Review

Improving wellbeing of community-dwelling people with mild cognitive impairment: the SENIOR (SystEm of Nudge theory based ICT applications for OldeR citizens) project

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Abstract

Population aging with longer life expectancy represents one of the most relevant challenges of the next future, also because of a significant proportion of older adult people may present with dementia. Motivating senior citizens with mild cognitive impairment to maintain their independence and functional abilities, improve health status and quality of life as well as social interactions, constitutes the main target of preventive medicine. According to a nudge theoretical approach, the SENIOR (SystEm of Nudge theory based ICT applications for OldeR citizens) project— developed thanks to the collaboration among Catholic University of the Sacred Heart, Bicocca University and IRCCS Auxiologico Institute in Milan (Italy) — has been designed to adopt an advanced information and communication technology coaching system able to collect and integrate physiological, psychological and behavioral data, with the final aim of interacting with community-dwelling elderly people suffering from mild cognitive impairment and of providing them personalized feedback on lifestyle management. The SENIOR project proposes to use a smart-watch app for alerting family doctors, sharing information with family members in specific cases and monitoring patients at higher risk in hospital Units, in order to ameliorate health of senior citizens with mild cognitive impairment.

Key Words: community; older adult people; information and communication technology; mild cognitive impairment; nudge theory; smart watches

Future Scenario

One of the most relevant challenge of the next future is represented by the development and validation of a new nudge theory based on information and communication technology (ICT) coaching system for monitoring, empowering and motivating senior citizens with mild cognitive impairment (MCI), in order to maintain their independence and functional abilities, improve health status and quality of life as well as social interactions.

On one side, with the introduction of the Nudge Theory, Thaler and Sunstein (2008) proposed to reduce the gap between attitudes/preferences and concrete behaviors in a predictable way, by improving decision-making and helping people to perform rationally. The Nudge Theory was originally proposed in the field of American behavioral economy or philosophy of mind, but it can be adapted more widely for encouraging changes in individuals, groups or communities. Particularly, such a theory suggests that positive aids and indirect advice may influence motivations and attitudes that individuals or groups adopt for decision-making process, with a similar impact of regulations, laws and legal customs.

On the other side, MCI represents a core feature in the elderly. Structural and functional neuroimaging studies in patients with MCI have pointed out that slight brain alterations of specific brain areas (e.g., medial temporal lobe structures) precede many times before the onset of the disease (De Carli et al., 2007). The progression of these alterations may be counteracted by interventions contrasting synaptic functionality loss and enhancing brain plasticity. Thus, early identification of individuals with a high risk of conversion into Alzheimer's disease (AD) would allow clinicians and therapists taking advantage of brain plasticity, starting from early preclinical phases. MCI is characterized by the deterioration of cognitive functions — mainly pertaining episodic memory — at a level below than what is expected based on age and educational level, without any significant interference with personal and instrumental autonomy in daily life activities (Petersen et al., 2001; Winblad et al., 2004). From the original criteria, the concept of MCI underwent an evolution through the Recommendations of the National Institute on Aging-Alzheimer's Association workgroup exploring the pre-clinical phase of AD (i.e., MCI due to AD), by pointing out a set of criteria with increasing levels of certainty, depending on the presence and nature of biomarkers (Albert et al., 2011). The annual MCI conversion rate into AD is equal to 3–10% in community settings (Michaud et al., 2017). More recently, the classification of the DSM 5 (American Psychiatric Association, 2013) recognized the clinical entity of minor neurocognitive

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disorder due to different medical conditions (i.e., AD or Parkinson's disease) to establish a primary level of cognitive impairment, in comparison with major neurocognitive disorder reporting a more sever deterioration.

Not all the patients with MCI will develop dementia and some of them remain stable or even return to normal cognition. However, they are at higher risk than cognitively normal individuals to develop dementia (Michaud et al., 2017). In this light, it is relevant to identify risk factors for progression towards a more severe cognitive (and functional) deterioration and the *SENIOR* project (SystEm of Nudge theory based ICT applications for OldeR citizens) may represent a great opportunity to this end. To date, a progressive amount of studies has investigated the role of ICTs for people with MCI, underling that three major approaches have been used: ICTs as cognitive assessment, treatment, and assistance tools including robots, sensors and personal devices (Mancioppi et al., 2019). Topics related to the use of the ICTs for MCI pertain medicine, nursing, psychology and neuroscience. Specifically, on technology and bioengineering area, they address computer networks and communication, software, information systems, human-computer interaction and computer science, applied mathematics and modelling simulations (Mancioppi et al., 2019). Non-pharmacological interventions using ICTs represent crucial tools in managing care of MCI patients. They are tertiary prevention techniques contemplating many factors, such as patients' medical condition, sanitary resources and caregivers' support.

Enriched Environment and Mild Cognitive Impairment Development

There is increasing evidence about the role of individual features (i.e., education level), environmental (i.e., engagement in familiar, professional and leisure activities) and lifestyle factors (i.e., physical exercise and balanced diet), expertise and experience as protective agents against dementia development (Belleville, 2008). A healthy lifestyle supported by mental and physical activity as well as social engagement may help decreasing the risk of further cognitive decline in MCI patients. Lifestyle factors including cognitive activation, aerobic exercise and social interaction may improve MCI patients' wellbeing, by counteracting noxious processes in order to delay or even prevent dementia onset (Cammisuli et al., 2016). A recent prospective cohort study found a significant association between engagement in mentally stimulating activities of late life and decreased odds of MCI (Krell-Roesch et al, 2017). People performing cognitive stimulating activities at least 1 to 2 times per week reported a minor cognitive decline than those who were engaged in the same activities only 2 to 3 times per month or less. Furthermore, two systematic reviews of the literature concluded that regular participation in moderate-intensity aerobic training (which typically implies exercise sufficient to elevate heart rate or VO_2 to approximately 60% of the maximum for 50/60 minutes 3 days a week) may improve cognition in patients with MCI (Cammisuli et al., 2017) conversely to patients with AD reporting limited improvements after similar levels of physical activity (Cammisuli et al., 2018). Finally, the Monongahela-Youghiogheny Healthy Aging Team study following 816 MCI patients demonstrated that a lower risk of progression towards dementia was associated with a greater engagement in social activities (Hughes et al., 2013).

The last decade has seen growing popularity of self-monitoring technology including wireless sensor devices and mobile apps for tracking physical activity/sedentary lifestyle, positive/negative diet attitudes, mentally stimulating activities/

no hobby and eustress/distress even in people with MCI (Mancioppi et al., 2019). However, their application as means of monitoring and motivating patients in community settings remains to be developed and interaction between care providers and patients using innovative ICT tools for healthy behaviour is quite limited to date. Currently, there is no system able to comprehensively connect all the parties involved in a preventive medicine planning. To improve care coordination for older adult MCI patients living in the community, e-Health tools show some potential, such as sharing care plans among clinicians and connecting health service networks. According to a recent extensive literature review (Mancioppi et al., 2019), the most interesting results about initiatives put in place in this research field are about the use of wearable sensors, which would allow clinicians to assess patients during their activities in daily life improving the ecological validity of measures whereas the implementation of robots for patients' assistance represents a target for the future than a feasible reality. In our opinion, a comprehensive system like the *SENIOR* may represent one of the viable route to impact MCI patients' needs from knowledge to intervention, because it integrates a repository system in which assessment data are stored for further analysis, assists patients with immediate feedback and information for family members and clinicians and may contribute to instantly treat some medical conditions related to the aging process. Remarkably, we would stress that one of the most important challenge of the project remains the primary education of older people for using personal devices.

The SENIOR Project

The *SENIOR* project developed thanks to the collaboration between the Catholic University of the Sacred Heart, the Bicocca University and the IRCCS Auxiologico Institute in Milan (Italy) will adopt an advanced ICT coaching system collecting and integrating significant physiological, psychological and behavioral data, in order to interact with elderly people and to provide them personalized feedback about diet, physical and mental activity, cardiovascular risks avoidance, and lifestyle management according to a nudge theoretical approach. The *SENIOR* project will involve 200 seniors with MCI as a randomized controlled trial (i.e., 100 seniors for the experimental group and 100 controls) and will be evaluated by the MethoTelemed, a framework methodology to assess the effectiveness of telemedicine applications in Europe. Neuropsychological tests at baseline for MCI diagnosis will include the Mini Mental State Examination, the Boston Naming Test, the California Verbal Learning Test, the Dementia Rating Scale, the Wechsler Memory Scale-Revised, the Trail Making Test, the Delis-Kaplan Executive Function System, and the modified Wisconsin Card Sorting Test. In addition, the Activity of Daily Living and the Instrumental Activities of Daily Living will be used.

Physiological parameters recorded will encompass the body mass index, and the Charlson comorbidity index whereas psychological tests at baseline will involve the Minnesota Multiphasic Personality Inventory-II, the Experience Sampling Method-Based questionnaire for quality of the experience, the Short-form Health Survey-36 and the European Quality of Life Dimensions, the Symptoms Checklist-90-R, the Outcome questionnaire, the Beck Anxiety Inventory and the Beck Depression Inventory, the Insomnia Severity Index, the Pittsburgh Sleep Quality Index and the Sleep Disorder Questionnaire, the Pennebaker's method of inferring psychological states via language analysis and the Paykel Scale of Stressful life events. At the end of the intervention, the Telemedicine Satisfaction Questionnaire, the Quebec

User evaluation of Satisfaction with Assistive Technology, the Patient Activation Measure, the Patient Health Engagement scale, the University of Rhode Island Change and Assessment Scale will be used.

Interfering variables will be studied by considering the adherence to Mediterranean Diet and physical activity (measured by the Mediterranean Diet Scale and the Recent Physical Activity Questionnaire, the Physical Activity Recall interview, the CronoLife SenseWear® armband advance software, and the Self-Report Habit Index for seniors' lifestyle, respectively).

In order to help seniors to maintain their independence, the personalized virtual coach elaborates a customized profile by a machine learning algorithm that provides users with specific nudge-based notifications. Signals are collected from the user's device and delivered by the SENIOR app to the remote backend server. Its software analyses data and alerts clinicians/family members in presence of dangerous patterns. Beyond sectorial previous studies (Mancioppi et al., 2019), the most innovative feature represented by the SENIOR project is the presence of a system consisting of a smart watch dedicated app, a set of environmental sensors and a personalized cloud service.

The *SENIOR* virtual coach system is a non-invasive technology able to assist MCI senior citizens in an ergonomic and efficient manner, in order to preserve healthy conditions and social wellbeing as long as possible, including caregivers' support. Due to the interaction between engineers, ICT professionals, physicians, neuropsychologists, patients, caregivers and even stakeholders involved in the project, the *SENIOR* project will elaborate personalized intelligent algorithms allowing reasoning and autonomous learning-adaptation to patient's needs, emotional and behavioral patterns, conditions and preferences and provide everyday and real time solutions for copying with existing activities in a fast and efficient manner. The *SENIOR* applications also respect and take into account current legal and regulatory questions (i.e., ownership of data, data protection/privacy, liability and consumer protection). A summary list of the main objectives of the SENIOR project is reported in **Table 1**. The *SENIOR* project also considers up-to-date constructs such as patient engagement, user acceptability and satisfaction, technology acceptance, impact in realistic settings, cost-effectiveness, and generalizability of the results.

The SENIOR Project as an Information and Communication Technology Implemented Technique

The personalized virtual coach platform has two major components: a wearable device/app for the patients and a cloud backend server for health professionals (**Figure 1**). The patient's activities are daily monitored by using the app and a set of non-invasive environmental sensors. The patient daily behaviour is collected by the app, seamlessly, without user interaction. The app sends data continuously to the remote backend. The data retrieved is analyzed with machine learning techniques and processed by advanced intelligent algorithms, in order to suggest healthy actions to the patients. The advanced intelligent algorithms can be further customized by health professional teams, with the aim of designing new use modality in personalized medicine.

Suggested actions are sent to the user's device by an application. According to a recent study (Ehn and Eriksson et al., 2018), devices to monitor psychophysiological parameters

Table 1 | Main objectives of the SENIOR project

Scientific and clinical objectives:
- To develop tools for monitoring, supporting, and giving feedback to MCI senior citizens;
- To develop protocols for patients with MCI in the field of preventive medicine;
- To evaluate cost and benefit of a new managing model for people with MCI;
- To evaluate clinical efficiency through data analysis comparing SENIOR platform vs standard care approaches.

Technological objectives:
- To design a SENIOR virtual coach platform to manage patients by their clinical and lifestyle data;
- To implement specific algorithms in order to support a nudge-based application for senior citizens;
- To provide tools for caregivers' monitoring;
- To evaluate the contribution of wearable devices for improving health systems.

Global and social objectives:
- To implement cognitive-behavioural techniques and strategies in order to modify dysfunctional and unhealthy behaviours and improving wellbeing;
- To integrate health status monitoring with primary care services.

MCI: Mild cognitive impairment; SENIOR: SystEm of Nudge theory based ICT applications for OldeR citizens.
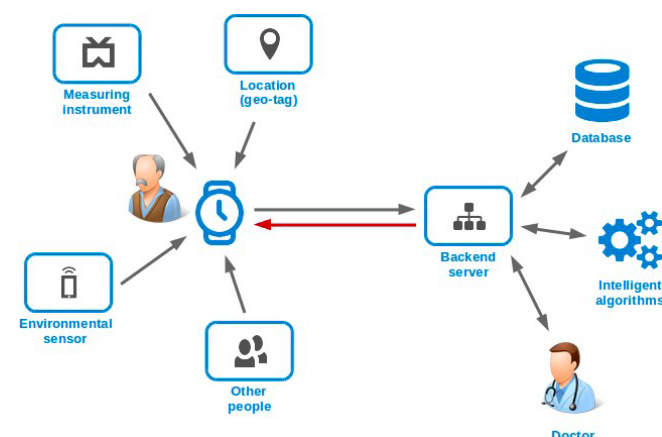

Figure 1 | SENIOR (SystEm of Nudge theory based information and communication technology applications for OldeR citizens) project general architecture.

should be easy to handle and not difficult to manoeuvre by older adults. In particular, wearable devices (e.g., smart-watches) are gaining popularity in many fields, especially for wellness monitoring (Castelnuovo et al., 2015). The SENIOR project thus proposes to use a smart-watch app for alerting the family doctor, primarily. Such a wearable device can also improve the efficacy of monitoring patients at higher risk in hospital Units allowing clinicians to access information at any time and from any place, secondarily.

The network built by the *SENIOR* project is very attractive and the key component is a dedicated app running on the smart-watch that is connected with bio-sensing platforms measuring different psychophysiological parameters. In case of anomalous measured values, incoming alert notifications are primary received by the patient to ask for a medical intervention. The main advantage of this new approach is that health care professionals and even caregivers can freely perform other tasks simultaneously and constantly monitor all the patient' parameters.

Smart-watches can collect data in a not invasive and demanding way for users. They have penetrated health research rapidly since the last decades and their technical function and effectiveness in supporting health is receiving validation in the last years (Reeder and David, 2016). The

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most common healthcare applications using smart-watches focused on clever home environments for elderly people and for chronic patients needing medication and therapy adherence monitoring (Ehrler and Lovis, 2014). Versatility of smart-watches provides an appropriate ground to implement a centralized platform with multiples services facilitating homecare. Smart-watches have definitively the potential to become close assistants to help older persons (especially those with MCI) in their daily life activities. However, this will not be achieved without dedicating a significant effort in designing appropriate user interfaces and certainly dedicated hardware to respond to the constraints associated with potential physical and cognitive impairment. The *SENIOR* project aims at better addressing these pending issues, too.

Big data and machine learning can create algorithms very useful in health care and prevention. According to a recent study (Beham and Kohane, 2018) considering the vast amount of information that a clinician needs to carefully evaluate patient's medical condition, give diagnosis and plan therapies such as personal history, familial diseases, genetics, comorbidity, drugs intake, admissions to the hospitals, etc., clinical decision represents a relevant task. Analyzing data from a great amount of patients using a carefully designed statistical model could produce new insights into the knowledge and management of different clinical conditions, such as those of senior citizens with MCI, as a population at high risk of developing dementia and the *SENIOR* project may facilitate this.

People worldwide are living longer. Between 2015 and 2050, the proportion of the world's population over 60 years will nearly double from 12% to 22% and by 2050 it is expected to total 2 billion (World Health Organization, 2019). Because of progressive population aging, neurodegenerative disorders (especially dementia), currently represent a social and health emergency in relation to clinical features (i.e., progressive disability, severe cognitive impairment, behavioral disturbances), economic implications (i.e., impact on the Welfare State), and human costs of patients and caregivers. Starting from these assumptions, it is necessary to experiment, to validate and to plan interventions for slowing down or delaying a severe cognitive deterioration, starting from early onset of cognitive symptoms. Many of the elderly people will live in their homes as long as possible and need multidimensional professional care, as a result of cognitive and functional deterioration. This group is at higher risk for further decline, specifically related to AD for patients with MCI. Multidisciplinary collaboration in primary care constitutes a real response for monitoring risk factors and developing personalized care plans. Moving from a clinical perspective to a preventive one, many older citizens with MCI could avoid to become severe chronic patients by maintaining a functional and healthy lifestyle and by modifying some dysfunctional behaviors according to a real-time feedback. Smart-watches have definitively the potential to become close assistants of elderly people with MCI by continuously monitoring psychophysiological parameters. Interventions like *SENIOR* are welcome to intercept potential unhealthy behaviors and promptly intervene in the framework of a nudge theoretical approach. Indeed, strategies moved from a nudge theoretical approach have demonstrated to be effective and feasible public health means for encouraging healthier choices. The *SENIOR* project can really improve an active aging lifestyle and disseminate more adaptive behaviors in older people with MCI in the next future.

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