How Can Intelligent Conversational Agents Help? The Needs of Geriatric Patients and Their Caregivers

Gerhard W. Eschweiler
Geriatric Center at the University Hospital
University of Tübingen
Tübingen, Germany
gerhard.eschweiler@med.uni-tuebingen.de

Leo Wanner
Catalan Institute for Research and Advanced Studies and
University Pompeu Fabra
Barcelona, Spain
leo.wanner@upf.edu

ABSTRACT

The population in Europe grows older; only between the years 2007 and 2017 the number of people aged 65 and older increased by 2.4%. With the increasing age, the time that an average individual suffers from illnesses, loss of autonomy, deterioration of mental capacity, etc., and is thus in need of care in their old age also increased substantially. This calls for qualified care personnel. However, qualified personnel is scarce. To alleviate the situation, embodied conversational agents (ECAs) that are able to interact with care recipients, their carers and medical personnel would be a great asset – for instance, by acting as social companions, coaches or medical assistants. In any of these roles, ECAs must be guided by the needs of the targeted interaction partner and act within a well-defined strict ethical and legal framework. Especially the interaction with geriatric patients requires an acquaintance with the basics of geritatric medicine, its ethical aspects and the available models that help to assess them.

KEYWORDS

intelligent conversational agents, geriatric applications, communicative structure, thematicity, prosody, text-to-speech, human-machine interaction

1 INTRODUCTION

The population in Europe grows older. According to Eurostat, over the last decade (i.e., between the years 2007 and 2017), the number of people aged 65 and older increased by 2.4%.[1] On the one side, this is good news since this means that the expectancy of life of an average individual in Europe keeps growing. On the other side, old by no means always means healthy. In general, the time that an average individual suffers from illnesses, loss of autonomy, deterioration of mental capacity, etc., and is thus in need of care in their old age increased substantially. Thus, according to the German Federal Statistical Office, 2015 saw in Germany 2.6 million elderly in need of care; 1.86 million of them live in their own households. In UK, The Independent reports that "more than 1.4 million people over the age of 65 are struggling without the help they depend on to carry out basic tasks such as getting out of bed, going to the toilet and washing themselves".[2] This calls for qualified care giving personnel. However, qualified personnel is scarce. Currently, only in Germany, there is a shortage of tens of thousands of professional care givers. One consequence of this shortage has been the shift of the burden to informal caregivers, most of them family members, which often results in a physical, emotional or mental burnout. Another consequence has been a massive recruitment of affordable work force from (first of all) Eastern Europe, which bears qualification, language and cultural problems.

In the light of this situation, the exploration of alternative solutions seems inevitable. One of these solutions may be grounded in the use of intelligent agent technologies. A considerable amount of work has been done on the design and realization of intelligent embodied conversational agents (ECAs) that act as social companions of elderly. Overall, ECA companions can be attested a great potential from the technical viewpoint – even if they are still far from having the skills needed to assist elderly as humans do. However, there is also another challenge: in order for ECAs to be appropriate for social care, the researchers working in the field must know well the needs of elderly and their caregivers, i.e., have at least basic knowledge on basic care, gerontology and old age medicine, also termed "geriatric medicine", and the legal and ethical frameworks into which geriatric medicine is embedded. This is not always the case. This paper aims to introduce researchers working on ECAs into the specifics and needs of geriatric medicine. In Section 2, we outline the basic notions of geriatric medicine. In Section 3, we then introduce the needs of elderly and in Section 4 we discuss how ECAs could address these needs. Section 5, finally, presents some conclusions.

2 BACKGROUND

In this section, we present the basic characteristics of geriatric medicine and geriatric patients that will allow us to derive the needs of medical professionals and the care recipients alike and identify some of the central ethical concerns that must be taken into consideration when targeting solutions that shall address these needs.

2.1 Geriatric Patients and Geriatric Medicine

First of all: who is a "geriatric patient" and what makes them receptive for ECA services? Unfortunately, there is no generally accepted and used definition of the term. According to the Geriatrics Section of the European Union of Medical Specialists (UEMS, *Union Européenne des Médecins Spécialistes* in French), a geriatric patient is mostly older than 70 years and suffers from multiple active disorders. We can adopt this definition as our working definition.

A dedicated branch of medicine, namely the geriatric medicine, focuses on geriatric patients. The UEMS definition of geriatric

[1] https://ec.europa.eu/eurostat/statistics-explained/index.php/Population_structure_and_ageing#The_share_of_elderly_people_continues_to_increase
[2] Independent, 9 July 2018 "Number of elderly people deprived of vital support hits record high, finds report"

medicine was coined in 2008.[3] Geriatric medicine is a specialty of medicine concerned with physical, mental, functional and social conditions in acute, chronic, rehabilitative, preventive, and end-of-life care in older patients. This group of patients is considered to have a high degree of frailty and active multiple pathologies, which requires a holistic approach. Geriatric medicine therefore exceeds organ-orientated medicine like cardiology or urology. It offers additional therapy in a multidisciplinary team setting, the main aim of which is to optimize the functional status of the older person and improve the quality of their life and their autonomy. The multidisciplinary team includes not only physicians and nurses, but also physiotherapists, speech therapists, social workers, etc., in order to address the mentioned frailty and multiple pathology of geriatric patients. Frailty implies a combination of at least three out of the following five symptoms, whose phenotype is a vulnerable person with a lack of resources to compensate stress, acute infections or injuries [31]:

(i) involuntary weight loss (over 10% in one year);
(ii) objectified muscle weakness (determined by manual force measurement in terms of a hand grip[4]), loss of muscle mass (sarcopenia), or osteoporosis (bone loss), often followed by fractures, falls and immobility;
(iii) subjective (mental, emotional, or physical) exhaustion;
(iv) immobility, instability, gait and stance with fall prone;
(v) decreased physical activity (in terms of basic and/ or instrumental activities of daily living (ADLs)).

The aim of the geriatric medicine with respect to frailty is threefold: (i) prevention of frailty, (ii) assessment of the degree of frailty, and (iii) treatment of the frailty aspects. Multiple pathology may include somatic pathologies and mental pathologies. The somatic pathologies may be manifold and the same as those from which other patients may suffer, although geriatric patients over-proportionally suffer from acute vascular events such as a myocardial infarction and stroke. Patients suffering from heart failure might lose their ability to climb steps or to walk longer distances; patients suffering from a stroke might suffer from impairments in reading or speaking (cf. aphasia).

Two of the main mental pathologies in elderly that are not related to vascular events are Parkinson disease and dementia of Alzheimer-type, caused by the loss of distinct neurons in the brain. The Parkinson disease[5] is a neurodegenerative disorder which has as typical symptoms slowness of movements (bradykinesia), an increased muscle stiffness (rigor), decreased mimic movements (hypomimia), and instability when standing (postural instability) or starting to walk. Most patients suffer early on from loss of smell, obstipation and nightmares or restless legs before they show the motoric symptoms since neuronal degeneration starts in vegetative nerves before motoric signs are present. For more details, see [11].

Dementia is a clinical syndrome, defined worldwide in the ICD 10 (The international classification of disorders 10th Revision, by the WHO)[6] as a progressive cognitive decline caused by a pathological process in the brain. The cognitive decline continues at least for six months and causes a loss of ability to manage the ADLs without support or help. About 70% of dementia is related to the Alzheimer Disorder (AD), which is caused by neurodegeneration of cortical synaptic connections, neurons, and deposition of Amyloid plaques and neurofibrillary tangles. This cortical degeneration first affects the encoding of memories and later the loss of semantic knowledge about locations, persons, tools and complex tasks [6]. Mild and moderate dementia may also show a number of non-cognitive symptoms that equally need to be assessed for better treatment and care of the patient, among them, in particular: (i) problematic (e.g., repetitive asking, crying or wandering about) and aggressive (e.g., spitting at or beating of fellow citizens) behavior, (ii) depression, (iii) reduced quality of life, (iv) paranoid thinking like feeling of being robbed, and (v) limited ADLs.

2.2 The Scope of Geriatric Medicine

Geriatric medicine does not only focus on the treatment of the diseases of geriatric patients; it is also concerned with the prevention of typical geriatric diseases. A number of studies show that physical and cognitive activities are crucial in the context of this prevention. Thus, a recent epidemiological study from Japan revealed that physically active subjects who walk more than one hour per day have a 28% lower risk to develop dementia, compared to subjects walking less than 30 minutes per day, even if the latter are monitored with respect to age-related symptoms, body mass index or stroke indicators [27]. In a larger study with more than 11,000 Japanese subjects, the risk of functional impairments was measured after a follow-up of nine years for three activities: (i) cognitive activity, (ii) walking, and (iii) social activities. Models of the estimated mediating effects showed that cognitive activity accounted for 9.3%, time spent walking for 8.3%, psychological state for 4.6%, and social support for 2.8% of the reduced risk of incident functional disability [21].

An additional important factor appears to be body weight. According to a study by Norton et al. [20], a reduction in obesity prevalence and thus diabetes prevalence in the mid-age reduces dementia prevalence by more than 10%.

In general, recommendations for physical, cognitive and social activities are found in all medical guidelines. These recommendations are buttressed by cohort studies. The gold standard is however provided not by cohort studies, but, rather, by forward-looking randomized controlled trials (RCTs). Recently, the FINGER study showed prospectively in an RCT that multimodal lifestyle interventions in Finland, including healthy diet, physical exercises and mental activities, were able to delay cognitive decline with moderate effect only [19]. Unfortunately, RCTs are expensive and thus rare.

2.3 Ethical Aspects in Geriatric Medicine

The importance of ethics in geriatric medicine requires a clear definition of the ethical requirements towards each individual solution and mechanisms for the control of the fulfilment of these requirements at the time of the implementation.

[3] http://uemsgeriatricmedicine.org/www/land/definition/english.asp#, last access on 2018-07-12.
[4] Hand grip depends also on motivation, but has real impact on the activities of daily living (ADLs) like to cut a piece of meat or to carry a bag.
[5] For the first time described in 1817 by the English physician James Parkinson.
[6] http://apps.who.int/classifications/icd10/browse/2016/en

2.3.1 Ethical requirements towards solutions in geriatric medicine. Geriatric medicine, including home and social care of elderly, deals with personal data and privacy of vulnerable persons, which must be protected from disclosure and misuse. Therefore, the European and member state legislations have implemented strict ethical data safety guidelines that must be followed by both humans and machines. For ECAs and ECA-related research, these guidelines are of special relevance since they need to "know" the elderly with whom they interact and whose momentary emotional and mental state they perceive. Only then will they be able to act as personal assistants in a way one would expect from a human caregiver. However, this presupposes, on the one hand, access to personal data such as age, gender, disorders, handicaps, family status, cultural and social environment, etc., and, on the other hand, perception and analysis of mimics, gestures, and voice during the interaction. Furthermore, to "have a memory", an agent must be able to access the history of previous interactions, health and mood conditions of the elderly and other relevant data, while due to better performance, easier maintenance, accessibility and other technical criteria, many services, including agents, are nowadays cloud-based. Technical solutions that store and process personal data must thus ensure data protection and give the users the choice to agree to the sharing of their data to an extent that will depend on the type of assistance they desire. In particular, ethical guidelines must be followed that foresee that any subject must, for instance, be fully aware about the nature and volume of their personal data that an agent acquires during the interaction or accesses prior to interaction and give an informed consent to the acquisition and use of their personal data. In case of advanced dementia, informed consent can only be given by a legal guardian, as patients suffering from moderate, let alone severe, dementia are not able to give informed consent. Therefore, the first question for a researcher working on the development of ECAs for elderly should be: "Does my ECA research really need patients with dementia or could also cognitively fit or only mildly impaired elderly be addressed as users?"

It is to be noted that if the ECA is an CE-approved medical product, it can only be used in its specific indication for patients with specific diagnoses listed in the ICD-10 (international classification of disorders) and cannot be applied in another medical diagnostic field since this would be "off-label", which means that a doctor would need to document very carefully the reasons why he or she uses the ECA or the medical product outside its diagnosis-related indication.

It is also to be kept in mind that in 2020 the risk categories for software applications as medical products will be further detailed.

2.3.2 Assessment of the ethical standards of a technical solution. The goal of any ECA (as of any virtual assistant) in the context of geriatrics should be, firstly, to provide better care of elderly, but, secondly, also to secure their empowerment and social engagement in order to avoid the risk that they become dependent from an expensive technology, impoverish or even lose their social life. That is, ECAs should target to:

- increase quality of life of the subjects;
- protect human dignity at any age;
- enable autonomy and participation.

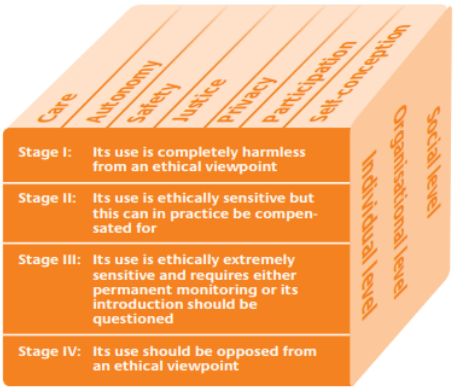

Figure 1: The MEESTAR model (from https://www.nks-mtidw.de/dokumente/meestar-studie-englisch)

But by no means should a technology attempt to substitute human care. The decisions concerning the design and functionality of an ECA are thus also moral decisions and require an assessment from this viewpoint. A framework is therefore needed for the assessment of the ethical standards of these decisions. The MEESTAR model [14, 30] illustrated in Figure 1,[7] which was developed for the assessment of Ambient Assisted Living solutions, but which can be readily applied to assistance systems in geriatrics as well, is such a framework. MEESTAR foresees four different outcomes of the assessment: (i) the solution is unproblematic; (ii) the solution is critical from the ethical perspective, but the critical aspects can be addressed in the practical application; (iii) the solution is ethically very problematic and needs to be permanently monitored or completely abandoned; and (iv) the solution is to be rejected from the ethical perspective. The assessment is to be carried out along seven ethical dimensions: care, autonomy, safety, justice, privacy, participation, and self-conception at the social, organizational or individual levels. Let us, in what follows, briefly interpret the description of these seven dimensions provided in [14] from the viewpoint of an ECA, without going into the detail of the levels.[8]

In accordance with Manzeschke [14], the evaluation of the care dimension must assess whether (and if yes, to what extent) an ECA negatively influences the self-conception of a subject and/or their relationship to the external world and whether it creates a dependency or limits the freedom of decision (assuming "a patronizing or negatively paternalistic" role). In the context of the autonomy dimension, we must assess whether the appropriate balance is kept between the right of an individual to autonomy, the fact that an individual's criteria concerning autonomous decision making and acting may have become questionable or even untenable, and the right of an individual to care and support.

The safety dimension concerns the security and self-confidence of an individual and the role of the ECA in it. It thus assesses whether the intervention of the ECA can lead to a more passive

[7] 'MEESTAR' stands for "Modell zur ethischen Evaluierung sozio-technischer Arrangements" 'Model for ethical evaluation of socio-technical arrangements'.
[8] https://www.nks-mtidw.de/infomaterial/ethische-fragen-im-bereich-altersgerechter-assistenzsysteme

stance of an individual in the sense that they delegate some tasks whose execution is beneficiary to them, to a subjective feeling of safety without objectively increasing safety, or whether the contribution of the ECA to the safety of an individual interferes with privacy or autonomy.

The privacy dimension shall assess whether an ECA records visual and audio information during interactions in intimate contexts (e.g., bedroom, bathroom, dressing room, etc.) and thus may violate the personal sphere or offend the honor of an individual such that the individual may feel ashamed or humiliated. Dignity is very important. Most subjects do not accept video monitoring or recording in rooms in which they might be exposed – even for fall detection.

The justice dimension shall assess whether the access to the services of the ECA is fair and in accordance with age-related services. Furthermore, it is concerned with the cost distribution of the services and the question on the responsibility assigned, e.g., to the care taker and to the social insurance.

In the context of the participation dimension, we need to assess to what extent the services of the ECA in question facilitate (or impede) an active participation of older persons in the working and social life and whether the kind of participation promoted by the ECA is in accordance with the personal preferences of the individual.

The self-conception dimension, finally, reflects on the personal and social constraints that an ECA and its services impose on an individual and, related to this, to what extent the ECA is personalized, i.e., takes the personal preferences and needs of an individual into account, instead of addressing standardized default user profiles.

Other ethically relevant questions that are not directly subsumed under the above seven dimensions concern, for instance, the accuracy and quality of the services (e.g., information, recommendations, instructions, etc.) of an ECA. An ECA is composed of several software modules, each of which can fail to a certain degree. Consider, for instance, speech recognition or reasoning over the statement of a user, where, e.g., unclear pronunciation (e.g., due to a poorly fitting denture) or use of irony can lead to misunderstandings and thus wrong reactions. The question on the liability thus comes up in case the ECA provides wrong information, misjudges the obtained information and symptoms obtained from the user, or fails to detect changes in the addressed health conditions of the user. Any of these failures may result in expensive and/or invasive procedures, with serious consequences for the user.

There are also several issues of data safety and legal aspects in the interaction of humans with ECAs. Thus, when an elderly individual develops a deep immersion experience with the ECA, they tend to share personal information about other individuals (relatives, friends, neighbors, etc.). This information may be of private nature (and thus violate their privacy) or apt to damage a third party's reputation.

3 BASIC NEEDS IN GERIATRIC MEDICINE

The health issues of elderly sketched in Section 2.1 give us some hints on the needs of all three involved parties: geriatric patients, care givers and medical personnel. In this section, we summarize these needs in general terms, without having in mind ECAs as an instrument that may address these needs. In Section 4 we assess then which of these needs can be, in fact, satisfied by ECAs.

3.1 Needs of Geriatric Patients

According to Section 2.1, the needs of geriatric patients revolve around frailty and handicaps (both somatic and mental). In the context of frailty, the patient is helped by an accurate assessment of the degree of their frailty with respect to all five symptoms listed in Section Section 2.1, as well as by support of the prevention and treatment of the determined frailty. The degree of frailty is often captured in terms of a "frailty index". A number of frailty indices (FIs) are known from the literature; cf., e.g., [4, 13, 26]. One of the most influential FIs is the Barthel Index, which measures the functional capacity of an individual on a 100 point scale in ten predefined Activities of Daily Living (ADLs) [12], which include, among others, help needed with grooming, toilet use, feeding, etc. More recent indices, such as the Frailty score from the European SHARE-Study [25], CSHA [24], and FI-VIG [1] go beyond the ADLs. For instance, the FI-VIG index also covers Instrumental Activities of Daily Living (IADLs), which target the capacity of an individual to manage money and medication and use the telephone, as well as the cognitive, emotional, social, nutritional, etc. capacities, which cover all five frailty symptoms listed in Section 2.1. The capacity of an individual with respect to a specific activity and the individual's frailty symptoms are assessed, as a rule, manually by medical and care specialists.

To prevent and/or reduce frailty, targeted exercises and healthy diet are recommended. The exercises and diet depend on the health condition of a person and should thus be proven by a medical specialist.

The needs of elderly with respect to their somatic disorders are not that different from the needs of other patients, although intense medical assistance may be required due to the susceptibility of elderly, for instance, to acute vascular events; see Section 2.1. In the case of Parkinson Disease, as one of the main mental pathologies from which elderly may suffer, medication and physiotherapy are of outmost importance. In the case of dementia (the other main mental pathology by which elderly may be affected), medication may also be needed to treat, in particular, non-cognitive symptoms, but personalized care is the key.

In general, (basic) care is of high relevance to the majority of elderly, as is social companionship. It is crucial for elderly to have someone to talk, to exchange memories and information (e.g., about places, times, people, etc.). Cognitive stimuli are also crucial. For instance, often elderly love to solve crossword puzzles or Sudoku. Bingo is also very attractive; in addition, Bingo has the advantage to train attention and reaction time, which are impaired most during aging. Curiosity for new technological devices might be a good indicator for mental health. However, no generalization is possible; each individual has their own preferences and their own needs.

3.2 Needs of Caregivers

The needs of professional and informal caregivers and thus also the way in which ECAs can support them are rather different. Let us, therefore, discuss them separately.

3.2.1 Needs of professional caregivers. As pointed out in the Introduction, there is a significant shortage of professional caregivers. Apart from an increased involvement of informal caregivers (discussed in the next subsection), this leads, on the one hand, to an increased recruitment of less qualified personnel (often with language barriers), and, on the other hand, to a higher workload of the well-formed caregiver personnel. To ease the pressure of the higher workload, caregivers often ask for simplification of the obligatory documentation in the care record of the health conditions of each care recipient and the procedures they carry out on them (such as washing, dressing, changing bandages, etc.).

The needs of ad hoc recruited less qualified personnel may be of different kinds, for instance: (i) to be coached with respect to basic care tasks and potentially also handling of the basic care equipment; (ii) in case of a language barrier, to receive support in the language of the caretaker; and (iii) to be informed about the needs, preferences, etc. of the caretaker.

3.2.2 Needs of informal Caregivers. Informal caregivers involved in care of geriatric patients are in their vast majority family members. In a recent study, in which 122 family members were interviewed with respect to the main negative personal consequences of the care of someone from their family (in this case, a patient who suffered an acute stroke), the distribution of the main worries was as follows; cf., [22]:

(1) not to have enough time for own needs and interests (57%);
(2) suffer from sleep disturbances (38%);
(3) feel tired and have no energy (34%);
(4) have an irritated and aggressive relationship with the partner (34%);
(5) miss common activities (with the partner) outside the house (30%);
(6) be responsible for paperwork and finances (29%);
(7) be afraid that something bad will happen (24%).

To support informal caregivers, in this study a telephone-based counseling service was implemented as a randomized controlled trial. However, this service resulted in no significant benefits compared to a control group without counselling. On the other hand, in the recent TABLU project,[9] a tablet-based prototype for informal caregivers has been developed and evaluated. The prototype contains four modules: (1) introductory training course for care, (2) video library of care, (3) written contact, and (4) video phone conversations with a professional caregiver. The modules 2, 3, and 4 have been positively tested by 41 caregivers, selected among more than 600 candidates, for up to 6 months. An online video from module 2 on principles of mobility[10] has been furthermore watched more than 48,000 times, which can be also interpreted as a positive evaluation outcome.

Overall, it is to be noticed that many problems perceived by caregivers are situated at a psychological level (as 3, 5, and 7 above) or cannot be solved (as, e.g., 1 or 2) by technological devices because the caregiver feels exclusively responsible for the care recipient. The acceptance of facts or circumstances which cannot be changed is a very helpful strategy to maintain emotional wellbeing despite increasing impairments and handicaps in old age.

[9]TABLU: Technological Systems of Assistance Enable Independent Living, sponsored by the German BMBF (http://www.tablu.de/index.html).
[10]https://www.youtube.com/watch?v=Qrttx1j6EUI

3.3 Needs of Medical Personnel

While the European legislation and ethical guidelines practically exclude the delegation of diagnoses or treatment of diseases to intelligent agents, such agents can provide assistance to medical specialists as intelligent symptom assessment instruments whose outcome can be then used by specialists for diagnoses respectively treatment, with the general goal to support the compression of morbidity to the last months before death beyond the late 80s or 90s of many subjects [8]. Such an assessment can be time consuming and medical specialists are always short of time. The needs of geriatric specialists with respect to symptom assessment cover the whole spectrum of characteristics and symptoms of geriatric patients. To begin with, there is the assessment of frailty, which is essential to obtain a general picture of the conditions of an elderly.

Geriatric specialists also routinely test elderly with respect to early symptoms of Parkinson disease and cognitive impairments, which may be related to Alzheimer's and other types of dementia. These tests are time consuming, but cannot be delegated to, e.g., nurses since they require experience and profound expert knowledge. For instance, the most common cognitive impairment tests are the paper- and pen-bound tests such as the Mini-mental State Examination (MMSE) by Folstein et al. [7] or the clock drawing test, which take less than 10 minutes. But there are also more elaborated tests that also cover attention and executive domains like the MoCA (Montreal cognitive assessment) [18], which takes more than 10 minutes and can be done, again, only by trained assessors.

In addition to the aim to identify as early as possible early symptoms of cognitive impairment, its prevention is a central issue in geriatric medicine – in particular, because causal therapies of such diseases as Alzheimer's are still out of sight for the next years. As pointed out in Section 2.2, a recent FINGER study in Finland shows that multimodal lifestyle interventions, including healthy nutrition, exercise and mental activity were able to moderately delay cognitive decline. Some aspects have been shown to be of higher relevance. For instance, control of obesity is a major topic as overweight patients suffering from diabetes mellitus have a significantly increased risk of developing dementia, both with Alzheimer's pathology or of the vascular type [5]. Unfortunately, such lifestyle interventions are not easy to implement since each individual has their own experience in life style changes. It requires a strong motivation and/or acute psychological strain, as it is given following a stroke or a heart attack. This might be a "teachable moment" which increases plasticity to new habits or new technologies (like tread mills or activity trackers and calories counting devices).

4 HOW CAN ECAS ADDRESS THE NEEDS?

Let us now examine how ECAs can address the needs of the different parties involved in geriatric care.

4.1 ECAs and the needs of geriatric patients

The general rule is that geriatric patients want to be treated with respect and the same effort as younger subjects, even if they are slower in getting familiar with digital devices and the terminology

of the digital community.[11] However, in contrast to the other two types of users of ECAs (i.e., caregivers[12] and medical personnel), when addressing geriatric patients, close attention must be paid to the design of the avatar that embodies the ECA.

4.1.1 Design of the avatar. Since the current generation of elderly is still not familiar with PCs, tablets and smart phones, the interaction of the ECAs with them should most appropriately be speech-based. In the context of all applications, the design of the avatar that embodies the ECA is crucial. In its default mood, it should have a friendly, sympathetic appearance.[13] The cultural, social and age/gender related features of the appearance should reflect the personal preferences of the elderly and thus be personalized. However, the observation of the design guidelines might still not be sufficient. ECAs have been proposed as a natural computer interface for humans, which should be easy to understand by humans who are not familiar with computer programs or computer devices. But it might be difficult for an elderly to communicate with an ECA, as most elderly are not familiar with human-like but not yet human faces, mimics, gestures and voices of an avatar. If the ECA is designed to resemble as much as possible a human, its acceptance might be below the expectance. The sensation of an elderly might be in the "uncanny valley" [16] since they might not be sure whether the ECA or robot they are looking at and talking to is a real person or an artificial agent.

From a neurobiological point of view, it has been demonstrated that young Japanese subjects show different brain activation patterns during a repeated interactive display of an android, robot and human. Violation of the expected norm could be measured by fMRI and by N400 waves in the EEG. The key assumption is that brain activity is higher for a stimulus that does not coincide with an expected (or predicted) norm or that is not explained by a generative neural model of the external causes for sensory states [9]. Recent studies buttress the hypothesis that the "uncanny valley" could be explained by the violation of the assumption what is human. They have measured different N400 brain waves in congruent human-like movements of a real human, a mechanical robot, and a realistic robot [28].

In a very recent study that used pupillometry, the uncanny valley has been confirmed via the pupillary reaction of young subjects during their confrontation with robotic and human emotions: when confronted with "uncanny" robots, their pupils were less dilated than when confronted with more human-like robots [23]. Although there are no data available for seniors or patients suffering from cognitive impairment,[14] the uncanny valley might be wider in older persons than in younger persons, reaching extremes in cognitive impaired or in paranoid subjects, as some of them suffer from propasognosia, i.e., inability to identify faces, or even have the delusion that a familiar person has been replaced by an identical impostor (cf. the mention of the Capgras-Syndrome in Section 4.1.2).

4.1.2 Tasks of the ECAs. Ethical concerns currently prevent the involvement of ECAs in such sensitive care tasks as identification of reasons for indisposition and taking measures against it, or daily medication intake control. We see the role of the ECAs in interaction with geriatric patients, first of all, as social companions. They should intervene to animate elderly to engage in physical and social activities and stimulate them cognitively in order to make them abandon their physical and mental comfort zone (such as passive movie watching and other passive entertainments) and thus stay physically and mentally active.

In these interventions, ECAs can act as intelligent sensor devices that support the subject in their interaction with the environment in case of sensory disabilities and/or as a social companion. Consider, for instance, age-related macular degeneration (AMD). AMD is the leading cause of central blindness or low vision among the elderly in industrialized countries [3]. Patients suffering from AMD are often not able to read written material without expensive reading aids. ECAs might help centrally blind persons by reading aloud the newspaper after the user has read aloud the headline of the article or the death announcement in the local newspaper. Patients with glaucoma also have problems to see obstacles in the periphery of their vision and need guiding systems with optical landmarks or feedback by vibrations or sound, which might be monitored by an ECA with optical sensors, in analogy to a guide dog.

Some patients suffering from Alzheimer's disease and related dementias (ADRD) have serious problems in recognizing faces. They might become unable to recognize the partner or even their children. Patients suffering from this condition, referred to as "Capgras syndrome" [2], develop paranoia or confusion about their own identity. The consequence is a tremendous stress in patients and also in caregivers. In this case, an ECA should not have a humanoid face as this might even worsen the condition. A familiar voice (e.g., of a known radio speaker) might be more helpful to provide serious and personalized information. However, to the best of our knowledge, there are no experiences so far with subjects suffering from the Capgras syndrome in ECA or AAL settings.

In its role of a social companion, the ECA could suggest specific social or cultural activities, offer news on specific topics, recommend diets, etc. and conduct small talk on topics known to be of interest to the patient. The ECA can be also of use to alleviate the sensation of loneliness, which elderly often perceive as a very negative condition. The feeling of loneliness may come up when a patient objectively lacks company or when they do not receive the attention they claim from their social environment. For instance, in the case of moderate (or even mild) dementia, patients tend to talk again and again about the same events of the past (behavior referred to as "perseveration") that left a deep impression in them, which may lead to a negative reaction of their conversation partners. ECAs may be very "patient listeners", as dogs and cats are. Their role could consist in dedicated affirmative reactions that encourage the patient to continue with their story.

In all of these tasks, personalization is crucial. The ECA should be knowledgeable about the personal characteristics and preferences of the patient and also take the reaction of the patient in previous interactions for future interactions into account. Obviously, this implies the consideration of data privacy and data protection issues, both of the patients themselves and of the individuals who might be

[11] This has consequences for the formulation of the informed consent to be signed by subjects in experiments with ECAs.
[12] In the case of relatives of geriatric patients as caregivers, the design of the avatar may also be of relevance.
[13] As verified in the KRISTINA project http://kristina-project.eu/en/, the subjects are very sensitive to "unnatural" or inappropriately serious facial expressions of an avatar.
[14] Importantly, our results imply that the mechanisms underlying the perception of other individuals are predictive in their nature.

mentioned or commented upon in the conversations. This concerns, in particular, family members, friends, neighbors, etc., who might see themselves exposed to public. In any case, an ECA should first build up trust by providing serious and reliable information, before it begins to intervene in the personal life of a subject. The first steps in the interaction of elderly with the ECA should be supervised by an expert. The time of assistance by an expert can be reduced to nearly zero within weeks or substituted by a technology affine relative.

Apart from "classical" geriatric rehabilitation at rehabilitation hospitals or on outpatient basis, serious gaming and networks of humans in change of life style might be a target of ECAs and smart technologies in general. It is still under debate whether older patients will be willing and able to also join those virtual communities. Experimental setups will be needed to obtain a clearer view in this respect.

4.2 ECAs and the needs of caregivers

In accordance with the differentiation of the needs of professional and informal caregivers, the involvement of ECAs may be also different.

4.2.1 Professional caregivers. ECAs can be of use to both, the less qualified and the overstrained qualified care personnel. For the first, an ECA could serve as a coach and intermediator. As a coach, it can train the caregiver in the basic care procedures (including, e.g., washing, bandaging, erecting, etc.), the use of medical or supportive devices, practices of interaction with care recipients, etc. This can be done in terms of interactive demonstrations, monitoring and correction, and/or guidance. ECAs can also search for relevant material in the web and offer to care personnel a summary of it – as is done by the KRISTINA agent for Alzheimer's related multilingual information [29].

As intermediator, an ECA can provide to the caregiver the personal dietary, social, or daily life routine preferences of a care recipient, their health conditions, medication, etc. In case of language barriers, advanced ECAs can also serve as interpreters. Migration is a big issue in the EU. For instance, in Germany less trained caregivers come from Poland and Romania; they are not familiar with the regional language, the habits or dishes. Multilingual ECAs might bridge the language barriers.

For overstrained qualified care personnel, an ECA can also assume some routine communication tasks with the patient and also act as provision instance of information related to the patient, obtained, e.g., in interaction with family members or with the patient themselves. Certain health-related information (such as, e.g., body temperature, heart rate, number of made steps, etc.) is more reliably obtained using sensors, rather than in a verbal conversation with the patient. For this purpose, bio sensor data need be provided to the knowledge processing module of the ECA. In any case, if ECAs are deployed to assist care personnel, they should not be perceived as controllers or surveillants. Most of care personnel object to be tracked by their companies and employers.

4.2.2 Informal caregivers. Empowerment of informal caregivers should be a central goal of tools and digital devices like ECAs since, as already pointed out above, they bear a significant share of the workload related to geriatric care.

Informal caregivers may profit from the same coaching functions of an ECA as discussed above in Section 4.2.1. In addition, when ECAs exercise their role of a social companion of a care recipient, they also help to mitigate one of the most negative consequences from which informal caregivers suffer, namely not to have enough time for own needs and interests (cf. Section 3.2.2).

4.3 Supporting medical personnel

Intelligent agents, including ECAs, can support medical personnel in the context of geriatric medicine first of all in tasks related to patient monitoring and health condition assessment. For instance, the five frailty symptoms presented in Section 2 can be controlled by an agent:

(i) involuntary weight loss can be measured and protocolled using standard procedures like scales;
(ii) objectified muscle weakness, loss of muscle mass and strength can be measured by pressure sensors on smart objects in households, such as, e.g., a roller shutter belt or a window handle;
(iii) subjective exhaustion can be asked about by an ECA or derived from changes of speech loudness and speed, pitch of the voice, mimics or gestures;
(iv) immobility, instability, and fall-prone gait and posture can be assessed by balancing in a virtual environment rather than in standard clinical environments that check the ability and duration of semi-tandem standing with open and closed eyes;
(v) decreased physical activity (in terms of basic and / or instrumental everyday activities) can be, again, inquired in interviews led by an ECA or be measured by digital activity trackers such as smart watches or by movement integration in ECAs.

ECAs can be also help in the diagnosis of age-related diseases. Thus, early symptoms of Parkinson include reduced perception and distinction of odors and disturbed sleep. Agents could carry out odor exposure tests and track sleep parameters by smart sensors.

The Aachener Aphasie Test (AAT)[15] is the standard assessment tool in Germany for the diagnosis of aphasia (which is a wide-spread phenomenon after a stroke, more prevalent in elderly), but it can only be performed by skilled speech therapists, psychologists or neuro-linguists. As recently shown by K$\acute{}$onig *et al.* [10], artificial intelligence can help to interpret the semantic verbal fluency (SVT) in a quick and efficient way. In this work, automatically extracted clusters and switches were highly correlated in SVT with manually established values and could separate healthy controls and patients with probable Alzheimer's dementia and with mild cognitive impairment with a good area under the curve (AUC) of 0,94 for healthy controls (HC) compared with subjects with – Alzheimer dementia (AD) and less between HC – and subjects suffering from mild cognitive impairment (MCI) AUC of 0,76.

Furthermore, ECAs can be supportive in the assessment of cognitive impairment, which is nowadays measured by neuropsychological screening and assessment tools. For instance, recent studies (cf.

[15] https://www.testzentrale.de/shop/aachener-aphasie-test.htm

[17]) showed that when the "classical" clock drawing test (cf. Section 2) is done on a tablet with an "active" pen, it offers additional information. Thus, the time in air before the subjects draw the digits and the hands is significantly longer in subjects with mild cognitive impairment compared to healthy control persons, as they hesitate to set the pen to the surface. This hesitation cannot be monitored by the "classical" paper and pen version of the clock drawing task. There is a huge potential in pen-based digital cognitive testing, especially if an agent is able to classify the performance and save valuable time for nurse and physicians.

As speech is early affected in several types of dementia and also in major depression, there are several quick tests such as the phonematic and semantic verbal fluency tasks, which count the number of correct words starting, e.g., with 'M' (phonematic) or all animals (semantic) a subject can give within a minute. But there is much more information in such a spoken row of words, which can be controlled by intelligent technologies: animals can be categorized by their frequency from very frequent like dog to infrequent like grasshopper. The speed of speech and the number of hesitation markers (such as *ummm*...and *aeh*...), repetitions, restarts, etc. also give information on the verbal abilities of the speaker. ECAs could be programmed to apply geriatric assessment tools and questions of different aspects:

(i) for depressive symptoms: geriatric depression scale (GDS),
(ii) for quality of life: quality of life in Alzheimers disease,
(iii) for cognition: mini mental state examination (MMSE), and
(iv) for ADL/ IADL: Katz activities of daily living and Lawton instrumental activities of daily living,
(v) For detection of problematic and aggressive behavior in the case of mild and moderate dementia, the revised memory and behavior problem checklist (RMBPC).

Besides easy and quick assessments, the transfer of this information into adequate care and medical procedures is essential for dementia-friendly hospitals and cities. A study from T́ubingen has shown that visual rehabilitation with reading training is beneficiary to seniors suffering from macula (retinal spot of best visual acuity) degeneration; it also improved their impaired mood [15]. Such a visual rehabilitation could also be coached by an ECA which displays the reading material, assesses the reading and gives feedback on improvements in reading speed and pronunciation.

5 CONCLUSIONS

Our aging society faces a continuously growing number of geriatric patients and an increasing shortage of professional and informal caregivers. No reversion of this tendency can be expected in the near future. This calls for intelligent technologies such as ECAs as part of the solution. However, no off-the-shelf ECA will work. ECAs have to be adapted to the special needs of elderly. Firstly, we must be aware about the heterogeneity of elderly from fit, to pre-frail and frail subjects. Apart from physical differences among elderly mental changes from cognitively fit to mild cognitive impairment and dementia occur. This decline separates subjects who can give informed consent and can adapt to new types of interaction from subjects in need of guardians and caregivers. Only the first group of subjects should be addressed by ECAs. However, in the case of this group , we must keep in mind that ECAs cannot be a fully-fledged substitute for human-to-human interaction, which is essential to elderly to overcome loneliness and cognitive and emotional decline; ECAs can only act as complementary assistants. As assistants they can be also be of use in different scenarios to caregivers and medical professionals that can be situated in private households, care homes or hospitals.

No matter which role an ECA assumes data security and privacy but also compatibility with care records is crucial. The user must own their data and be able to define which data are private and can be only shared with relatives, which data can be shared with medical and care professionals and which data can be made public. With the Digital Single Market Law "Communication on enabling the digital transformation of health and care in the Digital Single Market; empowering citizens and building a healthier society" from 25 April2018,[16] the European Commission provided a legal fundament for the use of ECAs in the geriatric context.

Recent initiatives such as the SOLID project[17] launched by T. Berners-Lee furthermore indicate solutions to the challenge of the storage and use of private data. As Berners-Lee writes in his open letter on Sept 28th 2018: "It gives every user a choice about where data is stored, which specific people and groups can access select elements, and which apps you use. It allows you, your family and colleagues, to link and share data with anyone".[18]

Finally, with the increasing maturity of ECAs, the opportunities for their successful commercialization in the geriatric sector (and in the health sector in general) also grow. Business models should be versatile and adaptive. A personalized entertainer, an interpreter of a caregiver from another culture, a promoter of healthy food with expertise in regional recipes, an innovative neuropsychological assessment assistant, or a life quality and health conditions monitoring device – all of them are potentially successful applications.

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