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Improving Wearable Solutions with Nudging Actions in the Chronic Care Management: The SENIOR Project

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Abstract. In order to avoid that many senior citizens with Mild Cognitive Impairment (MCI) could become chronic patients with a low level of functioning in many cognitive, behavioral and emotional domains, some technological solutions have been improved to better enhance less compromised healthy lifestyle, providing real-time clinically-based suggestions and reducing some dysfunctional behaviors. Moreover another critical problem is the overweight and obesity that can affect many people in Western but also Eastern regions. In order to cope with MCI and obesity, mhealth monitor-ing solutions (smart-watches based and wearable based) have been devel-oped. The major aim of this paper is to show the rationale behind the SENIOR Project, a Cariplo funded project that will develop and deliver wear-able monitoring solutions with tailored nudging feedbacks for patients with obesity an MCI. Scientific background, rationale, aims, outcomes measured and innovations are discussed.

Keywords. Obesity, MCI, chronic care management, mhealth, wearable devices, nudge theory, clinical psychology, health psychology

1. Chronic care management scenarios and mhealth solutions

1.1 The (Mild Cognitive Impairment) MCI chronic care scenario

Globally, the percentage of people over 60 will increase from 12% to 22% between 2015 and 2050. People are living longer and attempting to spend as much time as possible in their own houses. A large number of the elderly will require interdisciplinary or multidisciplinary care due to diminished capacity for self-care taking into account many morbidities and issues in the social, psychological, and physical domains, as well as function loss. This population is vulnerable when it comes to prompt health risk signaling,

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treatment alignment, and care coordination. The goal of multidisciplinary collaboration in primary care is to assess health risks and create treatment plans.

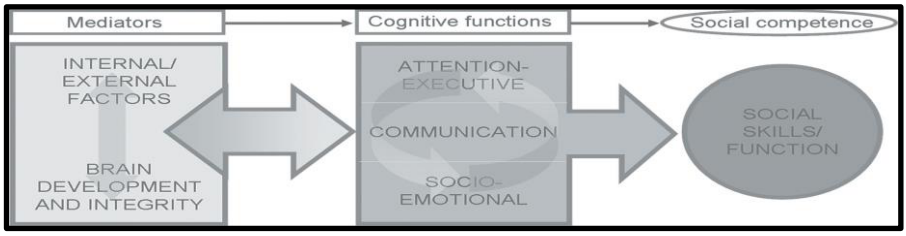
By adopting a preventive rather than a therapeutic approach, many senior citizens can stay out of the "severe chronic patient" category by performing a healthy, productive lifestyle and changing unhealthy habits in response to positive feedback that they can receive in real time.

For instance our cognitive capacities deteriorate. This process may be mediated by increased inflammatory responses and brain atrophy. Regular physical activity has been demonstrated to counteract these harmful processes, and it is believed that this can postpone or even prevent pathological conditions like dementing diseases.

Moreover mental activities may protect against mild cognitive impairment. In fact engaging in mentally and physically stimulating activities, even late in life, may protect against new-onset mild cognitive impairment, according to different studies [1-9]. Particularly, an interesting study [1] found that cognitively normal people aged 70 years or older who engaged in computer use, craft activities, social activities, and playing games had a decreased risk of developing MCI. The researchers followed 1,929 cognitively normal participants of the population in Minnesota, for an average duration of 4 years. After adjusting for sex, age, and educational level, researchers discovered that the risk of new-onset MCI decreased by 30% with computer use, 28% with craft activities, 23% with social activities, and 22% with playing games: persons performing these activities at least 1 to 2 times per week had less cognitive decline than those who engaged in the same activities only 2 to 3 times per month or less. This interesting prospective cohort study found a significant association between engagement in mentally stimulating activities in late life and decreased odds of mild cognitive impairment. So, even if a person is at genetic risk for cognitive decline, engaging in some activities was significantly beneficial.

Moreover, according to Beauchamp MH, Anderson V. [10], cognitive functions are strictly related to social skills (see Fig. 1).

Fig. 1. Cognitive functions are strictly related to social skills (from Beauchamp and Anderson, 2010, [10])



1.2 The Obesity-Overweight chronic care scenario

Body mass index (BMI) of more than 30 kg/m2 has historically been used to describe obesity; nevertheless, obesity is now recognized as a global health epidemic [11-13]. Therefore, obesity can be managed as one of the most significant contemporary health issues impacting millions of individuals worldwide, especially when taking into account overweight critical conditions as well [14]. In addition to being known to be a risk factor for a number of health issues, including diabetes, dyslipidemia, hypercholesterolemia, osteoarthritis, cardiovascular illnesses, and several forms of cancer, obesity has also been linked to early mortality [15, 16]. Additionally, obesity poses a significant risk factor for the onset of Type-2 Diabetes [17-19].

The primary causes of the obesity epidemic are environmental factors and interactions between human behavior and environments, even though inheritance plays a significant role in the genesis of obesity [20-22]. Therefore, the etiology of obesity is complex, involving complex interactions between a genetic basis and environmental and individual factors that result in a variety of situations and outcomes [23]. Behavioral factors, i.e., poor diet and physical inactivity, are among the main proximal causes linked to obesity [24], obesity-related morbidity [25] and mortality [26, 27].

Research in the modern era has shown that regular physical activity is highly effective in both primary (i.e., preventing disease from developing in the first place) and secondary (i.e., halting or slowing the progression of disease) prevention of a number of chronic diseases, including obesity and its complications, such as diabetes, cancer, heart disease, hypertension, obesity, and osteoporosis. In the adult population, there are significant relationships between high physical activity levels and lower risks of CVD, type 2 diabetes, and early mortality. Physical activity and exercise can have positive effects on metabolism and physiology in addition to enhancing mental health, mood, and self-perception—all of which are commonly linked to issues with weight or obesity.

1.3 Wearable solutions for mhealth in chronic care management

Even if the impact of lifestyle management, physical activity, neuropsychological training have been investigated, no functional solutions have been created to provide functional solutions to senior citizens in everyday life contexts.

In the last years self-monitoring technologies, such as wireless sensor devices and mobile apps for tracking physical activity, have tried to manage sedentary behavior, sleep patterns, diet and stress.

Many traditional mhealth monitoring solutions, smart-watches based ones and wearable ones have been developed in elderly people.

In order to monitor the daily activities in older people, is it better to use a smartphone or a smartwatch? [28-32]. According to a relevant article [33], to be useful, the devices must be easy to handle and in fact users perceived wearables as easy to handle, whereas tablets or smartphones were perceived difficult to maneuver.

Mercer, Giangregorio et al. [34] noted that wearable activity trackers are perceived as useful and acceptable for older adults living with chronic illness. So wearable technologies could be an opportunity to solve problems often related to older people (65+).

Particularly, some applications of the potential use of smartwatches in monitoring critical conditions are reported in [35], where smartwatch and smartphone digital measures (WATCH-PD study) are used in Early-Stage Parkinson's Disease. Moreover this study [36] proposed a smartwatch based tool, RapidHRV, in order to monitor many psychophysiological phenomena. Another example is the smartwatch and smartphone based application "dreaMS" [37], which could be a measure for better monitoring people with multiple sclerosis in order to promptly monitor disease progression

1.4 Possible solutions

One benefit of wearables and smartwatches is their widespread availability, which allows for continuous medical surveillance—something that is more difficult to accomplish with other technologies [38]. Furthermore, the adaptability of wearables and smartwatches offers a suitable foundation for implementing a centralized platform that offers numerous

services supporting senior homecare. The small screen size, tiny connectors, and low power autonomy of the watches, among other physical limitations, can pose serious obstacles to the widespread adoption of these devices. In addition to the real homecare system, a combination of environmental and assistive technology can be used to increase the autonomy and independence of older people living at home. There is little doubt that wearables and smartwatches will play a significant role in supporting the elderly in their daily lives. But this won't happen until a great deal of work goes into creating suitable user interfaces and, most importantly, hardware that is specifically designed to meet the needs of people who may have physical or cognitive disabilities. In order to address these unresolved problems, the SENIOR project will introduce numerous noteworthy advances on multiple levels:

1) SCIENTIFIC INNOVATION: collecting a significant amount of data about biomedical, psychological, dietary and physical activity variables, it will be possible to study outcomes as well as moderators and mediators of treatment effects in order to better tune and implement both treatment protocols and mhealth-based tools for older citizens. Big data and machine learning approach could improve the knowledge and management of growing phenomena (MCI, obesity, etc.).
2) PREVENTIVE-CLINICAL INNOVATION: the SENIOR virtual coach will not only collect a single range of data, but will also support health care stakeholders and professionals in a multidisciplinary approach including suggestions and feedbacks about biomedical, psychological, behavioral and social areas, thus promoting self-management practices for each older citizen and improving preventive and clinical protocols for patients with different diseases.
3) ORGANIZATIONAL INNOVATION: the state-of-the-art care will be provided using a new approach, no using only hospital admissions, but through a reliable mobile (wearable based) and Web–based monitoring and treatment integrated services. This will significantly reduce the costs for the Health Care Services and the time spent by patients attending clinics. It will also reduce the burden of disease of the patients and caregivers, improving their quality of life.
4) TECHNOLOGICAL INNOVATION: the SENIOR project will not develop new biomedical devices, but it will use the gold-standard tools-devices-apps integrated in a user-friendly platform, to monitor and assist each older citizen. The major aim of the SENIOR project is not to produce new patents, but to integrate the best up-to-date tools, such as wearable devices, in order to better integrate the already existing devices into a new intelligent-based system and service.

2 The power of wearable solutions: the SENIOR Project

2.1 Not only wearable monitoring solution in the SENIOR Project: the role of nudging feedbacks

According to Hansen [39], nudge could be defined as "a function of (condition I) any attempt at influencing people's judgment, choice, or behavior in a predictable way (condition a) that is made possible because of cognitive boundaries, biases, routines, and

habits in individual and social decision-making posing barriers for people to perform rationally in their own self-declared interests, and which (condition b) works by making use of those boundaries, biases, routines, and habits as integral parts of such attempts" Risk Regulation, Eur. J., 2016(1):1–20). The use of the Nudge Theory has become increasingly popular and diffused into a wide range of public policy areas, including public health. So far, there hasn't been much progress in using nudges in a systematic way to encourage behavior changes like making healthier decisions. Arno A. and Thomas S. (2016) conducted a review and meta-analysis of previous research, and their findings showed that Nudge Theory tactics can effectively encourage people to make healthier food choices. The SENIOR project will advance the Nudge Theory method to encourage better habits in obese individuals and an active aging lifestyle in older adults. Based on the previously given context, the SENIOR project added values are:
1) enabling continuous and ubiquitous monitoring of elderly and obese patients (wearables and smartwatches) without invasive modalities but with a disappearing and non-demanding approach;
2) increasing the knowledge of obese patients and senior citizens through the collection and analysis of large data sets containing a variety of data types;
3) customizing the recommendations, feedback, and indications for patients with MCI and obesity based on algorithms enhanced by big data-machine learning methodology;
4) employing technology to "nudge" older MCI patients, for example, in order to enhance their socializing.

2.2 The SENIOR Project core activity: using physiological sensors to improve physical activity

By combining numerous functions (measuring and categorizing physical activity, heart rate, and galvanic skin response) within a very light and comfortable device, the wearable sensors-based device will push the implementation of sensor and communication technology beyond current state of the art technology, resulting in a more accurate energy consumption and stress estimation. Advanced algorithms will be implemented by the sensors to detect various behaviors (e.g., running, walking, lying, or sitting), estimate energy usage, and measure stress. Initial validation tests have been conducted, comparing this sensor's performance to that of other research-grade sensors and gold standard energy expenditure measures. Anthropometrics, health indicators, diet, physical activity, and psychological wellness are some of the types of input data that the SENIOR system uses in order to provide the most complete picture of the user's or patient's health and behavior. Since not all of the input data will be available for every patient, just a small amount of mandatory data will be needed, and the automated analysis and suggestions will only use the minimal amount of information. Cut-points are provided by the SENIOR system in accordance with current clinical standards. With the help of the physical activity module, caregivers and medical experts will be able to "tailor" treatment plans for their patients. These plans will include information on the type and degree of activity, when to engage in it, how to schedule it, how to create reminders, and other details. Patients can make small changes to the training program, such as selecting between exercise types with the same intensity level, thanks to the programs' accessibility via a mobile app or web interface. The user will also receive an indicator from the physical activity module regarding how they performed in relation to the care provider's goal. Through feedbacks based on the Nudge Theory, the patient will receive reports from the system regarding his or her physical activity. The reports will offer the

capability to be filtered and arranged, giving the patient a means to monitor their physical status development.

2.3 The SENIOR Project cost-utility and cost-effectiveness analysis

Our ambition is to develop a technically and economically viable technology which will be a true connected health platform to be innovative, easy-to-use, convenient, and reliable that may work across different clinical centers and associations, and to have a large market appeal.

In order to have a robust demonstration that SENIOR project could deal with the challenge of improving the life-long health and well-being of all while maintaining economically sustainable care systems, according to Horizon 2020, we will make an overall evaluation of the project based on European standards. In particular, the new protocol developed in SENIOR will be evaluated by the validated model for assessment of telemedicine (MAST- Methodology to assess telemedicine applications - https://ec.europa.eu/digital-single-market/en/news/methotelemed-framework-methodology-assess-effectiveness-telemedicine-applications-europe). The MAST is the gold standard tool used as a basis for decision making in EU and the European countries in decisions on use of telemedicine applications.

For health care cost-effectiveness, direct and indirect cost savings will be considered and monitored.

2.4 The SENIOR Project timeline

The SENIOR Project is funded by one of the most important private foundation in Italy, the CARIPLO Foundation, that supports relevant social and scientifically based projects about the most important challenges in our society, such as the chronic care management. SENIOR solutions for elderly patients, using new technological applications and devices, have been implemented in 2021-2022 and tested in 2023. Final clinical and technological results will be produced and shared in 2024, considering a significative delay due to Covid-19 pandemic limitations in working with senior citizens and patients. The complete protocol of the project could be found here [40].

3 Conclusion

The SENIOR Project will try to move the care when it really needs finding portable, cheap, easy-to-use, comfortable and not invasive and not highly demanding solutions for our senior citizens. The real added value of this approach is the possibility to continuously monitor physiological, psychological and behavioral parameters, without interrupting the everyday life of our citizens if not necessary, but simply sending tailored and personalized nudging-based messages where necessary, promoting a healthy lifestyle through cognitive exercises, physical activity suggestions and so on. Perhaps a smartwatch will not be the only tool in a quickly evolving scenario of apps, wearable devices and so on, but the main advantages of a smartwatch are that these tools are light, accepted, full of reliable sensors and able to send audio and video messages. Future applications have to be further explored.

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