Designing Multidimensional Assessment of ICTs for Elderly People: The UNCAP Clinical Study Protocol

S. Anzivino, G. Nollo, V. Conotter, G. M. A. Guandalini, G. Conti and F. Tessarolo

Abstract The elder with mild or moderate cognitive impairment (MMCI) suffers from progressive cognitive decline with increasing difficulties in performing activities of daily living. Information and Communication Technology (ICT) for Healthcare can provide solutions to relief the caregivers' burden and to support the elder in maintaining dignity and independence. The UNCAP European project aimed at developing and testing a bundle of hardware and software technologies able to fit the individual needs of the elder with MMCI and his/her formal and informal caregivers. A multicenter clinical investigation was designed for assessing improvements in the quality of life of all users (elderly with MMCI and their caregivers) and the impact on the use of resources for care. Six pilot sites in Italy were involved in this clinical investigation. A complex set of assessment tools allowed exploring a wide range of dimensions and to extract common indicators and outcomes in accordance to the assessment dimensions required by the Health Technology Assessment approach.

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1 Background and Rationale

1.1 Aging of EU Population and Needs for Innovative Technologies

The world's population is ageing rapidly with an estimation of one out of five people over 65 years old by 2030 compared to one out of 10 today. Due to chronic age-related illnesses, many seniors progressively lose their autonomy and become more dependent on others, finally reaching the stage when they need round-the-clock care from their family members or caregivers.

One of the most important chronic diseases that affect the ageing population is dementia. It accounts for 4.1% of total disease burden among people aged over 60 and 40% of people older than 85. The number of people affected by this disease is increasing exponentially. Worldwide, 47.5 million people have dementia and there are 7.7 million new cases every year (WHO Fact sheets N° 362, March 2015). Numbers are nearly doubling every 20 years [18].

The Global Deterioration Scale (GDS) [19] categorizes cognitive and functional abilities are into seven stages, ranging from "no cognitive decline" in the first stage to "very severe cognitive decline" in the seventh stage. Stage five denotes the point where it becomes difficult for the patient to live independently and assistance is needed from his/her family and/or caregivers. During stages three to five (mild and moderate cognitive impairments, MMCI), the elder suffers from progressive cognitive decline and experiences increasing difficulties in performing Activities of Daily Living (ADLs). In some instances, MMCI elders may understand what they are supposed to be doing but they may not understand the instructions, or forget them midway through a task. They may also fail to recognize objects for what they are (agnosia) or know how to execute learned tasks (apraxia). This means that the caregivers have to be present to support patients during their activities, and slowly, over time, increase the support they provide as the disease evolves [1].

Older adults, including people with MMCI, desire to remain in their homes as they age [9]. Declining physical and mental capabilities create significant challenges to manage increasing care needed to remain living at home (home care scenario) or at long-term care facilities (residential care scenario).

People with MMCI have more than triple the number of hospitalizations compared with older adults with other conditions [7] and consequent burden of care is relevant. Family caregivers experience high levels of stress, burden and custody charge that lead to negative physical, psychological and social, outcomes [8, 18, 20, 25]. Caregivers of people with MMCI must cope with their loved one's progressive memory loss, self-care impairment and communication breakdown. Caregiving

stress, strain and burden contribute to negative physical and mental health outcomes that include depression, insomnia and psychotropic medication use, with notable increases in caregiver morbidity and mortality [16]. Caregivers separated by distance face unique challenges as they manage caregiving from afar. They may worry about their family member's safety and security, medication schedules, wandering, and need for information and socialization. The distant caregiver may be unaware of the needs of their family member, placing further burden on the onsite caregiver(s) [7].

Since the 1980s, technology has been investigated as a possible support for aging in place [20]. As technology advances, so will new opportunities to reduce the burden of caregiving elderly with MMCI.

1.2 Evaluating Safety and Effect of Innovative Technologies

UNCAP technology has been developed under the framework of the UNCAP European Projects (Ubiquitous iNteroperable Care for Ageing People, EU Grant Agreement number: 643555) and was specifically aimed at addressing the needs of ageing people with cognitive impairment (CI) and dementia.

Enhancing the well-being of people with these conditions is a complex and evolving task. UNCAP fostered a modern non-pharmacological approach as an appropriate initial strategy in the support and care of individuals with CI. UNCAP was designed to assist the individual in maintaining dignity and independence and generally improving users' quality of life. It exploited the latest available technologies to create a sensitive bundle of tools to aid individuals, families and carers in managing their specific needs.

UNCAP was aimed at alleviating a disease (i.e. mild and moderate cognitive impairment), thus being a medical device. Before entering into the market, a premarket clinical investigation was required to assess safety and effects of the innovative medical device.

The design of a clinical investigation for such a technology represented a complex task because the technology allows personalization according to the specific needs of the target user. To this aim, a clinical pilot study has been proposed and realized. The study presented here was designed and performed in different settings (home care and long-term care facilities) representative for the potential setting of use of the system. Moreover, subjects were enrolled according to common inclusion and exclusion criteria, but eliciting specific personal needs that required testing personalized configuration of the system.

The clinical investigation has been evaluated by both the local ethical committees and the National Competent Authorities before starting subjects' recruitment.

2 The UNCAP Bundle

2.1 System Architecture

Individuals with CI or dementia may have problems with their environment leading to stress, agitation and anxiety, and UNCAP can facilitate a reduction of these and other stressors. These interventions can be simple, such as redirecting and refocusing the individual, increasing social interaction, establishing regular habits eliminating sources of conflict and frustration, or more complex. UNCAP provides a range of sophisticated technologies assisting the individual to move safely around their home or general environment by using "transparent" monitoring tools and sensing aids. UNCAP also has the capability to monitor physical movements, cognitive levels and clinical parameters, promoting exercise and training at emotional, physical and cognitive levels.

In practice, UNCAP is a product suite comprising of a low-cost Android-based unit, called the "UNCAP BOX" and a set of hardware and software compatible technology that can be tailored on user needs. The box is connected to a standard digital television set with a USB port. This allows for the collection of data from different indoor and outdoor localization technologies including sensor flooring and camera-based detection systems and from sensors measuring vital parameters such as glucometer, oximeter or blood pressure meter. The system makes the data available, via secure communication channels, to the "UNCAP CLOUD" for the access of authorized caregivers. The UNCAP BOX provides also an interface for individuals, caregivers and family members who can communicate (also via video conference), exchange health data (via HL7 standard http://www.hl7.org), access assessment of the individual's health conditions (through InterRAI™ assessment tools and methodology, http://www.interrai.org and Atl@nte suite, http://www.sistematlante.it) as well as place emergency calls (Fig. 1).

The UNCAP BOX supports interoperable communication, via KNX open protocol (http://www.knx.org), with building automation systems and delivers tailored services including individual lighting controls and "activity reminders", for example flashing lights. The UNCAP BOX is completed by an App for smartphones or tablets. This provides a convenient portable access to UNCAP services and allow accessing selected UNCAP services in online and offline mode or from locations that are not compatible with the UNCAP infrastructure.

UNCAP is made available as a bundle composed of multiple detachable modules and services. The set of compatible devices and software packages is:

- UNCAP box
- Web app
- UNCAP app
- System bus
- Clinical record (Atl@ante)
- Communication system

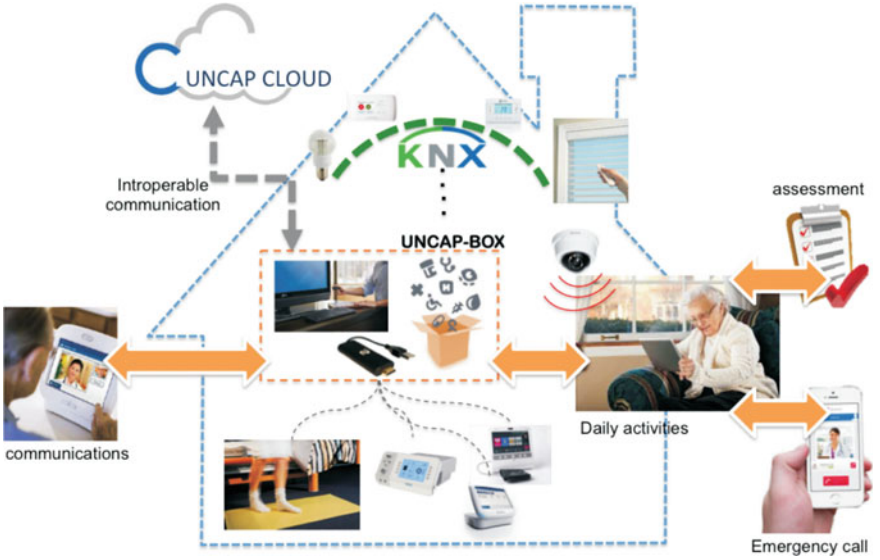

Fig. 1 The UNCAP system (http://www.uncap.eu/)

- Glucometer (e.g. iHealth BG5 gluco-monitoring system)
- Safety support (MentorAge®)
- Sensor mats (SensFloor®)
- Oximeter (e.g. jumper medical JPD-500F oximeter system)
- Blood pressure monitor (e.g. BM-85, Beurer)
- Scale (e.g. iHealth Lite system)
- Smartwatch (e.g. Pabble Watch Classic)
- EEG monitor (e.g. EPOC, Emotiv)
- Serious Game (from Media and MIRo Lab, University of Trento)
- Serious Game (webFitForAll, from Aristotle University of Thessaloniki, Laboratory of Medical Physics)
- Location System (energy efficient Real Time Localization System from ZIGPOS).

2.2 Indication for Use

UNCAP is a medical device intended for the use by the human being with the aim of alleviating a disease.

Specifically, UNCAP is a bundle made of software and hardware components that:

- supports the autonomy and the improvement of the quality of life and dignity of the elderly with mild or moderate cognitive impairment;

- allows the remote clinical evaluation and the monitoring of the health status through the shared management of the elderly with mild or moderate cognitive impairment in home-care and residential healthcare settings by formal and informal caregivers;
- provides services and tools for the physical (exer-games) and cognitive (serious games) rehabilitation and tools for fall prevention with the aim of postponing the cognitive deterioration of the elderly with mild or moderate cognitive impairment.

A comprehensive view of all UNCAP services and functionalities is provided in Table 1.

3 Available Evidences on ICTs for the Elderly with CI

Since no previous clinical study for testing safety and performance of UNCAP was available at the time of the study planning, a clinical evaluation on equivalent or similar technologies was performed according to the EU guidelines on medical devices (MEDDEV. 2.7.1 rev.3 "Clinical Evaluation: a guide for manufacturers and notified bodies"). The literature search resulted in few studies conducted on integrated solutions with claims similar to UNCAP.

There was very little in the systematic reviews specifically concerning patient safety and it was not clear whether adverse events did not occur or whether there was a lack of reporting. Available information showed that cognitive stimulation did not induce differences in the MMCI user mood, and no behavioral function or problem behavior was noted [2, 23]. There was no indication of increased strain on family caregivers adopting technologies for elders with MCCI [23] that in general appeared to be safely used.

Literature search reported, in general, a good acceptability and satisfaction by demented persons and caregivers, a good usability and performances, ranging from moderate to good, for technologies with available clinical data [6].

Results of rigorous clinical studies on integrated technologies are still missing. Studies including people with MMCI exposed to single IT systems or smaller bundle of technology showed that monitoring systems could significantly decrease the burden for formal or informal caregivers [12].

Ambient Assisted Living technologies that required minimal interaction from the service user and appliances that were specifically designed to address particular problems led to more successful outcomes for the person with dementia [10]. In a clinical trial of 10 subjects with moderate to severe dementia, the COACH system increased by 25% the number of handwashing steps that were correctly completed without caregiver assistance [15].

Systems for monitoring of vital signs and basic metabolic parameters have high potential [14, 21], but no clinical studies with dementia subjects were retrieved from literature [5]. Tracking and wayfinding systems, based on GPS intervention, increased the ability of people with dementia to go outside independently, resulting

Table 1 UNCAP functionalities

Service	Short description
Monitoring	To continuously assess health state of users from a range of different sensors as well as their physical activity levels. The information collected and securely stored in digitalized clinical folder allows remote assessment by doctors when the direct contact is not necessary
Digitalized clinical folder	To allow store and exchange of clinical data based on existing open standards. This ensures continuity of care at different levels of intensity. This service includes the management of: • Care protocol, necessary treatment and medications, including appointments with caregivers, reminders about which medicine should be taken at the right time, support for checklists, etc • Historical information of the patient's clinical records, including the caregivers involved • Support of a diary containing general observations on the patient, often used in the case of access to "daily care" structures, not involving medical cares
Reminder	To help users recalling activities and help finding the needed items to perform them
Communication	To help the user easily communicating with family members, friends, and caregivers via simple interfaces available through their TV or smartphone/tablet. Communication between formal and informal caregivers is facilitated to consider all the dimensions of the elder profile and needs: from the objective information concerning the MMCI user health, habits, and practical needs, to more subjective considerations, for example concerning the users' mood, desires or relationships with the care givers
Emergency call	To trigger alert messages to caregivers when abnormal clinical health is detected or when "sentinel events" are identified
Fall detection	To trigger alert in case one of the different technologies detects the user falling (e.g. the sensor floor, the cameras, the smartphone algorithm, etc.)
Clinical assessment	To assert the MMCI user's conditions (physical and cognitive) and evolution in time through the use of the internationally validated multi-dimensional test scales
Cognitive or physical exercises	To create incentive mechanisms to help keeping users healthy from a physical and cognitive point of view through games (or other strategies) based on use of data from localization technologies (e.g. to challenge users to walk more)
Guiding	To help users reaching a given location (inside or outside the building) or locating devices/objects of daily use, e.g. the remote control of the TV
Spatio-temporal geofencing	To trigger alerts to caregivers when the user leaves designated areas or behaves abnormally at unusual times (e.g. leaving the room during the night)
Data repository and exchange	To provide a secure cloud storage space used to archive confidential data through open cryptographic libraries or on encrypted partitions

in more freedom of the elder away from caregivers, and decreased the levels of stress of both the primary user and the caregivers [17].

Tracking systems integrated with fall prevention device were highly effective in reducing the relative risk of falls in person with dementia [22].

Cognitive aids can reduce the number of nighttime calls [4]. Cognitive stimulation has been shown to have positive effects in elderly with MMCI over and above any medication effects with a consistent benefit on cognitive function, self-reported quality of life and well-being at follow-up [23]. Although the cognitive effect of Serious Games played by older adults has not yet been studied thoroughly, combined physical and cognitive training have the potential of improving global cognition in patients with MCCI [3]. Results of a multicentre study including 322 older adults indicated that combined physical and cognitive training improves global cognition in a dose-responsive manner but these benefits may be less pronounced in older adults with more severe neurocognitive disorders [3].

In a summary, indications for use of UNCAP technology were supported by knowledge and data available in literature from several partially-equivalent technologies that have been experimented on MMCI elders and their caregivers. However, considering the scarcity of specific clinical data supporting the use of ICTs in alleviating cognitive impairment and improving quality of life of older adults affected by CI, new clinical investigations were needed.

4 Study Design

UNCAP modularity is conceived to allow the customization of the bundle features according to the actual care setting and the needs of both primary (seniors with MMCI) and secondary (informal and formal caregivers) users' needs. According to this, UNCAP was tested for caring elderly people with MMCI in two different settings:

- long term care facilities as an additional care device;
- primary user home for providing home care services.

Each of the pilots implemented a specific set of UNCAP features chosen according to the specific application scenario, environment and users' needs.

The modularity and adaptability of UNCAP in different scenarios reflects the complexity of the clinical investigation to assess UNCAP usability and safety, users' acceptance, satisfaction and quality of life. However, all pilot sites shared the same research questions, with a common set of primary and secondary endpoints and evaluation tools.

The investigation was conducted as a pre-market randomized controlled prospective parallel multicentre study.

4.1 Objectives and Research Questions

The study aimed at assessing improvements in the quality of life of users and the impact on the use of resources for care due to the adoption of UNCAP technology. The objective of the investigation was also to assess safety and usability of UNCAP in responding to the needs of elderly people with mild and moderate cognitive impairment as well as evaluating primary and secondary users' acceptance and satisfaction.

The above reported objectives were summarized in the following research questions:

- Does the introduction of a personalized UNCAP bundle improve the users' quality of life?
- Does UNCAP have an impact on the caring for elderly with MMCI?
- What is the safety and usability of UNCAP in caring elderly patients with MMCI?
- What is users' satisfaction and acceptability of UNCAP?

4.2 Study Dimensions and Outcome Variables

Considering the multiple dimensions to assess in the study, a comprehensive set of outcome variables was defined as reported in Table 2.

4.3 Primary and Secondary Hypotheses and Study Endpoints

To properly address the research questions reported above, primary and secondary endpoints of the study were formulated and challenged by well defined working hypothesis making use of the outcome variables reported in Table 2. Study endpoints and working hypotheses of the study are summarized in Table 3.

4.4 Criteria for Recruiting Participants

The study was designed to examine UNCAP technology as an intervention within the subject home or at long-term facilities. Therefore, participant samples included only people who live at their home or at long-term facility and who were diagnosed from mild cognitive impairments to moderate cognitive decline (MMCI).

Detailed below are conditions regarding all user groups, inclusion and exclusion criteria and procedures for recruitment.

Table 2 Outcome variables of the study (EP: elderly person, primary end-user; ICG: informal caregiver; FCG: formal caregiver; QoL-AD: Quality of Live Alzheimer Disease [13]; FES-I: Falls Efficacy Scale-International [24], SQLC: Scale of Quality of Life of Care-Givers [11])

Study dimensions	Outcome variables
Quality of life	QoL-AD score (EP)
	SQLC score (ICGs) FES-I score
Perceived usability	Number of primary users (%) in the test group considering UNCAP features as "usable"
User acceptance	Number of primary users (%) in the test group considering UNCAP features as "acceptable" Number of primary users (%) in the test group willing to complete the study by using UNCAP technology for 6 a months period
User satisfaction	General satisfaction EP score General satisfaction ICG score General satisfaction FCG score Number of primary users (%) in the test group expressing as "satisfied" about UNCAP in respect to the specific need Number of ICGs (%) in the test group expressing as "satisfied" about UNCAP in respect to the specific UNCAP component Number of FCG (%) expressing as "satisfied" about UNCAP in respect to the specific UNCAP component
Safety	Number of Adverse Events (AE) Number of Adverse Device Effect (ADE) Number of Serious Adverse Events (SAE) Number of Serious Adverse Device Effect (SADE)
Impact	Number of medical examinations by general practitioner Number of medical examinations by other physicians Number of referrals to the emergency department Number of hours per month spent by nurses caring for participant Number of hours per month spent by FCG caring for EPs Number of hours per month spent by ICG caring for the EP Number of days off work for family members for caring EP Number of technical interventions for device malfunction
Primary user needs, health profile and autonomy	Personal Health Profile (PHP) key from ATL@NTE

4.4.1 Users Definition and Needs

Primary end-user: the old person (subject) with Mild and Moderate Cognitive Impairments who was using UNCAP or to which UNCAP technology was provided for. These people have difficulty in their everyday life, which comes due to cognitive problems and mild or moderate dementia. This group could directly benefit from the UNCAP technology and was expected to increase the quality of life of its members.

Table 3 Study endpoints and working hypotheses. (EP: elderly person, primary end-user; ICG: informal caregiver; FCG: formal caregiver; QoL-AD: Quality of Live Alzheimer Disease [13]; FES-I: Falls Efficacy Scale-International [24], SQLC: Scale of Quality of Life of Care-Givers [11])

Priority level	Study endpoints	Working hypothesis
Primary	UNCAP increased the "Quality of Life" for the elderly with MMCI	UNCAP will increase the QoL-AD score of primary users by 9% in the test group in respect to control group
Secondary	UNCAP had positive effects in the "Quality of Life" of the primary users and their caregivers	UNCAP will increase SQLC score of ICGs in the test group after six months of use UNCAP will reduce FES-I score of EPs in the test group after six months of use
	UNCAP had no negative effects in the safety of the primary users	UNCAP will not determine any severe adverse events related to the device in the test group after six months of use
	UNCAP was positively accepted and used	75% of participants in the test group will be able to use UNCAP features 75% of ICGs in the test group will report acceptance of UNCAP as support in their care for EP 75% of test group participants will report satisfaction of UNCAP
	UNCAP had a positive impact on the burden of care for elderly wit MMCI	UNCAP will reduce the overall burden of care by 10%

Secondary end-users: persons directly being in contact with the primary end-user, such as formal and informal care persons, family members, friends. This group was expected to benefit from UNCAP technology directly when using the services and indirectly when the care needs of primary end users are reduced. Secondary end users were grouped into two sub-categories according to the following:

- Informal care-givers (ICG): very often the closest family members are the direct care-givers and supporters in the daily care for the MMCI subjects
- Formal care-givers (FCG): Professional care providers (physicians, nurses, professional caregivers at home).

4.4.2 Inclusion Criteria

Based on the main user groups considered in the study, the safety, acceptability and satisfaction of UNCAP were evaluated on the following three test groups:

- EP group—of primary end users: Elderly People with cognitive problems or mild dementia.

- ICG group—of secondary end users: Informal Care Givers. This includes close family members or family friends who take care of the senior.
- FCG group—of secondary end users: Formal Care Givers. This test group includes home care personnel and specialized care-giver personnel at long term care facilities.

The target primary end-user group (EP group) were elderly persons with Mild and Moderate Cognitive Impairments (MMCI) (2–3 stage and partially 4 stage, since some of 3 stage subjects, in 6-month duration of the test project periods, might progress to stage 4). The trial participants were classified according to CPS score at enrolment.

Specific inclusion criteria for primary users included:

- Age above 60 years
- Lives at home, or in a long term facility
- Diagnosed with Mild or Moderate Cognitive Impairment (MMCI) with a CPS score of 2–3 at enrolment
- The MMCI diagnoses and stage is defined by a specialist (neurologist, geriatric specialist, etc.)
- Can self understand and give consent to participate in the project trial
- Having a close relative or family-friend which is willing to help for the participation to the project trials as an informal caregiver is considered as preferential but not mandatory.

ICGs was considered as secondary users if they were:

- 18 years old or older
- actively involved caregiver for the care recipient (provide at least on average of 5 h of supervision or direct assistance per week)
- planning to remain in the area for the duration of the intervention and follow-up
- has performed the informal caregiver role for more than 6 months
- Not having dementia at any stage.

FCGs was considered accordingly to their willingness to cooperate. Once the potential FCG were identified, they were contacted by one of the researchers (e.g. pilot responsible) who further explained the project and answered any questions they might have. Formal caregivers were asked to identify the care giving situation from their (professional) point of view regarding ICG status, EP status and care giving situation. FCG completed a screening tool to determine their occupational status and role in the care team. Formal caregivers were encouraged to participate in the home visit of EP to assess the situation, setting and possible solutions. They were asked for general satisfaction and specific satisfaction about UNCAP system features. Moreover, they were asked to provide data for addressing efficiency of the care system in respect to the primary user at both the enrolment and discharge time.

4.4.3 Exclusion Criteria

The following exclusion criteria were identified for the primary end-user. Those subjects meeting the following conditions were excluded from the study.

- Mild neurocognitive disorder due to:
  - Drug abuse due to the presence of co-morbidities with Personality Disorder not compatible with this study
  - HIV infection, since medical complications are not manageable
  - Nutrition deficiencies
- Participants whose dementia is reversible (nutrition deficiencies)
- Presence of psychiatric co-morbidity
- Presence of behavioral disorders (difficult research management)
- Individuals with severe functional or sensory impairment (e.g. visual impairment or certain physical disabilities), that could jeopardize the use of technological devices tested in the study
- Individuals enrolled in a pilot study whose condition shows a rapid decline towards more severe forms of cognitive diseases or other conditions that result in an inability to use the technological devices tested in the study.
- Life expectancy <1 year

Due to matters related to budget limitations and costs per pilot, secondary exclusion criteria for the subjects of the test group were:

- Participants living at home who do not have Internet access or for whom there is no possibly to provide such infrastructure.
- Participants living in big homes (due to the limitation to buy and install many sensors in their homes).

4.5 Recruitment Process

Several strategies were defined and implemented for realizing an effective and unbiased recruitment process.

Potential participants were recruited with the help of general practitioners and nurses, aging and cognition specialists, memory and dementia clinics operating at the local care structures.

Another activity which helped recruiting test subjects living at home was the availability of a living lab, where a ready, full optional UNCAP bundle, was installed with the purpose of:

- demonstration of the systems to potential test participants and their relatives (they were able to see, and experience the system before deciding to join the controlled study and be convinced that UNCAP technology was user friendly and also aesthetically acceptable);

- try in reality the system and provide indication for customization of UNCAP bundle according to specific patients' needs;
- provide training to enrolled end-users;
- gain hands-on experience of the full options UNCAP system to informal and formal caregivers.

Another used approach was to contact the informal caregivers of potential primary users. This approach was pursued for recruiting MMCI elders living at their home. The advantage of this approach is that when the close relative or partner is positive about the possibility of assessing UNCAP technology, he/she could easily convince the primary end-user to take part in the trials. During this contact, primary caregivers assessed eligibility criteria or primary and secondary end user before asking for availability to participate in the study.

Primary users then needed a clinical evaluation by a specialist (neurologist, geriatric specialist, etc.) and a rating of cognitive decline.

Eligible participants received a visit by one or more research members at their long- term facility or at their home according to the local setting.

This visit served to present both oral and written information regarding the research and the clinical investigation as well as:

- Obtain informed consent of participants.
- Measure the level of cognitive impairment with Atl@nte.
- Measure quality of life at enrolment (with QOL-AD questionnaire).
- Conduct an assessment of the participant needs.
- Document user's behaviors that could present safety concerns.
- Identify potential sites for UNCAP equipment deployment at the user's premises.
- Ascertain caregivers' familiarity with technologies.

4.6 Sample Size

A total of 120 elderly persons with mild or moderate cognitive impairment were recruited at the six Italian pilot sites. In addition to the primary users (elderly persons, EPs), the study plan aimed also to enroll 102 secondary users, including 72 informal caregivers and 30 formal caregivers (Table 4).

Among the recruited users, a randomization procedure allocated the primary users (EP) and their ICGs (when available) to test and control groups for a total of:

- 96 users (60 EPs + 36 ICGs) in the control group (enrolled in the study and managed according to the local standard of care)
- 96 users (60 EPs + 36 ICGs) in the test group (enrolled in the study and managed with UNCAP in addition to the local care).

The primary hypothesis is that UNCAP technology can improve the quality of life among elderly with mild or moderate dementia.

Table 4 Target end-user involvement per group and per pilot center

Pilot site	Geographical location	EP—elderly with MMCI	ICG—informal caregivers	FCG—formal caregivers
Rehabilitation center "Villa Rosa"	Pergine (TN)	20 10 tests, 10 controls	12 6 tests, 6 controls	5
Long term care facility "Creusa Brizi Bittoni"	Città della Pieve (PG)	20 10 tests, 10 controls	12 6 tests, 6 controls	5
Long term care facility "Villa Bianca"	Tarzo (TV)	20 10 tests, 10 controls	12 6 tests, 6 controls	5
Long term care facility "Villa Serena" ULSS n°5 Ovest Vicentino	Lonigo (VI)	20 10 tests, 10 controls	12 6 tests, 6 controls	5
Long term care facility "La pieve" ULSS n°5 Ovest Vicentino	Montechio Maggiore (VI)	20 10 tests, 10 controls	12 6 tests, 6 controls	5
Long term care facility "Villa Serena" ULSS n°5 Ovest Vicentino	Valdagno (VI)	20 10 tests, 10 controls	12 6 tests, 6 controls	5
Total participants		120 60 tests, 60 controls	72 36 tests, 36 controls	30

No previous research was retrieved from literature to document quantitatively such hypothesis with a controlled study. Only references have been found that indicate that there is a relation between quality of life and cognitive impairment. Logsdon et al. [13] reported an average QoL-AD score of 39.8 (spreading 5.8) and 39.2 (spreading 4.7), respectively for elderly with a MMSE within the range 17–21 (mild cognitive impairment) and with MMSE > 22 (moderate to severe cognitive impairment).

Considering that a MMSE within the range 17–29 characterized the primary users recruited in this study, a QoL-AD at approx. 39.5 points (spreading 5,3) were expected among the EP test group.

The study was aiming to measure a relative increased QoL with 9% (QoL-AD = 43, spreading 5, 3), p-value of 5%, power 90%.

It was calculated that $N = 49$ subjects need to be used in the control and test group (total 98 subjects), in order to prove the hypothesis with significance.

Considering a potential 10% drop out and an additional 10% of EPs unwilling to accept the UNCAP technology after the training phase and leaving the study before the planned discharge time, the number of test EP was set to $N = 60$, meaning 10 persons in the test group and 10 persons in the control group for each pilot site.

In order to have statically valid test results, the test and control groups of the elderly were randomly selected by using block randomization procedure.

4.7 Control Groups for Primary End-Users (EP) and ICGs

The control EP group was expected to be as characteristically similar to EP test group as possible. EP were recruited with the very same procedures and in the same structures where the test group was obtained.

The control group consisted of an equal number of subjects from primary end-user group to allow for a good comparison. They were going to be involved as the test participants from the beginning months of the test period and relevant tests were applied to them too. As for the test group, control group was also administered by all tests, except for specific test addressing user acceptance and user satisfaction of the UNCAP technologies because they were not expose to any technological intervention.

Control group of Informal care givers was constituted by the ICGs of the EP control group.

FCG had no control group since this clinical investigation provided only an inventory non-comparative study in respect to the FCG satisfaction about UNCAP technology.

4.8 Randomization Procedures

Randomization was performed on primary users at enrolment using block randomization of five subjects through specific software on a centre-by-centre basis.

Since there was also an interest in studying QoL of informal caregivers, a total of 72 ICGs were recruited and associated to the same test or control group of the elderly person they take care. Therefore, ICGs grouping was based on EP randomization.

Sealed envelopes containing the randomization assignment were provided to each pilot centre. On the external side of the envelope, a number was reported. At the enrolment of the EP, after obtaining his/her informed consent to participate to the clinical investigation, the randomization envelope identified by the same number reported in the EP's ID was opened. The result of the randomization assignment was recorded on the "Matching sheet".

4.9 Criteria for Discontinuing Individuals

The participant could voluntarily elect to discontinue participation in the study at any time.

Moreover, if at any time the investigator determined it was not in the best interest of the participant to continue in the trial, the person was excluded from the study.

At the end of the training phase the EP was asked about the acceptability of the UNCAP system. If the participant did not wish to use UNCAP, the subject was

discontinued from the study and the collected data was used only for acceptance evaluation. Whenever the EP asked to exit the study, the corresponding ICG (if present) was discontinued as well.

If the participant failed to follow the procedures of the study, the investigator might discontinue participation in the study, providing supporting documentation in the study file.

The reason for removal of a participant from the study after the enrolment had to be always documented.

5 Study Procedure

A total of about 7 months was expected from the involvement of each participant (from enrolment to discharge).

The study timeline was structured according to the following time-points:

- T0: Enrolment time.
- T1: Test group training with UNCAP (within 1 month from enrollment).
- T2: evaluation of UNCAP acceptance and starting of UNCAP evaluation (immediately after training)
- T3: intermediate UNCAP evaluation (after three months from T2)
- T4: End of the evaluation period and patient discharge from the study (after six months from T2).

The total expected length of the study was 12 months. This allowed a gradual enrolment of the primary users and caregivers, thus guaranteeing an adequate training and proper time for UNCAP hardware installation at users home or long term care facilities.

5.1 T0 (Enrolment Time)

Individuals with MMCI and their informal caregivers were recruited in each pilot site according to the procedures reported in "Selection process". FCGs was recruited after an informative meeting describing UNCAP technologies and study design. The investigator responsible of the pilot site organized the informative meeting in collaboration with the principal investigator.

The investigator checked inclusion and exclusion criteria as detailed in "Inclusion criteria" and "Exclusion criteria" sections. Participants fulfilling inclusion criteria were informed on the possibility to participate to the clinical investigation. Information were provided to the primary user and to his/her caregiver by the local investigator or a delegate representative. Brochures and informative documents describing UNCAP technologies were also provided.

Written informed consent was obtained from EPs and ICGs (when available) by using dedicated forms (Primary End user information sheet and informed consent form; ICG information sheet and Informed consent form). A participant ID was generated at the time of enrolment, just after having obtained the participant informed consent. Participant ID was immediately reported on the matching sheet together with name and surname of the participant, birth date and group allocation (test or control). Participant matching sheet had to be stored under the responsibility of the local investigator and was not accessible to any other person.

A baseline clinical evaluation with recognition of patients' needs was performed at enrolment by using Atl@nte online form. Atl@nte ID was the same ID code defined at enrolment. A set of data collection forms and questionnaires were filled/administered by each user type at enrolment. The following data collection forms and questionnaires were obtained for both test and control group users.

Primary user:

- EP enrolment data collection form (DCF)
- Narrative collection of needs
- Administration of validated questionnaire "QoL-AD"
- Administration of structured questionnaire "General EP satisfaction"
- Administration of validated questionnaire "FES-I".

Informal caregivers:

- ICG enrolment DCF
- Narrative collection of needs
- Administration of validated questionnaire "QoL-AD"
- Administration of validated questionnaire "SQLC"
- Administration of structured questionnaire "General ICG satisfaction"
- Administration of structured questionnaire "Impact".

Formal caregivers:

- FCG enrolment DCF
- Administration of structured questionnaire "General FCG satisfaction"
- Administration of structured questionnaire "Impact".

Based on the data collected with Atl@nte (e.g., activities of daily living, personal health profile) and from enrolment questionnaires, including the narrative description, the local investigator defined the list of user's needs and filled the "DCF for participant needs and UNCAP personalization".

5.2 T1 (UNCAP First Time Exposure for Test Groups. Training)

Hardware and software configuration of the UNCAP bundle to be delivered to the users (test group only) was defined according to the user needs defined at T0 and were

indicated in the "DCF for participant needs and UNCAP personalization". UNCAP configuration was defined with the support of engineering and technical personnel from the UNCAP project.

A period of system testing and users' training was planned to guarantee the correct usage of UNCAP hardware and software components.

5.3 T2 (Evaluation of UNCAP Acceptance and Starting of UNCAP Evaluation)

At the end of the testing and training period, primary end user (test group only) were asked to fill the questionnaire on "UNCAP perceived usability and user acceptance". They were also asked if they wanted to accept continuing the study or prefer exiting.

Before deploying the personalized UNCAP bundle at the primary user home or at the long-term facility where the primary user was hosted, a final optimization of the system was possible according to the environmental and structural context or other specific users' requirements.

Primary users and their ICG in the test group showing (at least partial) acceptance of the technology and willing to prosecute with the study used UNCAP bundle for a total of six months. Conversely, primary users and their ICG in the control group willing to prosecute with the study received the local standard of care for a total of six months.

5.4 T3 (Intermediate UNCAP Evaluation)

At T3 (three months after the start of the UNCAP evaluation period) both test and control groups of primary users were assessed with Atl@nte for obtaining their updated personal health profile.

The concern for falls of primary user in both test and control groups was re-assessed by administering the FES-I questionnaire.

Primary users and their ICGs in the test group used UNCAP bundle for the remaining three months before study completion while primary users in the control group received the local standard of care for the remaining three months before study completion.

5.5 T4 (End of the Evaluation Period)

At T4 (six months after the start of the UNCAP evaluation period) a set of data collection forms, questionnaires and open questions were filled/administered by each

user type at the end of the evaluation period. The following data collection forms and questionnaires were obtained for both test and control group users (except from differently indicated).

Primary user:

- Administration of questionnaire and narrative self-report form "Usability and Satisfaction EU" (only for EU test group)
- Administration of validated questionnaire "QoL-AD"
- Administration of structured questionnaire "General EP satisfaction"
- Administration of validated questionnaire "FES-I".

Informal caregivers:

- Administration of structured questionnaire "Usability and Satisfaction ICG" (only for EU test group)
- Administration of validated questionnaire "QoL-AD"
- Administration of validated questionnaire "SQLC"
- Administration of structured questionnaire "General ICG satisfaction"
- Administration of structured questionnaire "Impact".

Formal caregivers:

- Administration of questionnaire "Usability and Satisfaction FCG"
- Administration of structured questionnaire "General FCG satisfaction"
- Administration of structured questionnaire "Impact".

At both test and control groups of primary users were assessed with Atl@nte for obtaining their final personal health profile.

Once all questionnaires were filled and information were collected, participants were discharged from the study.

6 UNCAP Multidimensional Assessment

The evaluation of a complex bundle of assistive technologies is a not straightforward issue as it should provide evidence of safety and effect for a variety of needs elicited from several different users (primary end users, formal caregivers, informal caregivers).

Moreover, the impact of the adoption of such a technology in different settings (home care, residential care), requires the feedback from different stakeholders. Eventually, the developed technology has to be compliant with the legal and ethical framework, its use should be compatible with recommendations and existing guidelines and its introduction in the care system supported by a body of scientific evidences.

The evaluation process should be multifaceted and requires a well-defined framework to be pursued effectively and exhaustively.

Healthcare Technology Assessment (HTA) is the scientific methodology able to evaluate in a comprehensive way these technologies according to several different dimensions including safety, effectiveness, costs, impacts and more.

The assessment tools used in the study and above illustrated meet the requirements of a multidimensional assessment in accordance with the HTA methodology.

The "HTA Core Model" is the reference framework for the HTA methodology that has been delivered by the EUnetHTA European Project (http://www.eunethta.eu/hta-core- model) aiming at the universalization of the elements of an HTA evaluation. However, ICT applications for health present specific characteristics, in terms of reliability, accuracy, etc. compared with other medical devices, making the traditional "HTA Core Model" not easily applicable.

More recently, a new goal was reached in Telemedicine, defining the "Model for Assessment of Telemedicine" (MAST) (http://www.mast-model.info/) delivered by the MethoTelemed European Project. MAST re-adjusted the "HTA Core Model", identifying the following seven dimensions for the analysis of Telemedicine technologies:

- Health's problem and use of technology;
- Safety;
- Clinical effectiveness;
- Patient perspective;
- Economic aspects;
- Organizational aspects;
- Socio-cultural, ethical and legal aspects.

Noteworthy, the tools used for the UNCAP multidimensional assessment allowed to evaluate many of the dimensions required by MAST methodology (Table 5).

Table 5 Assessment tools used for UNCAP technology in accordance to MAST multidimensional assessment methodology (QoL-AD: quality of live Alzheimer disease [13]; FES-I: falls efficacy scale-international [24], SQLC: scale of quality of life of care-givers [11])

UNCAP assessment tool	MAST dimension
Systematic review Market analysis	Health problem and characteristics of the application
Clinical evaluation (according to MEDDEV. 2.7.1 rev.3) Adverse event reporting form (according to MEDDEV 2.7/3)	Safety
Systematic review of clinical literature Clinical evaluation INTERRAI assessment tools Validated questionnaires (QoL, FES-I)	Clinical effectiveness

(continued)

Table 5 (continued)

UNCAP assessment tool	MAST dimension
Users reporting forms and structured questionnaires (acceptability, usability, satisfaction)	Patient perspective
Structured questionnaire on impact	Economic aspects
Structured questionnaires for healthcare providers	Organizational aspects
Structured questionnaires and User reporting forms Validated questionnaires (SQLC)	Socio-cultural, ethical and legal aspects

7 Conclusions

In order to comply the forthcoming Regulation on Medical Device (2017/745 EU), CE marking of any innovative medical device based on ICTs should be supported by data on safety and effect. If required data could not be extrapolated from the existing literature, new clinical investigations should be realized. Moreover, a more comprehensive evaluation, covering also the economic and social impact for the introduction of a radically new technology is advised to support the adoption of new technology in the healthcare system.

This paper reported a possible framework for facing the complex issue of innovative technology assessment when indications for use include multiple users and settings as it is the case of ICTs developed for assisting the elderly with CI.

The UNCAP study was approved by all local ethic committees and results are available on the project web site (www.uncap.eu).

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References

1. Aloulou H, Mokhtari M, Tiberghien T et al (2013) Deployment of assistive living technology in a nursing home environment: methods and lessons learned. BMC Med Inform Decis Mak 13:42. https://doi.org/10.1186/1472-6947-13-42
2. Armstrong N, Nugent C, Moore G et at (2010) Using smartphones to address the needs of persons with Alzheimer's disease. Ann Telecommun 65:485–495
3. Bamidis PD, Fissler P, Papageorgiou SG et al (2015) Gains in cognition through combined cognitive and physical training: the role of training dosage and severity of neurocognitive disorder. Front Aging Neurosci 7:152. https://doi.org/10.3389/fnagi.2015.00152
4. Baruch J, Downs M, Baldwin C et al (2004) A case study in the use of technology to reassure and support a person with dementia. In Moriarty J (ed) Dementia. Innovative practice vol 3(3). SAGE Publications, USA, pp 371–392

5. Bharucha AJ, Anand V, Forlizzi J et al (2009) Intelligent assistive technology applications to dementia care: current capabilities, limitations, and future challenges. Am J Geriatr Psychiatr: Off J Am Assoc Geriatr Psychiatry 17:88–104. https://doi.org/10.1097/jgp.0b013e318187dde5
6. Boman IL, Persson AC, Bartfai A (2016) First steps in designing an all-in-one ICT-based device for persons with cognitive impairment: evaluation of the first mock-up. BMC Geriatr 16:61. https://doi.org/10.1186/s12877-016-0238-x
7. Bossen AL, Kim H, Williams KN et al (2015) Emerging roles for telemedicine and smart technologies in dementia care. Smart Homecare Technol Telehealth 3:49–57. https://doi.org/10.2147/shtt.s59500
8. Brodaty H, Green A (2002) Who cares for the carer? The often forgotten patient. Aust Fam Phys 31:833
9. Centers for Disease Control and Prevention (2013) The state of aging and health in America. http://www.cdc.gov/aging/help/dph-aging/state-aging-health.html
10. Cook DJ, Augusto JC, Jakkula VR (2009) Ambient intelligence: technologies, applications, and opportunities. Pervasive Mob Comput 5:277–298
11. Glozman JM, Bicheva KG, Fedorova NV (1998) Scale of Quality of Life of Care-Givers (SQLC). J Neurol 245:S39–S41
12. Lexis M, Everink I, van der Heide L, Spreeuwenberg M et al (2013) Activity monitoring technology to support homecare delivery to frail and psychogeriatric elderly persons living at home alone. Technol Disabil 25:189–197
13. Logsdon RG, Gibbons LE, McCurry SM et al (2002) Assessing quality of life in older adults with cognitive impairment. Psychosom Med 64:510–509
14. Medical mood ring (2004) Technology review. http://www.techreview.com/Biotech/13546/. 2007
15. Mihailidis A, Barbenel JC, Fernie GR (2004) The efficacy of an intelligent orthosis to facilitate handwashing by persons with moderate-to-severe dementia. Neuropsychol Rehabil 14:135–171
16. Monin J, Schulz R (2009) Interpersonal effects of suffering in older adult caregiver relationships. Psychol Aging 24:681–695
17. Pot AM, Willemse BM, Horjus S (2012) A pilot study on the use of tracking technology: feasibility, acceptability, and benefits for people in early stages of dementia and their informal caregivers. Aging Ment Health 16:127–134
18. Prince M, Jackson J (2009) International AD: world alzheimer report 2009. In: Alzheimer's disease international. http://www.alz.co.uk/research/files/WorldAlzheimerReport.pdf
19. Reisberg B, Ferris S, De Leon M, Crook T et al (1988) Global deterioration scale (GDS). Psychopharmacol Bull 24:661
20. Schulz RS, Sherwood PR (2008) Physical and mental health effects of family caregiving. Am J Nurs 108:23–27
21. Tadiran Life Care Aerotel Medical Systems (2007) http://www.tadlifecare.com/index.php?id=197
22. Tchalla AE, Lachal F, Cardinaud N et al (2013) Preventing and managing indoor falls with home-based technologies in mild and moderate Alzheimer's disease patients: pilot study in a community dwelling. Dement Geriatr Cogn Disord 36:251–261
23. Woods B, Aguirre E, Spector AE et al (2012) Cognitive stimulation to improve cognitive functioning in people with dementia. Cochrane Database Syst Rev 15:2 CD005562
24. Yardley L, Beyer N, Hauer K et al (2005) Development and initial validation of the Falls Efficacy Scale-International (FES-I). Age Ageing 34:614–619
25. Zarit S (2006) Assessment of family caregivers: a research perspective. Family Caregiver Alliance, San Francisco, CA