is the theme of the personalization. Again, this aspect was most often mentioned in discussing the questionnaire app and it has in general a positive connotation but a negative perspective: that is, participant recognize personalization as important and they complain for a lack in personalization in the questionnaire. Specifically, there emerged three different but related meaning of personalization.

The first regards the possibility for the dietician to adapt the questions to the specific diet followed the person (while in the current study the questionnaire was a standard set of generic questions): o01 "*[…] for some questions, I did not understand their meaning and consequently very often I take them almost for granted, I give them always the same answer, anyway I don't get what's their purpose*". The crucial nature of the personalization is emphasized also by nutritionists, which had to prepare questionnaires before the selection of participants was over because of recruitment delays: d03 "[…] *if I have to prepare a questionnaire for a person I know in advance, I can do that, but if I do it without knowing her, I have necessarily to use a system of standardization*".

The second regards the adaptation of the questions posed to the same participant over time according to his/her compliance to the diet. For example, o01 "[…] *I did not think any longer valuable asking always the same questions. I think it had to be structured so that later evolved as we were a result of the diet, isn't?*"

Finally, the last one regards the possibility for the app to vary the questions in order to avoid to be perceived as a sort of routine task: o02 "*[the questionnaire] is too much … how to say that … a little bit stiff*".

Nevertheless, in general participants were able to overcome these weaknesses and grasp the potentialities of the questionnaire app: o01 "*the approach is great […] and I believe it can provide an important contribution. The content of these questions, in my opinion, has to be improved*".

3.2.4 Theme 3: Lack of Feedback

A negative aspect was related to the lack of feedback, specifically in the questionnaire app, in two senses: (i) a feedback integrated in the app itself and (ii) from the coach in considering and reporting to the patient about the data collected.

In the former sense, several participants found somehow frustrating the fact that the questionnaire app did not provide a summary of the answers or even an elaboration of some questions (y07 "*[…] if I answer 'no' to a question, it stays there as it is! It should automatically propose an in-depth analysis of the problem*").

Two participants in the younger group expressed the willingness to access the data collected in order to be able to appreciate the evolution of compliance over time (y04 "*For example, I cannot control how was the course of the month. I answered every night I do not remember what I said the day before. I'd like to have this functionality. So, you would realize where you are wrong if you did too little on one* *side or another*”). Even for the coach it is essential to have at a glance the trend of diet compliance: d01 “*[…] the availability of weekly statistical evolution of the various parameters in order to gather a vision of how the patient is behaving.*”

In the latter sense, during the trial the young participants would have expected a constant feedback from the coach: y07 “*Maybe she could tell me, “I saw that this week therapy has not taken three times, what happened?” And maybe give advice or corrections, because I say “this medication bothers me I do, I feel stomach ache” and so on and so forth, so I could fix immediately*”. This aspect included both the aspect related to considering (and reporting to the patient) about the data collected from the questionnaire but it also extended on the use of the chat: as said above, the Trento dietician was able to reply to the chat messages only once a week but the use of the chat app apparently raised the expectation of a more frequent availability of the coach.

3.2.5 Theme 4: Immediacy of Communication (For the Chat App)

The chat was much more problematic and difficult to accept by the majority of the participants. In many cases, the technical problems were a big issue that discouraged, especially the oldest participants, in trying out the tool: o03 “*[…] that is, I’ve tried to get into the chat but, you know, I usually get discouraged at the first attempt and I never try again*”.

In other cases, the problem was the specific way the chat was planned to be used, with the only one slot at a week schedule: o01 “*The availability of the dietician is problematic for me in the sense that if you have a chat, it should be a tool that if you need something, the doctor should answer [immediately]*”. Indeed, the dietician in Trento actually uses a messaging app (Telegram) to communicate with her patients and tries to be online as much as possible. Yet, for this trial, she was not able to be more readily available because the coach chat was integrated in the web management app and therefore accessible only from a desktop device (d01: “*I use Telegram on daily basis, so I am in constant contact with the patient; if there is a tool that speeds up patients management, it becomes very precious; if it hinders me and it is difficult to use, then I prefer an easier tool such Telegram*”).

Finally, in some cases it seemed that the participants lacked the actual motivation for the chat tool: o02 “*I’ve not used it because I did not feel the need. Because if you are in a weight reduction program, you don’t really need […] a correspondence with your physician*”.

In some cases, the younger participants considered the chat as useless per se y07 “*I did not used it because I did not need it […] the couple of hours per week with the physicians [face-to-face] are enough.*” but in some cases it was considered much useful than the questionnaire for the feedback from the dietician y08 “*It was convenient, I got in touch with [the dietician] once and she replied to me. It is a faster and more convenient than email or other things*”. Yet, several of the younger participants lamented the impossibility of asking quick and immediate feedbacks. One of them, suggested that the main problem with a diet program is the “nutrition diary", a sort of log to keep all the food taken during the day and she suggested to take photographs rather than writing the food and send them directly to the dietician by the chat app. It is interesting to note that the same functionality was also requested from one of the older participants.

4 Discussions

In general, the result of the study was quite positive for what concerns the general approach of the "assisted coaching" and similar to other studies, our findings suggest that mobile coaching services are promising services to promote healthier life styles and prevent or manage chronic conditions [7–9].

In particular, even the participants with lesser technical skills perceived the questionnaire as easy to learn and easy to use. The compliance with its usage was satisfying. Furthermore, several participants noticed how its use was useful not only as a tool to provide the physician with reliable data, but also as a tool to reflect on one own's behavior and to provide a support stay on track with the program. This aspect was not initially foreseen as part of the design and we think that it could be furthermore supported by the app. According to [18] and [19], the interactions between a 'felt need' for assistance (for example the need to stay on track with a weight reduction program), the recognition of 'product quality' as well as the dimensions of learnability, easy to use and satisfaction are the basic components of the complex process of acceptability for technology to older people.

The chat app, only deployed in the Trento cohort, was much less appreciated and though the vast majority of the concerns regarded the limited availability of the dieticians, there is some evidence that the problem might be that an open and direct communication, in this case, might be less useful than a structured tool for data collection and for "feeling controlled".

We observed some differences in the two groups, specifically younger and older participants, with the younger participants being more skeptical at the beginning and more positive at the end while the opposite happened to the older participants. This may be due to the fact that younger participants had already been able to try other diet support traditional apps with disappointing outcomes. The initial skepticism due to past experiences has been overcome during the experiment by the novelty of integration between mobile technology and the human coach; according to y06 "a*t the end of the day when someone follows a diet* [using a traditional app] *the main issue is that he is alone, while if he feels helped, it changes everything*". For the elderly people, probably the initial enthusiasm was linked to the overall novelty, but later it was partially depreciated by the technical issues.

Still, the older people did not have more problems or demonstrated less willingness toward this approach. Indeed, two older people dropped out the program but their motivation was not related the use of technology. Nevertheless, these differences reinforce the idea that age is not a cause in refusing new technologies even if older adults are less likely to use technology compared to younger adults [20].

Despite the technical issues and trial limits, the results of the study provided a clear evidence of the potentiality of the "assisted coaching" approach in which the mobile technologies is used to collect data that may facilitate the human coach in the management of each individual case. Furthermore, our study provided evidence as the use of this type of technology is per se a motivation for the patients involved.

In particular, the tight integration between IT technology and human coaching should enable:

(1) the dynamic personalization of the objectives/modalities of the diet and (or—more generally—of the lifestyle improvement plan) not only at the beginning, but also over time, depending on the particular patient's behavior;
(2) the discrete and constant presence on the patient's side in both forms of automatic feedbacks to structured data collected as well as of quick interactions through chat (enriched with photos and videos). They could let the human coach on one hand contextualize the data collected by the system, on the other relate empathically with the patient to reinforce the perception of "control" as a kind of friendly and helpful company.

Still, the results of the study suggest that in order to achieve those goals, the specific apps and the service need to be at least partially redesigned to better fit their needs and expectations. In particular, we learned that it is important that the questionnaire app contains some aspects of personalization as well as some visualizations embedded in order to foster the sense of "reflection" which was appreciated by many participants. Furthermore, the chat should either be based on a standard tool (like Telegram) or be more integrated in the coach's practices in order to make it fully usable and used by the coaches.

5 Conclusions

This paper presented an initial study aimed at investigating an approach to coaching called "assisted" coaching that consists in providing the patients (and the physicians) with some form of technology that may support the required behavior change (or in general foster the compliance with the program) without replacing the physician in his/her role of a coach. The result of the study suggests that the general approach is interesting and appreciated by the patients but the specific apps need to be at least partially redesigned to better fit their needs and expectations.

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Service Design: Thinking Experiences for Playing an Active Role in Society

Chiara Olivastri

Abstract Reflecting on a safe and autonomous home life for the elderly does not necessarily and exclusively apply to building products and the technology of specific products such as independent life support strategies, but also to service design. The core of service design is understanding the needs and motivations of consumer behaviour in order to provide simple and functional experiences that go beyond the use of products but lead to the psycho-physical well-being of the users. The focus is on that range of people, constantly on the rise thanks to the advancement of medicine, who enter old age without any particular illness, but are affected by loneliness and sense of uselessness for society. This paper intends to draw a mapping of services oriented towards co-design processes that include weak users in social dynamics and focus on their role as essential, active citizen still able to play an important role in society.

1 Active Elderly/Old Age

In 2060, the amount of people over 64 years is anticipated to be almost 30% of the EU population. This will increase the burden on social and healthcare sectors, meaning that fewer people will be active in the workforce, but more elderly will be included in different ways in the society.

An Italian survey carried out by Istat[1]—Central Statistics Institute—in 2015 states that there are 13,219,074 people aged 65–74 years equal to 21.7% of the total population and 40.2% of them are in good health, which is 8.9% more than in 2009,

[1] Report Istat Anziani: le condizioni di salute in Italia e nell'Unione Europea, 26 September 2016, available at http://www.istat.it/it/files/2017/09/Condizioni_Salute_anziani_anno_2015.pdf?title=Condizioni+di+salute+degli+anziani+-+26%2Fset%2F2017+-+Condizioni_Salute_anziani_anno_2015.pdf.

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but only 8.5% of the elderly take part in cultural meetings, associations, recreational activities. Thus only a small part of them participate in city life.

This scenario shows a positive health change but underlines an urgent threat regarding the loneliness and the sense of uselessness which can hit the elderly in good health if they are not considered active citizens.

Europe needs innovative solutions and improved policies that enable efficient social and health care services.

Design is a simple and powerful tool to tackle tough social challenges. Demographic ageing is identified by the EU 2020 Strategy as one of the main long-term postcrisis challenges that Europe is facing.

An important research entitled "Making Ageing better" conducted by DAA (Design led innovations for active ageing) shows how service design and better senior service practices across Europe can increase the understanding of the complexity of senior care and can create real pathways for innovative services and solutions that help address demographic challenges in Europe.

One of the answers to demographic ageing identified by the Innovation Union is the imminent launch of the European Innovation Partnership on Active and Healthy Ageing (EIPAHA). In line with EIPAHA, the DAA project contributed to improving the quality of life of an ageing population with new innovative solutions and the development of products and services specifically suitable for the elderly.

In order to tackle the challenges of the ageing population, European cities, regions, and national governments need to find sustainable solutions to inspire people to live healthier, to keep ageing people both physically and socially active in order to live independently in their homes for as long as possible and to make the models of care more economically sustainable.

Designing for the public interest represents a professional opportunity for service designers interested in playing a transformative role in the affecting positively the lives of individuals who are more vulnerable.

2 Autonomy and Loneliness

The greater evil afflicting contemporary civilization is depression,[2] more than 300 million in the world (4%) are concerned, Italy being the second country in Europe (after Germany) with 3 million people affected with ages ranging from 60 to 74.

In fact, if the elderly are healthier, but excluded from society, another issue takes over: the depression.

It's important to consider this topic not as a problem but as a benefit for contemporary civilization, founded on inclusion, integration and subsidiarity.

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[2] An article entitled 'Depressione quante persone ne soffrono' written on Corriere delle Sera on 17th march, 2017 and available at http://www.corriere.it/salute/neuroscienze/17_marzo_30/depressione-quante-persone-ne-soffrono-aeaf0a14-1558-11e7-9957-bbceb60275cc.shtml.

Depression in the elderly is also frequently confused with the effects of multiple illnesses and the medicines used to treat them. The National Institute of Mental Health considers depression in people aged 65 and older to be a major public health problem.

In addition, advancing age is often accompanied by loss of social support systems due to the death of a spouse or siblings, retirement, or relocation of residence. Because of changes in an elderly person's circumstances and the fact that elderly people are expected to slow down, doctors and family may miss the signs of depression. As a result, effective treatment often gets delayed, forcing many elderly people to struggle unnecessarily with depression.

One of the causes on which service design can work is the lack of a supportive social network.

Three main 'challenges' should change the current situation: home base versus home shelter, inclusiveness versus specificity and role versus commitment.

2.1 Home Base Versus Home Shelter

It is vital to maintaining the elderly in their own homes if their health allows it, but if the domestic setting becomes a shelter to run and hide from its surroundings, it can create a problem and become a breeding ground for depression.

In old age autonomy and loneliness are separated by a fine line.

The elderly need to feel comfortable not only in their homes but also in their towns and neighbourhoods as extensions of their living spaces.

2.2 Inclusiveness Versus Specificity

It is important to create activities and events for everyone and not only explicitly for the elderly in order to not make them feel left out. In fact specific objects, actions and assets designed only for their age group are refused by them as matters that underline categories and differences not so rewarding for them.

Thinking along the lines of cross-cutting spaces and activities where people can collaborate in different ways giving their own contributions to each other and for the community is of special importance.

2.3 Role Versus Commitment

Depression is usually caused by a sense of uselessness and the lack of a role in business or in a family or in society.

This aspect is one issue: to change this fear in a resource. A lot of activities in public spaces and in the neighbourhood can be implemented by the important presence of the elderly as they have a lot of time to invest in the common good.

It is crucial that they are designed not as a cure or as a commitment imposed from above, but as interesting and very useful services for the society.

3 Active Citizenship

Unfortunately, urban spaces and public services are undergoing a major crisis.

This crisis is determined by two factors. The first is the deficit and decline of public or collective spaces, in the suburbs as well as in central areas, both at the time of transformation into facilities as well as during their maintenance.

On the contrary, the second factor occurs when citizens gradually lose interest and attention for public urban spaces, perceiving them as nobody's or local public authority's places, rather than common areas.

The emergent and more collaborative aspects of design suggest that policy options could be increasingly co-designed through an interplay between policymakers at different levels of the governance system, interest and lobby groups, external experts and, last but not least, end-users such as citizens or business representatives.

If we look around we can observe countless activities that have been moving in this direction in the complexity of contemporary. Systems have been made more efficient in environmental terms and more cohesive socially, directing the attention towards 'common good' (both social and environmental) and towards an idea of 'active welfare' [1]. When we learn to recognise them, we see that altogether they constitute a phenomenon of extraordinary importance: a great and growing wave of social innovation (*ibidem*). This phenomenon focuses on a new kind of living and reading the city with flexible and adaptable spaces according to the needs of citizens.

Not only, what is changing in this perspective is a new kind of user, no more a passive one but a user who participates actively in the designing of the city in which they will be an active component themselves, within their own capabilities.

Service designers are being asked to develop proposals to improve channels, interfaces, and touch points between government and the public, to draw new policies, new roles for citizens and new active ways of living the cities.

The profile that emerges is a user who plays an important role both in a service proposal and its performance. There is also an interesting variant i.e., the subject is not an individual but a community: a collective subject who asks questions and possesses the skills and abilities to conceive and manage new kinds of services. This is giving rise to an evolution in traditional user-centred design, extending it towards community-centred-design [2].

The collaborative services are expanding from services for the elderly based on mutual help to service that involves everybody for public green spaces and for neighbourhood communities made possible by digital platforms, which are spreading thanks to the internet and mobile devices (In accordance with the other references [3].

Nobody is excluded from the community, differences are resources and weaknesses are balanced by strengths. In the community, the elderly take an important role, so the re-designed city based on community and collaborative service must be a senior-friendly city.

3.1 Service Design

The role of service design is to activate and develop collaborative local enterprises, creating a network of interconnected and complementary service models.

The role of the designer is like that of a participant who is able to listen to users and facilitate the discussion about what to do.

The main feature of a service is that it generates interactive performance where service producers and service users are involved alike.

It means designing on different levels; levels involving service organisation, creation, interaction with the end user, and all the features of the physical or virtual environments, as well as people's actions (behaviour, attitudes, language) and so on.

The new perspective suggests a design approach that does not necessarily focus on existing actors and institutions but engages latent resources deriving from volunteers, associations, organizations, neighbourhoods and online communities that are generally neglected when planning public services.

Design can offer tools to generate solutions in co-design and user centred perspectives.

Here the designer no longer acts as a problem solver, but rather as a facilitator that supports users' capacity to develop autonomous and highly individual solutions. The results of the designer's activity are a set of tools, physical and communicative support for interaction and decision-making.

Drawing on crowdsourcing mechanisms and the people's spirit of self-organisation, these are restricted to providing the right conditions for meeting up, making resources and competences circulate, and accessing activities and services. It is the economy of sharing (goods, resources, activities and know-how).

It is certainly one of the most striking emerging phenomena, sharing is in our genes.

Thackara [4] added some points in respect to what already is known: most designers are trained to change things first and ask questions afterwards. A better use of a designer's fresh eyes is to reveal hidden values and thus mobilize hidden local resources.

Empower local people: any design action that rearranges places and relationships is an exercise of power. In fact, it is not necessary managing or organizing people, but unleashing their capacity to self-organize themselves in creative, constructive, humane ways (p. 148).

This new social, economic, institutional and legal paradigm is going to characterize the 21st century as the "CO-century, the century of COmmons, COllaboration, COoperation, COmmunity, COmmunication, CO-design, CO-production, CO-management, Coexistence and CO-living. For all these reasons it is urgent to design the rules and institutions of this new century" [5].

Designers become part of a team or community attempting to undertake the challenge. Here, the conventional professional advice is here replaced by a situation where the designer is 'embedded' in the community. This allows speaking about design and community coaching: using professional tools to make things happen and enable people to do it [6, 7].

In the sharing, peer to peer and collaborative age, there might be space for a new designing of public institutions, capable of responding to the actual needs of citizens and of adapting better and more quickly to social changes.

3.2 Case Studies

It is important to show and compare different aspects and interpretations of service design applications for the elderly through a list of effective case studies in order to clarify previous aspects described and define different strategies.

These services change the perspective of solving problems related to the elderly, often we wait for problem reveals the pathology to cure, in this approach we anticipate needs redesigning new active experiences for ageing citizens.

An interesting research developed for Active Ageing project (DAA) entitled 'Making ageing better' brought together eight cities (Antwerp, Barcelona, Berlin, Helsinki, Oslo, Sofia, Stockholm and Warsaw) to think sustainable solutions for demographic ageing. The project's goal was to contribute to social innovation and public sector transformation in the field of senior care.

New solutions were sought by sharing best practices and utilising the process of service design, a user-centered method of innovation combining the experience of senior care specialists, with the expertise of service designers. Service design brings together various stakeholders and creates innovations through cooperation, prototyping, and assessment.

The research is a project co-financed by the European Regional Development Fund and made possible by The Interregional Cooperation Programme which helps regions of Europe to work together to share experiences and good practices in the areas of innovation, knowledge economy, environment and risk prevention.

The plan created in Sofia is very interesting because the project is based on the aim to be an age-friendly city where policies, services, and structures support people to age actively.

In this project, Sofia Development Association uses service design as a tool to identify and assess practical solutions along different aspects in order to create services that will have a real impact on elderly citizens.

Many concrete actions were taken during the project to make the city of Sofia more age-friendly.

Five major and several smaller prototypes were designed and tested to create accessible urban environments and to promote active ageing in Sofia. Other prototypes included new possibilities for different generations to meet each other, age-friendly public space seating, as well as awards and programs for senior entrepreneurs.

The aim of these services is to re-establish the importance of social relations and interaction focusing not only on developed urban areas but also a return to what was once a reality and way of life in the countryside and villages where relationships were historical of fundamental importance in daily life. This modern tendency to focus on the 'self' has undeniable consequences, urban decay, lack of social control (ownership) of the territory, loss of a sense of belonging and many people are basically living in isolation.

Another important feature is that services come from people, including in the development of the project interested community from the first steps, through their direct participation in the co-design of solutions to their needs.

This kind of involvement transfers to users trust and responsibility.

The Social Street[3] model started in Bologna in 2013. It proposes a possible ground up the solution and aims to recreate social ties and acknowledgement as well as changes in behaviour between neighbourhoods.

The main features that probably marked success are represented by the use of Facebook as a free medium to spread info via social networks as a facilitator of the transition from "virtual to real", and the decision to restrict the closed FB group in a predetermined territory of a small size. The Social Street model is absolutely free.

Every single group can act to reintroduce appropriate social relations taking into account the peculiarities of its territory.

The fact that any economic and legal aspect is completely ruled out, proved the innovative aspect that has characterized this experience differentiating markedly from all other structured experiences.

In time, these elements have become fundamental and successful. More than 350 groups have started in Italy and abroad in just over a year and are the demonstration of the latent need for infinite changes in the way we socialise and interact independently of economic aspect. The interactions cannot be defined or quantified in financial terms. In this bottom up service, the elderly are part of the group and they can give some of their time to stay with the neighbour's child in exchange for help going to the supermarket or such like. Thanks to this initiative, it is possible to create a lot of occasions to meet other people and combat the loneliness at all ages.

[3] http://www.socialstreet.it.

Another example regards the 'crossing guard'[4] adopted in many Municipalities to give a hand to the Police, a feeling of security to the citizens, a surveillance service in the vicinity of schools and to play an active role in society.

It is a socially useful voluntary activity and aims to pursue the goal of incorporating anxieties into society to prevent and counteract the phenomena of marginalization, assistance to minors and control of pedestrian crossings and adjacent areas. In particular, the Vigilant Grandparents control and facilitate the autonomous mobility of school-children in the home-school pathway by simply offering protection and help on the way to school.

Another service is the "neighbourhood porter"[5] which originated in Paris and was recently imported to Genoa. It is a kiosk, in the heart of a central neighbourhood garden in Piazza Palermo, where anyone in need can send mail or call for help. It can solve small and big problems, from buying medicine for those who are ill or have difficulty moving, carrying bags up six floors without an elevator, picking up a parcel or registered mail to watering the plants. The porter is a sort of concierge who can be contacted and reports problems to the administrator.

This free service is especially dedicated to our elders because the "street door" can create a sense of security. The project was created in collaboration with local and public institutions, associations and thanks to an important contribution from San Paolo Foundation.

In Paris, Place des Vosges, in front of the Saint Paul church in Marais, it was a great success and in just a few months it counted more than 4000 interventions. "Lulu dans ma rue" is an idea by Charles-Edouard Vincent, a professor of Economics, with experience at Stanford University.

If the project works, then it will go to the next stage and the costs will be subdivided between the condominiums and it can be expanded to the whole neighbourhood. Another upgrade is to keep the kiosk open at night: it would be a lighthouse against crime in this neighbourhood in Genoa with over 60,000 residents, of whom 18,000 are over 65; 12,000 are over 75 and these 3800 of them live alone.

Everyone can use the service, although it is mainly dedicated to the elderly who can not move from home.

'CiVediamo'[6]—SeeYou—is a project started in 2014 in Turin, Santa Rita area, which has a population with the highest old-age index in the city and offers a lot of activities specially designed for elderly people.

Project beneficiaries are the elderly, who live alone and are in a state of need but do not want or can't ask for help. The project works to develop the network of proximity, composed of neighbours, doctors and traders, to report to any difficulties, to sustain

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[4]The regulation of the crossing guard written by Municipality of Foggia available at: http://ww2.gazzettaamministrativa.it/opencms/export/sites/default/_gazzetta_amministrativa/amministrazio-ne_trasparente/_puglia/_vico_del_gargano/010_dis_gen/020_att_gen/2013/Documenti_1387798770164/1387798771037_progetto_nonno_vigile_serviziocivicovolontario_approvazione_regolamento.pdf.

[5]An article on Secolo XIX written by Edorado Meoli on 4 april, 2017 and available at: http://www.ilsecoloxix.it/p/genova/2017/04/04/ASg664rG-risolvere_quartiere_qualsiasi.shtml.

[6]http://www.civediamotorino.it.

actions for active citizens with different skills and to promote a better society based on mutual aid.

The last reference is the important DESIS Network (Design for social innovation and sustainability) that has functioned for a long time in creative communities and social innovation fields in several countries all around the world.

The main idea is based on the idea that design can help in supporting and accelerating the spontaneous organizations of people to solve daily problems in order to integrate and consolidate in larger programs.

The Network aims at using design thinking and design knowledge to co-create with local partners frameworks and platforms to connect the diverse local cases with larger regional projects.

Carla Cipolla with Fernanda Zanela and Marcia Tavares as project managers, coordinated a collaborative lodging service—Rio Vivido—in older people's homes in Rio de Janeiro.[7]

The project proposes a collaborative service between older people who live in Rio de Janeiro and tourists through domestic hospitality.

This service focused on community, empowers older people and values their experience and their skills.

The project involves older people who have skills, interesting life stories or good experiences linked the city, as part of the "cultural heritage" in Rio. These older people remain active, integrated and participate in their community. The project is supported by an online platform, which contains the registrations of guests and hosts. Based on the active ageing concept, this project focuses on the unexplored potential of older people linked to the city.

All these different services work on the same goal: to strengthen the relationships between citizens of different ages who live in the same area of the city and don't know each other, to mend a disrupted social fabric able to work together in order to design new bottom-up policies able to face our days' necessities.

4 Conclusions

A variety of social participants throughout the world have moved outside mainstream models of thinking and doing, generating a variety of promising initiatives that propose viable solutions to complex problems of the present and, at the same time, they represent working prototypes of sustainable ways of living.

Service design is identified as an approach to enhance innovative solutions able to influence demographic changes and as a method to think up scenarios to give a new reason of life, new roles, new responsibilities and ultimately a feeling of well-being to everyone, especially to the elderly.

[7] http://www.desisnetwork.org/wp-content/uploads/2016/03/Rio-Vivido.pdf.

This on-going process transfers solution attempts in more effective systems that make the adoption of social policies involving public administrations and stakeholders easier.

Service design is an opportunity to think about problems in a different perspective. Design has the power to enrich our lives by engaging our emotions.

It can use our empathy and understanding of people to design experiences that create opportunities for active engagement and participation [8].

The power of design thinking is of exploring new possibilities, creating new choices, and bringing new solutions to the world. In the process we may find that we have made our societies healthier, our business more profitable, our own lives richer, more impactful and more meaningful (*ibidem*).

Non-exclusive cities with an active protagonist role for elderly

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