Addressing Digital Divide and Elderly Acceptance of Medical Expert Systems for Healthy Ageing

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Abstract

The constantly growing number of elderly people may represent a challenge for the healthcare system of different countries, especially when the goal is to promote a healthy ageing for older adults.
COVID-19 pandemic is demonstrating the necessity of moving from traditional care to telemedicine, which may provide a broad number of services without losing direct contact with the experts.
Therefore, the elderly users should be able to maintain a certain independence, while caring for their physiological and psychological health.
The introduction of new knowledge-based solutions like medical expert systems coupled with wearable healthcare technologies, however, have to cope with two major issues: the digital divide and the elderly acceptance of new technologies.
In this work, these two topics are investigated and the advantages in using a well-designed medical expert system for healthy ageing highlighted.

Keywords

digital divide, elderly acceptance, healthy ageing, medical expert system

1. Introduction

The growth trend of the population over 60 years of age, compared to the population between 15-59 years of age, has been depicted in the plots (Fig. 1 and Fig. 2, respectively) generated through the data acquired by the *2019 Revision of World Population Prospects* (https://population.un.org/wpp/).

The over 60s growth (Fig. 1) has a steeper slope compared with the curve of the 15-59 years old (Fig. 2), thus representing a constant increase in the number of older adults in respect to the rest of the population. Even though the plots consider the data collected before the COVID-19 outbreak, they remain good indicators of the ageing population.

The main challenge represented by this tendency is to promote a *healthy ageing* [1] of the older adults.

With this term, the World Health Organization defines

> the process of developing and maintaining the functional ability that enables wellbeing in older age

(https://www.who.int/ageing/healthy-ageing/en/).

Therefore, key factors for healthy ageing are the acquisition and preservation of 1) capabilities that enable an elderly person to give the right meaning and consideration to his/her life, called *functional ability*, and 2) healthy body and mind, called *wellbeing*.

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To guarantee, improve and/or promote healthy ageing, two actors are needed: the elderly person his/herself and the country he/she lives in.

In fact, an elderly person healthy ageing is influenced by the older adult acceptance of his/her ageing, his/her cultural and economical levels, digital competences, psychological and physiological conditions as well as by the resources that a country puts into its healthcare system.

The healthcare system should cope with the increase demand of assistance and with new necessities arising from out-of-the-hospital care, wanting to improve the elderly people's independence and safety in managing their health and having to answer some critical emergencies deriving from unpredictable happenings, like the COVID-19 patients.

A solution to these issues may be represented by new technologies and knowledge-based solutions, especially by Medical Expert Systems (MESs) exploiting Wearable Healthcare Technologies (WHTs). In fact, the MESs are Artificial Intelligence (AI) applications which provide expert knowledge to every kind of user and mimic the experts behaviour in managing a peculiar problem. Adding wearable solutions to the MESs, a constant monitoring and connection between elderly users, their relatives and caregivers should be possible, especially by exploiting Internet of Things and 5G technologies.

Even though the MESs may represent an ally for healthy ageing, they may also have to address two major issues: the Digital Divide (DD) and the Elderly Acceptance of New Technologies (EANT).

Therefore, this work will focus on the analyses of these two issues and will provide some guidelines to mitigate these aspects, while considering the use of MESs for the promotion of healthy ageing.

2. Digital Divide

As stated in the introduction, the digital divide is one of the major issues in designing MESs aimed at the support of elderly people.

The presence of the DD has been particularly noted during the ongoing COVID-19, having the need of telemedicine solutions [2], while lacking proper infrastructures and advanced healthcare systems.

Following the definition brought by *Ramsetty & Adams* [3], the DD is a gap in the accessibility to technology due to the following factors:

- the limited presence or total absence of adequate technological infrastructures, e.g. of broadband Internet [3, 4];
- the widespread reluctance to adopt and the mistrust in [3, 5] the new technologies for healthcare management;
- the majority of population inability to understand the possible advantages in adopting telemedicine [4];
- the different educational and economical levels, digital literacy capabilities [3] and linguistic proficiency [5] of the end-users (e.g. patients);
- the need of devices that could be costly [3], especially for the patients;
- the overall economical condition of each country [4];
- the presence of healthcare systems that are not up to date [3], considering the digital transformation and the new demands required in the last years.

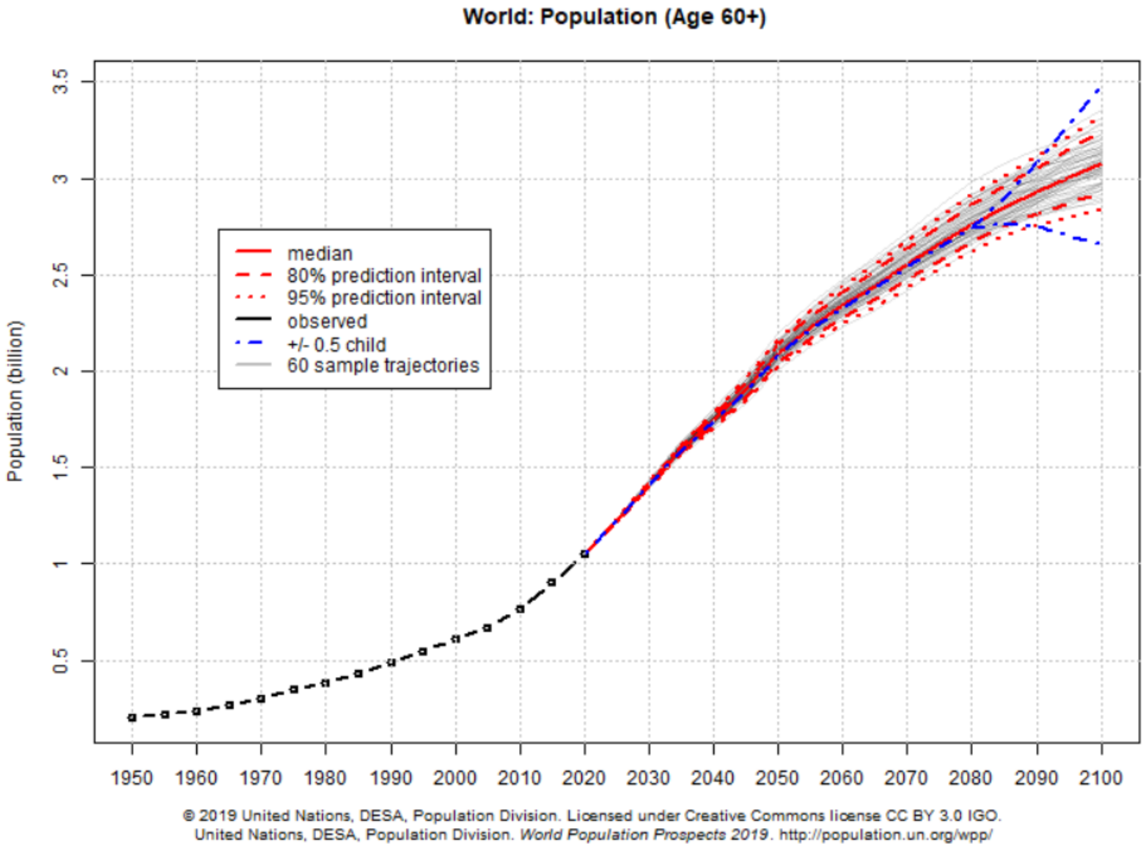

Figure 1: The plot shows estimates and probabilistic projections of the over-60s population, taking into account geographical aggregates and income groups of the World Bank. These projections are based on the probabilistic projections of the total fertility and life expectancy at birth, performed by a Bayesian Hierarchical Model (https://population.un.org/wpp/).

Even though the DD is constituted by a great number of factors that may have a negative impact on the adoption of MESs and, generally, of telemedicine solutions, some successful examples may be found in the literature.

The same *Ramsetty & Adams* [3] proposed a system for online visits, in order to avoid the presence of patients in the hospitals during the major COVID-19 outbreak. Given the difficulties the patients had in accessing and using the provided system, the authors decided to implement its hybrid version: the patients could contact a volunteer operator, who could then fill the users' DD gap by providing assistance for the system usage or even act in their stead.

Similarly, *Omboni* [6] reported his experience with the tele-monitoring and counseling solutions acquired by the private Institute he is working at. The caregivers have been able to manage chronically ill patients from different Italian regions. Moreover, the usage of their monitoring services has increased during the COVID-19 pandemic.

However, *Omboni* highlights the need for Italy to convert and improve its infrastructures and give more reliance on telemedicine systems. The author lists some of the major reasons for this unpreparedness, confirming the previously described factors.
Especially, the heterogeneity of available devices, the difficulties in accessing and managing the na-

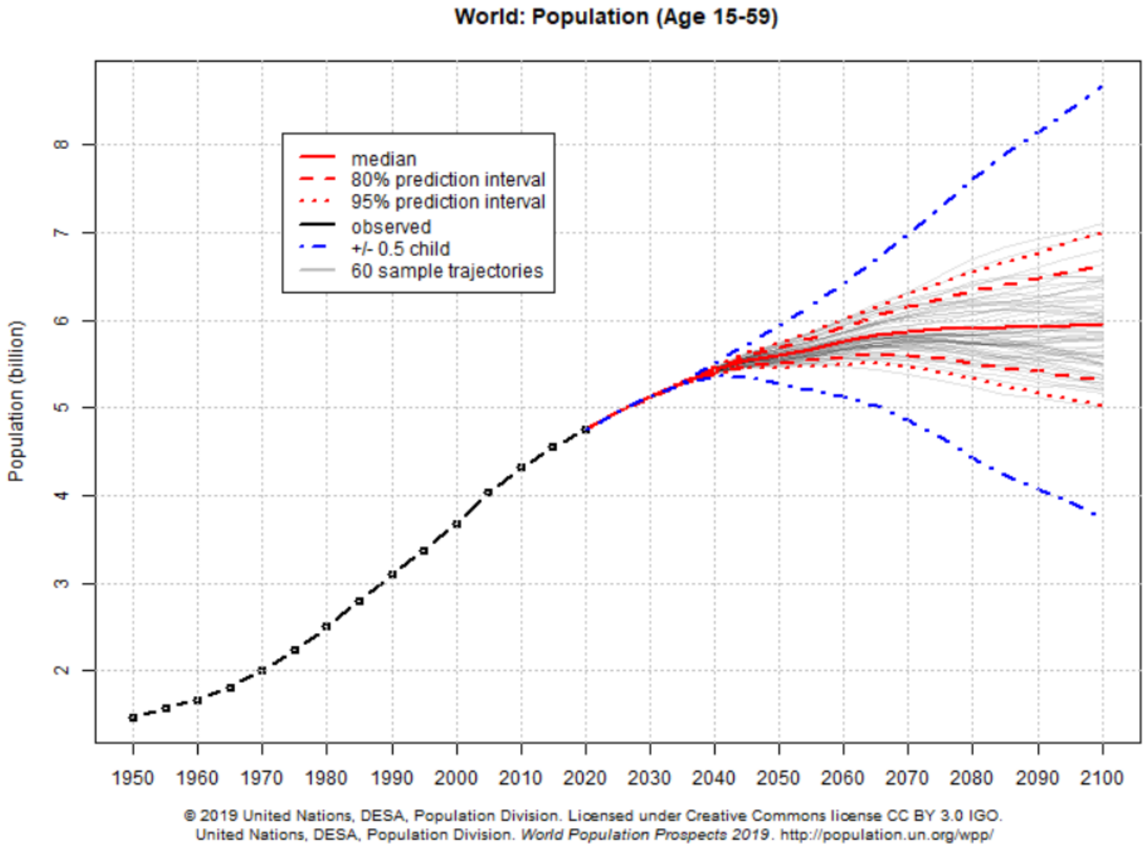

Figure 2: The plot shows estimates and probabilistic projections of the population between age 15-59, taking into account geographical aggregates and income groups of the World Bank. These projections are based on the probabilistic projections of the total fertility and life expectancy at birth, performed by a Bayesian Hierarchical Model (https://population.un.org/wpp/).

tional electronic health record, the issues arising in the development of personalised medicine and technological healthcare solutions, due also to the lack of scientific validations and clear and easy to follow regulations, are reported.

Finally, these observations are supported by recently published works [7, 8, 9], in which the necessity and efficacy of telecare applications in case of disease outbreaks are documented. The authors also suggest some solutions to mitigate the described issues, e.g. instruct patients about the telemedicine alternatives, show the benefits deriving from this new approach and always provide help.

These topics easily introduce to the problem of elderly acceptance of new technologies, described in the following Section 3.

3. Elderly Acceptance of New Technologies

The second major issue, introduced in Section 2 and complementing DD, concerns the older adults approach to technology that clearly affects not only the telemedicine applications, but also the MES design choices that are of interest in this work.
The EANT can be described by different factors, each influencing the elderly users.

Generally, what arises from different studies on this topic is that, even though there is interest in approaching new tools, their adoption by the elderly population is low and inconsistent [10].
To access EANT factors, researchers have generated or exploited different theoretical models.

An example is represented by *Pal et al.* [11] work, on which were applied the features of the Unified Theory of Acceptance and Use of Technology (UTAUT) model.

The authors found out how expert advice represents a positive factor, while the concerns about privacy and data security have a negative role in the EANT.

In fact, elderly people seem to have a tendency to heavily rely on physicians and nurses' point of view for their health management, while they tend to, even unconsciously, mistrust the acquisition of their personal information to benefit from new systems and technologies.

On the other hand, the authors found out that social influence has unexpectedly no significant value for the EANT, supposing that older adults do not particularly value other people opinion with the exception of field experts.

This observation was actually overturn in the research conducted by *Talukder et al.* [12]. The authors used a modified version of the UTAUT2 model (an ulterior extension of the UTAUT model) to understand the EANT on the specific domain of WHTs and make a survey on Turkish older adults.

They discovered that the recommendations from their social connections, being them relatives and/or friends, have a positive influence in the approach to technology.

Other factors represented in this work are elderly people resistance to change and technology anxiety, which had a negative influence on the EANT, and self-actualization and technology enjoyment, which had a positive connotation.

Moreover, other resulting evidences were that the older adults were more interested in approaching new technologies not only if their social connections had a positive attitude towards the WHTs, but also if they believed the technology could effectively benefit their wellbeing and improve their functional ability. A positive EANT was also bounded to the idea of having devices with an affordable price.

A further investigation was conducted by *Wildenbos et al.* [10]. They identified four different constraints which could prevent technology acceptance:

- cognition, that is linked to cognitive impairments, memory loss and dementia;
- physical abilities, which concern physical impairments and/or diseases related to the reduction of motor skills;
- perception, that may be bound to hearing or visual impairments;
- motivation, which could be represented by the lack of perceived usefulness or ease of use of the new technologies.

The presence of the described acceptance factors involves heavily the WHTs.

In fact, *Fensli et al.* [13] define a new and validated questionnaire called Sensor Acceptance Model (SAM) to measure the patients' acceptance of telecare solutions, noticing an absence of effective questionnaires targeting the information about wearable sensor usage and the patients' evaluation of these technologies.

Moreover, an ulterior research was conducted [14] in order to address this topic, focusing in particular on wearable sensors acceptance by older adults. The authors researched in depth how to structure the questionnaire, finding different influencing factors which could guide the subjects' opinions on the presented systems, confirming some of the evidences previously reported.
Perceived ease of use and usefulness of sensors and systems, as well as the patients' intention of using

them are factors widely adopted to predict technology acceptance behaviours, but they are complemented in this novel questionnaire by factors more sensor-bounded. These additions focus on sensor compatibility with other systems and performance risks. The authors also analyse the facilitating conditions for sensors acceptance, highlighting the peculiar influence of social connections.

Therefore, a good solution to have a better acceptance of WHTs could be represented by the introduction of an immediate feedback from the elderly users. A virtuous example is provided by *Wu & Munteanu* [15], who focused especially in designing and testing their sensor-based fall risk assessment solution, by presenting a set of questions to older adults regarding how the system should work and how it actually worked in the testing session.
This should be considered as a good practice to test a MES based on WHTs and assess the subjective perception of the proposed system.

4. Medical Expert Systems towards Healthy Ageing

Knowing the issues emerging from DD and EANT, the possible advantages of using Information and Communication Technologies (ICT) solutions for healthy ageing should be investigated.

In fact, AI applications, like MESs, should have a specific set of features in order to mitigate or totally answer the problems described in Section 2 and Section 3.

According to the work of *Siegel & Dorner* [16], mHealth, telecare and telehealth/behaviour monitoring solutions may reveal to be good tools for constant and effective communication between older adults and professionals. On the one hand, the elderly people increase their autonomy and awareness in managing their own health and, on the other, physicians can quickly intervene in case of emergency.

For example, *Almarashdeh et al.* [17] focus on elderly people instability, immobility, intellectual impairment and incontinence. The proposed system consists of smart bracelets equipped with microcontrollers and embed medical sensors. The objective of the device is to help the physician in tracking and monitoring the patient health and to provide notification in case of emergency.

Therefore, this MES has two major advantages: it allows a constant connection between its elderly user and the caregiver, guaranteeing more safety, while hiding the sensors required for the monitoring activity into every day objects, thus providing a comfortable device.

These claims are supported by *Chernbumroong et al.* [18], who suggested that a good improvement could come from the integration of MESs with commonly used devices, such as watches and smartphones, in order to decrease the stress coming from the new technologies and also make it easier for older people to communicate with their loved-ones and thus to increase their EANT.

Another aspect to keep in mind is the possibility to integrate the device with a user-friendly interface and, in general, to provide assistance in using the device.

Espin et al. [19] studied a system for nutritional recommendations, which is provided with an interface especially designed to be simpler for and more accessible to the elderly users.

In fact, they need to receive clear and easy to follow suggestions, based on expert knowledge, taking into account their preferences and possible allergies.

Moreover, according to *Guner & Acarturk* [20], the ICT solutions can overall increase the elderly quality of life. In fact, the authors observed that Turkish elderly people use these technologies mainly to get in touch with family members and to access information and news. This confirms the fact that, thanks to these devices, elderly people keep more autonomous and active while maintaining their social interactions.

Therefore, considering the literature and the previously cited necessities, the main components of a MES are: a knowledge base, an inference engine and a user interface.

The knowledge base [21] is constituted by expert information and by the rules required for the MES correct functioning. The rules are frequently fuzzy in order to comply with the uncertainty of medical data [22].
Consequently, to make decisions based on the knowledge base, the inference engine [23] simulates the expert behaviour when receiving specific inputs.
Finally, the user interface [24] engages both the experts (e.g. physician and nurses) and the patients (e.g. the elderly patients to be monitored).

Besides these technical characteristics, a MES should be trustable, which is related to the concept of user acceptance and system reliability [25].

As mentioned above, considering the specific needs of the elderly people, the best solution might be to combine MESs with WHTs.

In fact, they allow a constant contact between user and experts, even with the possible help of recent developments in IoT and 5G technologies [26, 27].

A good example is represented by the MES developed by *Rescio et al.* [28]. They propose a wearable device for fall detection, composed by a tri-axial microelectromechanical system and a ZigBee module for wireless communication. The sensor allows to receive information on the 3D spatial relative position of the person who wears it.

The researchers have also added a validation step to their work, simulating specific type of falls to test the system functionalities.

Even though the validation is frequently not reported as part of the MES design, it is extremely important to improve the system trustability and to have a completely reliable final product.

Finally, knowing the general components of a MES, it is also necessary to depict some of the AI techniques underlying its functioning.

4.1. Exploiting Artificial Intelligence

In recent years, AI solutions have been widely used in the healthcare sector, especially to deal with copious amount of information and aid the clinicians in their decision process.

In fact, AI may allow a multi-level modelling [29] that takes into consideration different data types like physiological signals acquired through WHTs and sociomarkers to present a constant monitoring, prediction and recognition of peculiar diseases.

This predictive and recommendation power represents also an aid in cloud computing and IoT based solution [30], being the system provided with a great amount of data.

Therefore, considering the field of knowledge-based solutions, telemedicine and wearable devices, there are many examples on the application of AI techniques that could be exploited for the investigation and promotion of healthy ageing.

Dragoni et al. [31] present a motivational platform to support the monitoring of users' behaviours and to persuade them to follow healthy lifestyles.
The system is based on semantic technologies and relies on four layers.

The first detects triggering events, such as sensor data or environment information, while the second layer, called knowledge layer, consists of the reasoning operations and deals with domain knowledge and structured rules.
An ulterior layer is based on a natural language generation system and it exploits the output of the knowledge layer to create the more appropriate persuasion messages.
Finally, an output layer provides a feedback to the users.

Another type of approach is presented bt *Ali et al.* [32], who developed an intelligent healthcare monitoring framework for chronic patients, such as diabetes and abnormal blood pressure patients. In this case, sensor devices, medical records, social networking platforms and drug reviews are the main sources of data.
First, they applied a preprocessing step to reduce noise and to deal with missing values. Then, the generated datasets were used to build AI models for the classification of diabetes, blood pressure, mental health, and drug side effects.
Therefore, the system may represent a support for physicians to offer personalised treatments to their patients by smartly monitoring their patients' health conditions.

These examples represent some of the advantages in exploiting AI techniques in the healthcare domain. In fact, they are able to provide a MES with a set of usable data to make expert-like decisions, starting from uncertain and complex inputs [33].

5. Discussion

Having provided a general overview of DD, EANT and MESs exploiting AI techniques, in the previous sections, some guidelines for the modelling of systems able to enhance or, at least, improve elderly people healthy ageing are here discussed.

Notice that the discussion focuses on the resources presently available in Italy, however, the guidelines could be extended to broader scenarios, adding to the basic and general concepts some specific necessities and limitations.

As stated in Section 4, a MES should be composed of a knowledge base, an inference engine and a user interface.

The knowledge base should result from the integration of the expert knowledge, required to efficiently assist and monitor the elderly user, with the health-record, both of the specific user and of the most diffused pathologies and conditions of older adults.
Therefore, the issues highlighted by *Omboni* [6] and reported in Section 2 should be considered and addressed, at least partially, in the modelling of this component, especially the accessibility of the national electronic health record.

Subsequently, the inference engine should be able to give alerts, notifications and/or recommendations to caregivers and elderly users alike, relying on the knowledge base and its rule set and being constantly inputted with the user data acquired through heterogeneous sensors.
These sensors should be embedded in every day objects like smartphones, watches and clothing items, in order to decrease the elderly discomfort and stress levels while using the provided WHTs. Many of these wearable devices have been studied in order to be flexible, adaptable and low-cost [34, 35, 36].

The idea of using such common devices answers the need of user-friendly interfaces, which should improve the EANT.
In fact, the survey conducted by *Buccoliero & Bellio* [37] on a population of over 65 years of age, confirms the indicators reported in Section 3: the ease of use and perceived usefulness are determining factors for healthcare technologies and Internet adoption as well as the educational level of the users.

Moreover, guaranteeing an easy to access assistance and thus a constant communication between the older adults and human experts is also a way to help the elderly users in managing new technological means, without incurring in the widespread risk of technophobia and perceived inadequacy [38, 39].

Therefore, wanting to obtain this constant communication between elderly users and experts, the MES should always be connected and thus should exploit the most diffused technologies in order to

comply with the problem of DD.
Considering a system that is modelled for an Italian audience, the choice should be on first generation broadband, whose technologies cover almost completely both rural and urban areas [40].

Finally, the MES should always be tested by a sample of the target users with different EANT and DD conditions. Therefore, to assess the perceived usefulness and efficacy of the proposed solution, the testing could exploit well defined models like the UTAUT2 and SAM, described in Section 3.

6. Conclusion

This work has given attention and promoted a discussion towards the concept of healthy ageing exploiting new technologies, like MESs, and also analysed the difficulties deriving from DD and EANT. Some guidelines for MES modelling have also been presented.

The differences in accessibility to healthcare infrastructures and systems, being the problem related to the resources provided by a specific country and/or to the conditions of the elderly population, have their regional connotations and thus require to be considered while developing a MES.

This digital divide may represent a barrier for older people use of new technologies and may add to the factors influencing the EANT.

Some of these factors have been accessed through theoretical models, revealing that the social connections influence positively the elderly acceptance of new devices, while the absence of ease of use may have a negative connotation.

For these reasons, the importance of a good MES design has been highlighted in Section 4 and 5. Apart from having well-defined knowledge base and inference engine, the system should have a user-friendly interface and be provided with embedded sensors, in order to be easy to use, constantly connected, comfortable and trustable.

The described characteristics, should enable the elderly user to act independently in order to care for his/herself, while maintaining the security provided by the contact with relatives and caregivers. Moreover, the elderly user would improve his/her overall psychological and physiological health by having a change in behaviour towards the new technologies.

In brief, the medical expert systems, provided with solid AI technologies, could be the mean through which aid the older adults to maintain their functional ability and improve their wellbeing, thus a way to promote the healthy ageing.

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