Long-term care: how to improve the quality of life with mobile and e-health services

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***Abstract*—In the last decade, ageing has become a world-wide increasing phenomenon leading to an increased need for specialised help. Continuous monitoring, training and rehabilitation improve the quality of life of older adults and discard the risk of depression and social isolation. To this end, the use of mobile and e-health personalised services at home and in residential long-term care facilities can help to stabilise the health conditions of the subjects, in terms of physical, mental, and social capabilities. In this context, we propose a set of personalised monitoring and rehabilitation services based on mobile, wearable, free contact, and touch screen technologies designed to provide an integrated care and monitoring programme for elderly frail subjects. We evaluated the proposed solutions by deploying the services in a nursing home in Italy and defined customised protocols to involve both guests (primary users) and nursing care personnel (secondary users). In this paper, we present technical details of the proposed solutions and the results obtained by the recently conducted surveys on the Quality of Experience and user acceptance of both user categories after 4 months from the deployment.**

I. Introduction

Ageing population has become an increasing phenomenon world-wide in the last decades. While life expectancy has risen systematically, often the quality of life decreases while ageing, due to increasing medical problems and/or deficits in different ability domains (i.e., cognitive, motor, social) that make the health conditions more complex and often chronic [1].

Eurostats annual demography data collection[1] shows there were 510.3 million people living in the EU-28 as of 1 January 2016, of whom almost 98 million were aged 65 years and over. The proportion of older persons in the population differs greatly from one EU Member State to another. In 2016, it peaked at 22.0% in Italy, while people aged 65 years and over also accounted for more than one fifth of the total population in Greece (21.3%), Germany (21.1%, Portugal (20.7%), Finland (20.5%) and Bulgaria (20.4%). In most of the remaining Member States, the elderly generally accounted for $17.0 - 20.0\%$ of the total population.

Most elderly people would prefer to continue to live in their own home, while maintaining their independence and autonomy. However, in 2011 the proportion of elderly persons in the EU who were aged 65-84 years and living in nursing homes was 1.7%. Considering people aged 85 years and over, this percentage increases more than seven times, reaching 12.6%, with a substantial prevalence of women. These persons need specialised help and continuous monitoring, training and rehabilitation to maintain their quality of life and discard the risk of depression and social isolation. To this aim, the introduction of e-health services in nursing homes and, in general, in residential long-term care (LTC) facilities, can help stabilise the health conditions of the subjects, both in terms of physical, mental and social capabilities. In addition, the use of personalised monitoring and rehabilitation services can contribute to LTC costs reduction and can be customized both for nursing home institutions (with appropriate spaces and personnel support) and directly at home (for those who can continue living independently). Today, the investments in LTC are limited and variable in different EU Countries.

Another fundamental point of LTC is the possibility to implement an individual integrated care program, providing a complete picture of the health status of each subject during time, and personalised feedback and coaching solutions helping reducing unhealthy behavior, typical of older persons. The integrated care approach has been recently defined also by WHO in the ICOPE programme [2] (i.e., Integrated Care for Older People) with a focus on reorienting primary care providers and health systems to respond to the great diversity in physical and mental capacities of older people, and to provide person-centred and integrated services. This type of programs can also help physicians addressing acute conditions based on a complete clinical picture.

In this paper, we present the deployment of a set of personalised monitoring and rehabilitation services based on mobile, wearable, free contact and touch screen technologies designed to provide an integrated care and monitoring programme for subjects living in a nursing home in Italy. Each technological solution has been designed and developed to support older people in maintaining healthy behavior in terms of dietary habits, physical and social activities, and to enrich the offer of the nursing home with personalised training of cognitive

[1] http://ec.europa.eu/eurostat/web/population-demography-migration-projections/

and motor functions, in addition to stress monitoring while performing specific activities. This work has been conducted in the framework of the INTESA research project[2] [3] funded by Tuscany region and with the collaboration of the nursing home RSA Tabarracci in Viareggio (Italy), being part of ICARE srl[3].

INTESA services have been deployed in the nursing home after the presentation of the project objectives both to the personnel and to the guests and familiars in February 2018. Then, we implemented a screening of the interested guests and, for each of them, we collected a signed informed consent on the privacy and security policies adopted in the project for personal data management, according to the recent EU GDPR. We started the monitoring sessions in mid March 2018 and they will continue until the end of the year in order to implement a long-term analysis on the health and behavioral status of the involved subjects.

In order to evaluate the impact of the proposed solutions in the daily life of guests (primary users) and nursing care personnel (secondary users), we recently conducted a survey to evaluate the quality of experience (QoE) and the level of acceptance of the proposed solutions from both user categories after 4 months from the deployment.

The paper is organized as follows: Section II introduces the project objectives, the nursing home structure and its standard activities; Section III presents the overall architecture of INTESA system and the technical details of the deployed services; Section IV provides details on the recruitment phase and criteria, while results from QoE surveys are shown in Section V. Section VI presents conclusions and future works.

II. INTESA AND THE REFERENCE NURSING HOME

The INTESA project is designed to provide a suite of personalised and highly innovative mobile and e-health services to improve the quality of life and well-being of elderly, with particular attention to frail people, both living in their own home and institutionalized. The overall INTESA system and every service is developed by using modular programming techniques, in order to easily introduce additional services and tools, and to provide a complete integrated care approach through integrated data analysis tools applied to medium and long-term monitoring of heterogeneous health conditions: body composition and diet, motor and cognitive abilities, sleep quality, stress conditions and social interactions. From a technological point of view, each module is developed using the best state-of-the-art technologies in terms of e-health, e-inclusion, wireless sensors networks, data mining and artificial intelligence. As a first experimentation of INTESA with real users, we decided to deploy the services and the global system in a nursing home hosting up to 60 guests distributed on 3 floors. Each floor is equipped with bedrooms, a kitchen and living room, 2-3 dining rooms for social interactions and guided activities. In addition, there is a gym for rehabilitation, and additional common spaces for interactions, both indoor and outdoor. From the medical point of view, the nursing home has a 24H nursing service while it relies on General Practitioners (GPs) of single guests as a medical support. It provides the possibility of psychological, nutritional and neurological consultation through the collaboration with medical specialists and a daily support from physiotherapists.

The general offer of the nursing home towards each single guest includes a daily check on the pharmacological therapy adherence and the general health conditions, 1 hour of cognitive and motor rehabilitation in group, and a session of socio-educational activities. Through the collaboration with INTESA, the nursing home has significantly increased its offer, both in terms of innovative health monitoring solutions and data collection on its guests, providing a more accurate and integrated care approach, and new tools for the personnel, aimed at simplifying their job in the daily assistance.

In the following section, we present the INTESA services currently deployed in the nursing home, their technological details and how they have been improved and personalised for the reference environment and the users' characteristics. The project team has been allowed to instrument a dedicated ambulatory room of the structure to execute individual sessions of motor and cognitive rehabilitation and monitoring, and the bedrooms of voluntary guests for the installation of the sleep monitoring system (Fig. 1). The project includes also the introduction of an indoor localization system to support the monitoring of social interactions among guests, and the use of a dedicated wearable device for calories consumption monitoring and additional physiological parameters. These additional services will be deployed in the nursing home in the next few months, to further enrich the offer of INTESA.

(a) Motor and cognitive monitoring. (b) Sleep monitoring system.

Fig. 1: INTESA deployment in ambulatory and guests rooms.

III. PERSONALISED MONITORING SERVICES

Fig. 2 shows an overview of the deployed services and their interaction with cloud-based services for collecting and analysing data. In particular, each service uses a local gateway responsible for collecting, uploading and sync raw data with the cloud-based modules. In the cloud back-end, dedicated software modules are deployed in order to filter data and extract pertinent features for the computation of behavioural and physiological markers. A data visualization platform will also be provided to secondary users (GPs and caregivers), showing feedback and personalised coaching guidelines.

[2]http://www.progetto-intesa.it/
[3]http://www.icareviareggio.it/

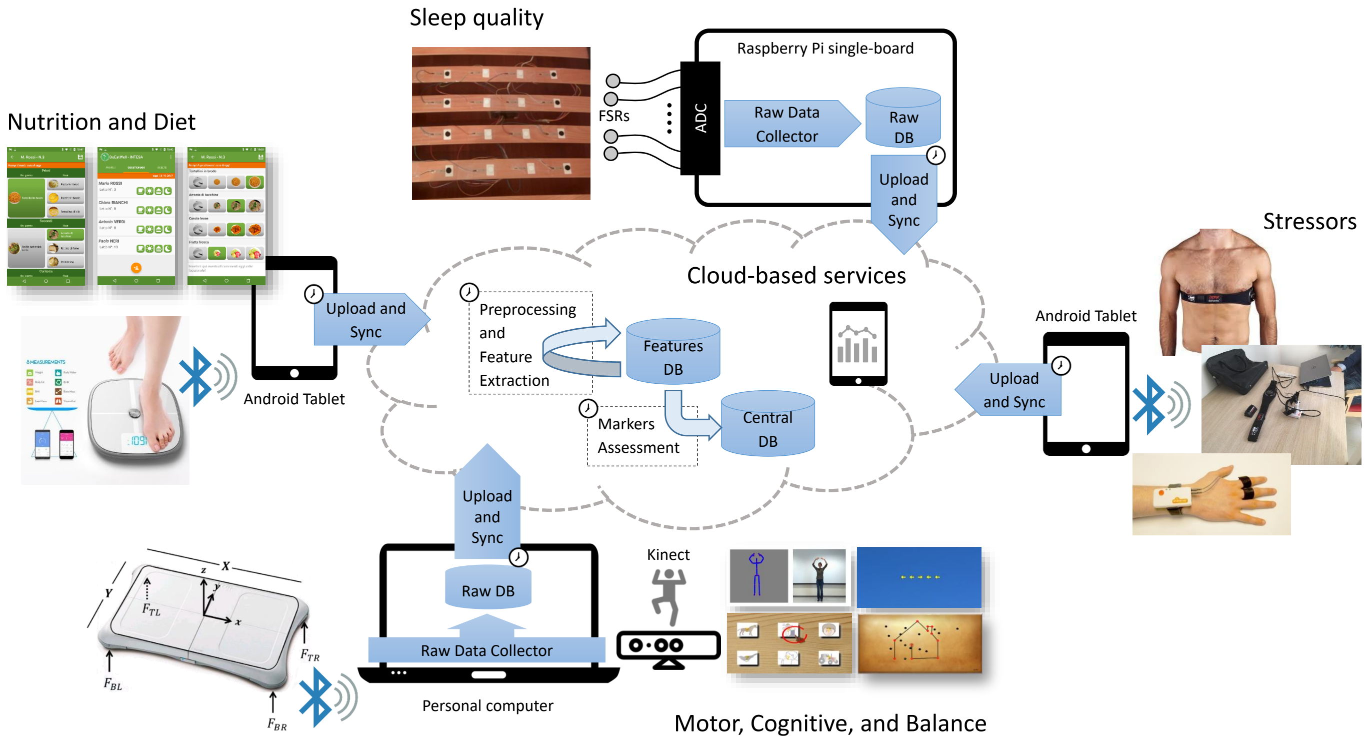


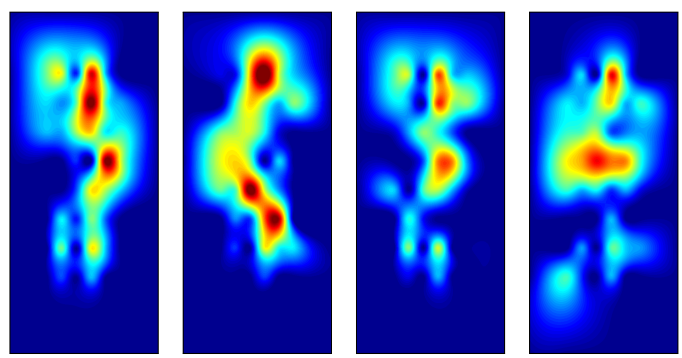
Fig. 2: Overview of the deployed services with their devices, local gateways, cloud-based back-end modules.

A. Sleep quality

One of the most important markers of a healthy lifestyle is represented by the quality and quantity of sleep. These factors directly affect the waking life, including productivity, emotional balance, creativity, physical vitality, and the general personal health. Indeed, poor long-term sleep patterns can lead to a wide range of health-related problems, such as high-blood pressure, high stress, anxiety, diabetes, and depression [4]. In this context, the monitoring of sleep patterns becomes of major importance for various reasons, such as the detection and treatment of sleep disorders, the assessment of the effect of different medical conditions or treatments on the sleep quality, and the assessment of mortality risks associated with sleeping patterns in older adults [5].

Several studies have dealt with the sleep monitoring research challenge [6]. In [7], authors show an actigraphy-based system in order to provide users' feature along a sleep session. In [8], a breathing detection system is presented, while, in [9], authors show an innovative electrocardiography-based approach. The main drawback of these methods is that an obtrusive system is required.

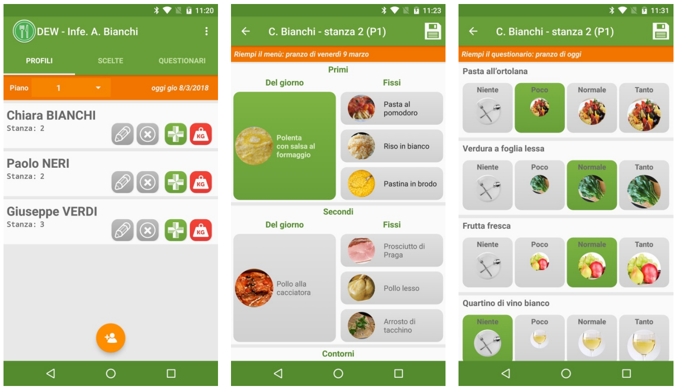
The sleep quality assessment module of INTESA is able to provide sleep features in an unobtrusive way, using a small amount (16) of Force Sensor Resistors (FSRs) [10] and a Raspberry Pi[4] mini pc installed under the user's bed. A similar approach is shown in [11] but, in their work, authors reach the same goal using several expensive transducers, increasing the cost and maintenance of the system. Further details, together with the data set used for training and testing the system in the laboratory, can be found in [12]. The outcome of this module is represented by time series (Fig. 3) of sleeping positions of the user inferred by means of machine learning techniques. This information is useful not only to detect the sleep quality in terms of movements, but also to prevent bedsores in case of users permanently lying in bed [13], providing an automatic turning plan (usually, the caregivers use a turning sheet to record the last position, the elapsed time, and the next position).



(a) Right lateral (b) Left Lateral (c) Prone (d) Supine

Fig. 3: Top view (X-Y plane) of the actual user's bed. The colormap of the applied force (blue=low, red=high) represents the sleep position extracted from the FSR time series.

[4]https://www.raspberrypi.org/



(a) Guests' list. (b) Menu choices. (c) Meal questionnaire.

Fig. 4: The DoEatWell application.

B. Nutrition and body composition

This service aims to monitor and evaluate the temporal evolution of very common pathological conditions in elderly people such as sarcopenia (muscle mass loss/reduction), osteopenia (bone mass loss/reduction), dehydration and excessive visceral fat percentage. The service is based on a mobile application designed to record dietary habits on a daily basis, connected with a bioimpedance scale to collect the following physiological parameters: weight, BMI (body mass index), BMR (basal metabolic rate), percentage of body water, body muscle, and body fat, in addition to body bone mass. The data collected by this monitoring service represents a valid support for the integrated care process, especially for important pathological conditions concerning frail subjects. In particular, dehydration and sarcopenia are considered risk factors for postural instability, falls, fractures and even cognitive decay (that can degenerate in Alzheimer disease), and they can often represent malnutrition indices.

The proposed mobile application is called DoEatWell (DEW), and it has been customised for the nursing home by implementing the daily menu proposed by the internal canteen. In this specific version, considering the characteristics of the target population, the application is designed to be used by the nursing care personnel. They are in charge of asking the voluntary subjects to get on the scale three times per week (in the morning, before breakfast) to store the body composition parameters. Then, for each meal (i.e., breakfast, lunch, dinner and snacks), the care giver fill in a questionnaire on the app selecting a qualitative measure (i.e., nothing, few, normal, too much) of the consumed dishes for each subject. The same service is used by the nursing care personnel to select the preference of each guest before the meals and automatically manage the orders for the canteen. Fig. 4 shows the screenshots of the main DEW functionalities.

Several recent works in literature point out that malnutrition is one of the most relevant conditions that negatively affects the health of elderly people, both in home-based living and assisted living facilities. In almost all the studies the nutritional status of the subjects is evaluated using the Mini Nutritional Assessment (MNA) or its short form (MNA-SF) as nutritional screening tools. One of the most extensive studies presented in [14], which included more than 4,500 elderly subjects of 12 countries in 4 different settings (hospitals, nursing homes, rehabilitation facilities and communities), showed that approximately two-thirds of study participants were at nutritional risk or malnourished, with different rates among the settings. For this reason, we decided to integrate the physiological monitoring service with a nutritional monitoring service, based on the user profile and the dietary options provided by the local structure. All the collected data is stored in the cloud-based back-end server according to all the policy and security policies requested by the recent EU GDPR. In the last 4 months, DEW has been used (and it is currently used) alternatively by 13 care givers (mainly social health assistants), collecting preferences and assumed portions from 57 guests for a total of more than 44000 chosen meals and 170000 filled questionnaires for the assumed portions of each dish. In addition, 10 selected subjects use the bioimpedance scale on alternate days to collect also the body composition data. Currently we have collected more than 400 measurements. The analysis of this data is currently in progress.

C. Motor, Cognitive and balance

INTESA includes a subsystem aimed at implementing guided motor and cognitive exercises for frail older people. The subsystem consists of: (i) the portable Interaxon "Muse" EEG headset for the acquisition of four EEG traces; (ii) the Microsoft "Kinect" V2 infrared-based sensor for the characterization of gestures and movements; (iii) the Nintendo Wii Balance Board for the stabilometric assessment; (iv) a PC connected to the INTESA cloud-based services.

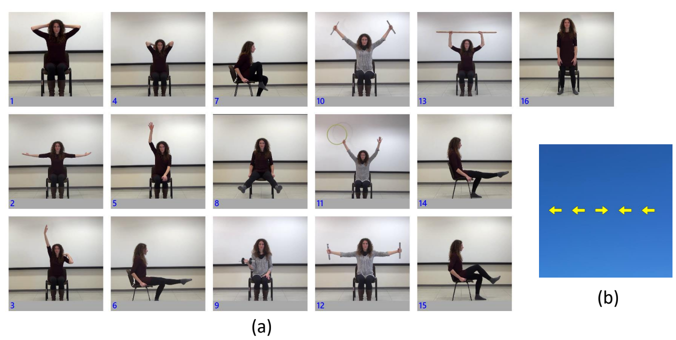


Fig. 5: The motor exercises (a) and the ANT stimulus (b).

The service provides cognitive and motor exercises, aiming to evaluate the performances of the subject and to improve her conditions while using the service over time. Motor exercises consist in asking the subject to mimic the movements proposed by an avatar projected on a large screen. A number of simple tasks, such as "connect-the-dots" and "select-the-tile", can be considered simultaneously motor and cognitive tasks. A simplified version of the classic Attention Network Task (ANT) [15] has been implemented: the subject is asked to lift the right or left arm according to the direction of the central arrow of a pattern projected on the screen: in the pattern the central arrow is surrounded by flankers with either neutral or congruent or opposite directions (see Fig.5b as an example). The service provides quantitative measures related to the subject's reaction time, the number of errors, and the basic features of the recorded EEG traces. Information about the position and movement of the subject is obtained by using Microsoft "Kinect" V2 infrared sensor, which measures the 3-D position of 25 junctions of the human figure, updating the information every 30 ms. As far the EEG recording is concerned, the Interaxon "Muse" portable headset is used for the acquisition of four EEG traces (Fp1, Fp2, TP9 e TP10) at the sampling frequency of 256 Hz by means of dry electrodes. This device has been chosen for its wearability and wireless connectivity.

The monitoring sessions of this service has been carried out according to two protocols: an initial protocol and a customized protocol, based on the results of the first session. Specifically, we observed the need of a significant temporal separation between the requested cognitive tasks and the motor tasks in order to ease the usability of the service for most of the users.

The initial protocol was divided in seven phases. The first four respectively consisted in asking the subjects to perform the following tasks: (1) a paper version of the Attentive Matrices Test [16], (2) motor exercises, (3) the Attention Network Test (ANT) Test, and (4) the Select-The-Tile Game. In the last exer-game the subject had to select on the screen an icon corresponding to a sound emitted by the system. Initially the selection was designed to be made "hands free", using the Kinect. Then, due to the difficulty of the subjects to perform the exercise, we replaced the Kinect with a touch screen. After a recovery period lasting 30s, the subject is asked to get on the balance board to execute the Berg Balance Scale (BBS) exercise to collect the information about the stabilometric and postural assessment in bipodal modality. Then, the Attentive Matrices Test is delivered again to conclude the session.

The second version of the protocol maintains the motor and cognitive exercises separated in two different sessions consisting of six phases. In the cognitive session, after a (1) baseline EEG recording lasting 30 seconds, the participants are required to perform: (2) the Corsi Block-Tapping Test to assess visuospatial short term working memory (CBTT), (3) the Berg Balance Scale (BBS) [17], (4) the simplified version of the Attention Network Test (ANT), (5) the CBTT again, and (6) the BBS again. As far as the ANT test (Fig. 5), six patterns (a central arrow pointing at right / left with neutral / congruent / opposite direction of the flankers) are randomly visualized on a screen with a visual angle of 3.8 degrees for 2 seconds with a 4-second interval. The number of visualizations is limited to 21 to avoid a major amount of stress for the subject. The subject is asked to lift the right / left arm according to the direction of the central arrow. The service records the number of mistakes and the reaction times.

As for the motor session is concerned, motor exercises (Fig. 5a) replace the ANT Test, while the other phases are the same as the cognitive one. As previously described, the motor exercises are presented by an avatar on a large screen and the subjects should mimic the presented movements. After some sessions we decided to support the avatar animation with a real operator, additionally showing and explaining the exercises in front of the subject. The service uses the skeleton joints information, coming from the Kinect sensor, in order to evaluate the correspondence between the movements of the subject and those of the avatar.

The analysis of EEG signals are based on the calculation, after automatically discarding artifact epochs, of the mean power in three significant band activities: theta (4-8Hz), alpha (8-12 Hz) and beta (12-20 Hz). The bands have been chosen in the light of the vast literature about variations in band power according to attention levels (among the relevant literature in the last two decades, see, e.g., [18] and [19]). Comparisons have been made between: a) band powers before vs. during test; b) band powers during the first vs. the second execution of the Cube Test and the Berg Balance Test; c) before vs. during vs. after the visualization of the various patterns of the ANT Test. Preliminary results showed that the performance of the subjects to the Attentive Matrices Test presents better results when executed after the ANT Test.

D. *Stress analysis*

Stress and depression represent two important risk factors in frail older people, especially while living in a nursing home, in which the institution tries to provide a familiar environment but it is always different from living at your own home. Stressing agents (called also stressors) represent physical, environmental, social, cultural, psychological, affective and also nutritional stimuli that can induce high levels of stress in the human body and mind. Stressors can be distinguished in beneficial and harmful. The former ones act as challenges and generate the so-called positive stress or eustress, while the latter ones generate the negative stress or distress, which can lower the immune defenses and can lead to health problems, like anxiety and insomnia, sometimes followed by long-term disorders and diseases.

The Stress Monitoring Service (SMS) relies on the use of wearable devices for physiological monitoring with specific attention to physiological parameters describing the autonomic nervous systems functionalities (both sympathetic and parasympathetic branches). Such parameters include Heart Rate, Heart Rate Variability, Blood Pressure, Respiration Rate, Body Temperature and Galvanic Skin Response (GSR). The wearable sensors are represented by: a wrist unit with finger electrodes for GSR monitoring, a chest strap for cardiorespiratory monitoring, and a mobile personal device (smartphone/tablet) which acts as a gateway for collecting sensor data on standard Bluetooth or Bluetooth Low Energy communication channel. As far as the GSR sensor is concerned, we have used Shimmer3 GSR+ Development Kit[5], while the

[5]www.shimmersensing.com

cardiorespiratory monitoring is performed by using Zephyr Bioharness3[6]. Both the wearable devices included in the system are equipped with IMU sensors, like 3D accelerometer and gyroscope, to collect physical activity and posture data.

During each session, a subject sits on a chair in front of a table in the ambulatory (see Fig.1). The doctor and the physiotherapist help her to wear the wearable sensors. When the subject is ready, the doctor launches SMS mobile app, which is in charge of connecting with the wearable devices and beat time for the monitoring session.

In the INTESA scenario, we decided to start using SMS to monitor the stress condition of 10 subjects while executing a standard cognitive rehabilitation exercise with the medical specialist and, subsequently, to use SMS while performing the cognitive and motor session proposed by INTESA in the previous section. The aim of this work is to evaluate the stress impact of performing this type of activities on elderly frail subjects.

For the first analysis we set up a protocol consisting in the following temporal phases:

- 5 minutes of baseline, in which the subject sat on the chair in a rest condition;
- first execution of the Stroop word-color conflict test;
- 3 minutes of recovery;
- 12 minutes of resting or physical exercise (cycloergometer)
- 3 minutes of recovery
- second execution of the Stroop word-color conflict test;
- last 3 minutes of recovery before stopping the session.

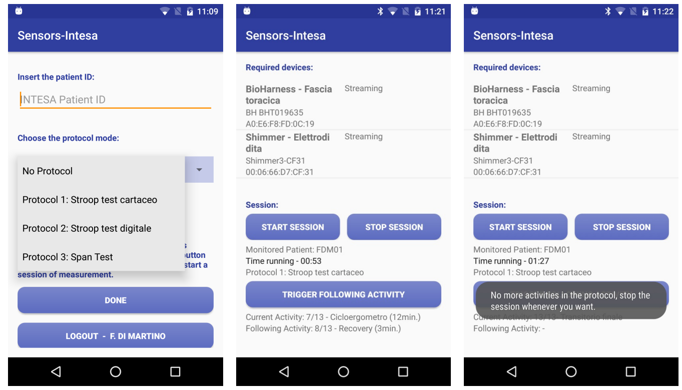
SMS app is responsible for the devices' synchronization and configuration (e.g., enabling/disabling sensors, setting sample rates) and to send the recorded data to a remote server for collection and subsequent analysis. At the moment, we have completed the first monitoring sessions for the selected subjects and we are running the data analysis. The target of this Fig.6 shows some screenshots of SMS app.

IV. Primary and secondary users (Participants)

After the presentation of the project at the nursing home, we received the interests of the majority of the guests (primary users) with the approval of their families. Specifically, 57 guests are participating to the nutritional monitoring through the mobile app compiled by the care givers, while only a subset are able to execute the body composition monitoring, since it requires the ability to maintain the standing position in autonomy for 2-3 minutes. Among those, 35 guests declared their interest in participating in all the services. In order to address the technical and user capability requirements of the proposed services, we implemented the following screening procedure to evaluate the ability of each guest. The participation of the same subject to all the proposed services allows us to evaluate the impact of the integrated care approach proposed by INTESA.

The general screening of each participant included: Mini Mental State Examination (MMSE), Berg Balance Scale assessment, Waterloo Test for limb dominance, and measurement of anthropometric parameters (BMI, weight, brachial and gastrochnelian muscle circumference), Mini Nutritional Assessment (MNA), Activity Daily Living (ADL) and Instrumental ADL, Apathy Evaluation Scale (AES), Hamilton Depression Scale (HDS), Cohen Perceived Stress (CPS) and Insomnia Severity Index (ISI). The follow-up consists in measuring every two months the Hospital Anxiety and Depression Scale, AES, CPS and ISI, in addition to the performance in the Stroop Test and the performance in the Digit Span Backwords Test.

[6]www.zephyranywhere.com



(a) Select monitoring protocol. (b) Trigger the activity. (c) Session end.

Fig. 6: Stress Monitoring Service (SMS) mobile app.

Among the 35 proposed, we recruited 10 subjects able to execute all the requested activities, and 5 control subjects. Until now 4 subjects dropped out due to health problems and complications derived from viral diseases. All the drop outs have been substituted by new enrollments.

TABLE I: Voluntary screening and recruitment

Test	Thresholds	Avg. Score
MNA (21 items)	<17 malnutrition, $[17, 23.5]$ risk of malnutrition, $[24, 30]$ normal	25.4
MMSE (30 items)	$>= 30$ absence of dementia	25.6
ADL (6 items)	$6/6$ normal	5.8
IADL (8 items)	$8/8$ normal	3.4
AES (18 items)	$[0, 42]$ higher values, more severe apathies	33
HDS (21 items)	$<= 7$ no depression, $[8, 17]$ slight depression, $[18, 24]$ moderate depression, $>= 25$ severe depression	20.5
CPS (14 items rated on a 5 point scale)	$>= 20$ high stress	16.2
ISI (7 items)	$[0, 7]$ absence of insomnia, $[8, 14]$ subthreshold insomnia, $[15, 21]$ moderate insomnia, $[22, 28]$ severe insomnia	16.1

The currently selected subjects have an average age of 80.4 (6 women and 4 men), with an education level related to 7.9 school years on average. Table I presents the threshold values generally used to evaluate the output of the screening tests and the average score of our population. As emerged from the results, the selected subjects are not affected by dementia but they can be considered MCI subjects due to the results of ADL and IADL tests, with particular reference to attentive and executive functions [20].

All the recruited subjects signed the INTESA informed consent, in which all the policies we adopt for storage, anonymization, analysis and use of the personal data, including the project objectives are described according to the new EU GDPR regulation.

As far as the secondary users of INTESA is concerned, the nursing care personnel includes 4 different categories: licensed nurses, social health assistants, educational operators and physiotherapists. In addition, a medical specialist has been enrolled by the nursing home specifically to support the project. The deployed services directly request the interaction with the 2 physiotherapists available in the institution for the cognitive, motor and stress monitoring sessions, while around 10 social health assistants have been recruited as main users of the nutrition monitoring service and DEW application.

V. User Acceptance and Quality of Experience

Being INTESA a suite of technological tools and services that assist older people to offer a more independent, healthy, comfortable, safe, and socially engaged life, we used the questionnaire proposed by Mosteghel and Oghazi [21] to assess the user acceptance of gerontechnology [22]. In order to simplify and adapt the questionnaire to the INTESA primary users population, we created a sub-list of 8 questions (Table II) related to the 7 areas of the gerontechnology acceptance questionnaire, namely Perceived Usefulness, Perceived Ease of Use, Gerontechnology self-efficacy, Gerontechnology anxiety, Cognitive ability, Physical function, and Self-reported health conditions, plus a general question about the overall satisfaction of the user. All items have been measured on a 5-point Likert Scale (1 = strongly disagree, 5 = strongly agree).

TABLE II: User acceptance (primary users)

Item	Avg. Score
UA1: I find INTESA useful for my daily activities	**3.4**
UA2: I find INTESA wearable technology easy to use	**3.0**
UA3: I find INTESA activities easy to perform	**2.8**
UA4: I feel calm and confident when using INTESA technology	**2.3**
UA5: I feel calm and confident when performing INTESA activities	**1.2**
UA6: I feel able to complete INTESA activities	**2.4**
UA7: I feel in a good health status	**1.7**
UA8: I feel satisfied participating in INTESA	**3.2**

From the average scores obtained for each item in the questionnaire (Table II), we can observe that the involved subjects consider the services offered by INTESA useful/very useful (3.4 on average for item UA1). We should observe, though, that most of the involved primary users has a high self-awareness of his frail health condition (1.7 on average for UA7), leading to apprehension in using the devices provided by INTESA (2.3 on average for UA4) and in performing the suggested activities (1.2 on average for UA5), with a low self-confidence in completing them (2.4 on average for UA6). However, they showed a good level of acceptance of the proposed protocol (2.8 on average for UA3) and of the wearable devices (3.0 on average for UA2), leading to a high level of satisfaction in participating and feeling included in the project (3.2 on average for UA8).

In order to quantify the Quality of Experience (QoE) of the overall INTESA system from the secondary user point of view, we exploited the System Usability Scale (SUS) questionnaire [23]. SUS provides a reliable tool for measuring the usability of a wide variety of products and services [24] and, for this reason, secondary users in charge of managing the structured activities of the project have been asked to answer it. SUS is based on a 10-items questionnaire (Table III) with each item presenting a five-options response using the same Likert Scale used in the gerontechnology acceptance questionnaire.

TABLE III: Quality of Experience (secondary users)

Item	Avg. Score
QoE1: I think that I would like to use INTESA frequently	**3.8**
QoE2: I found INTESA unnecessarily complex	**2.4**
QoE3: I thought INTESA was easy to use	**4.2**
QoE4: I think that I would need the support of a technical person to be able to use INTESA	**1.6**
QoE5: I found the various functions of INTESA well integrated	**4.2**
QoE6: I thought there was too much inconsistency in the system	**1.8**
QoE7: I would imagine that most people would learn to use INTESA very quickly	**4.2**
QoE8: I found INTESA very cumbersome to use	**2.0**
QoE9: I felt very confident using INTESA	**4.2**
QoE10: I needed to learn a lot of things before I could get going with INTESA	**2.8**

Results show a median of SUS score for the aggregated population (5 subjects) of 72 (normalizing each score on 1 to 10 scale), the minimum score is 68, and the maximum score is 84. According to the grade ranking of SUS scores, the observed SUS median indicates a good overall QoE of INTESA system [25].

VI. Conclusions and Future Work

INTESA presents a suite of mobile and e-health services for personalised monitoring of heterogeneous health conditions and habits of elderly frail people. The main target of INTESA is to provide a complete integrated care approach by using innovative technologies and personalised solutions that can be used both at home, by older people able to live autonomously, and at nursing care institutions, to improve the LTC offer with additional monitoring and rehabilitation functions to prevent risky situations, including cognitive and motor decline, depression and social isolation. To evaluate the efficacy of INTESA in a real scenario, we deployed INTESA services in a Italian nursing home hosting 60 frail subjects with about 30 people as nursing and social care workers. Most of the guests declared their interest in actively participating in the project. Due to technical and user capabilities requirements of the services, we recruited 10 subjects able to execute all the requested activities in order to evaluate the efficacy of the proposed integrated care approach. The deployment has been completed in March 2018 and the services are continuously running and collecting data. We evaluated the user acceptance and QoE of INTESA through specific questionnaires provided to the involved guests and workers, respectively. The analysis highlights a good perception of the guests about the utility and usability of the proposed services and a good satisfaction in their personal participation in the project, even though most of them experienced a not negligible anxiety in the presence and use of the technological solutions during their daily activities. As far as the nursing care personnel is concerned, they find the system useful, easy to use and learn, and a good support for the daily routine, as supported by the SUS evaluation. The experimental phase of the project is currently ongoing, both collecting data from the deployed services and with the future integration of two additional services for indoor localization and calories consumption monitoring, further enriching the integrated care process. In addition, we are deeply analysing the output of the single services to evaluate their efficacy and impact on the health status of the involved subjects, and their integration on medium and long-term periods, implementing machine learning and artificial intelligence algorithms to automatically detect anomalous behaviour and provide personalised feedback.

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