Human Factors in Aging and Special Needs, Vol. 133, 2024, 12–23
https://doi.org/10.54941/ahfe1004889

Design for Digital Ecosystems and Telemedicine Services to Improve the Quality of Care Pathways for Frail Older Adults

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ABSTRACT

Global population aging is one of the most critical factors in the coming decades (Eurostat, 2019). In Italy, the average age of residents, which was 32 in 1952, increased to 46.2 years at the beginning of 2022 (Istat, 2022). The overall effects of aging on the health and welfare system are considerable. Indeed, with ageing is associated with an increase in chronic pathological conditions, co-morbidities, or the inability to perform basic daily activities independently, and this leads to an increase in the care and assistance needs of the elderly. A distinctive factor of the new generation of elders is their approach to technologies, a factor that can greatly expand the possibilities of access to care and assistance, communication and information services (Istat, 2019). To provide, as far as possible, the continuity of care and assistance people need, telemedicine services can ensure safe and efficient care pathways while maintaining a strong patient-physician relationship. This article presents the first results of the research conducted by the Laboratory of Ergonomics and Design (LED) of the University of Florence as part of Spoke 3 of the project "THE - Tuscany Health Ecosystem" of the PNRR (National Recovery and Resilience Plan), funded by the Italian government with Next Generation EU funds - Mission 4 (Education and Research) - Component 2 "From Research to Enterprise". The project involves the participation of 22 partners including universities, research centers and companies in the Tuscany Region, organized in 10 Spokes. The goal is to develop guidelines for the design of interfaces and products for telemedicine services in digital diagnosis and therapy for neurodegenerative diseases. This article will discuss the research questions, applied research methodology, results and future developments.

Keywords: Human-centred design, Telemedicine services, Frail people, Older adults, Technology

INTRODUCTION

Population aging, together with low birth rates and longer average life expectancy, is one of the most critical factors in the coming decades, both at the European and global level (Eurostat, 2019). Currently, this process is not exhausted but still rising sharply: as estimates made by the United Nations highlight, "World population continues to grow, although at a slower rate

than at any time since 1950, due to reduced levels of fertility. From about 7.7 billion people worldwide in 2019, the projection indicates that the global population could grow to about 8.5 billion in 2030, 9.7 billion in 2050, and 10.9 billion in 2100. In 2018, for the first time in history, people aged 65 and older worldwide surpassed children under the age of five. Projections indicate that by 2050 there will be more than twice as many people over 65 than children under five. By 2050, the number of people aged 65 and older globally will also exceed the number of adolescents and young people aged 15–24" (United Nations, 2019). The global aging trend, has and will have a significant social and economic impact in the coming years and requires a combined effort by all governments, international agencies, professionals, universities, media and individuals to improve the lives of older people, their families and the communities in which they live. Global trends are also evident in Italy: the average age of residents, 32 in 1952, has risen to 46.2 in early 2022, and Italy is now among the countries in the world with the highest proportion of older people along with Germany, Spain and Japan. The population over 65 makes up 23.8% of the total population. The increase in life expectancy also determines the increase in the population of the "very old": the over-85s were 3.6% of the total population, and Italy holds the European record for the number of over-centenarians, together with France (Istat, 2019).

GLOBAL AGEING: HEALTH, INDEPENDENCE AND CARE NEEDS OF THE ELDERLY

The definition of the elderly is complex, especially in relation to ongoing generational changes and longer life expectancy. In this paper, we identify the elderly with reference to the conventionally recognized age of 65, although in the literature (SIGG, 2018; Segnini, 2018; Fini et al., 2023), depending on the scope of reference, it is also possible to refer to adults over 50 or over 60. The United Nations (2012) identifies age 60 for the definition of elderly, recognizing that this limit moves to age 65 in many nations. Czaja et al. (2019) state that, for research and design purposes, it is possible to divide the elderly into three groups: 65 to 74 years old, 75 to 84 years old, and over 85.

The current generation of the elderly is very different from previous generations: today people's life expectancy has lengthened, people stay active longer, and they live independently in their own homes for longer before needing care or assistance. Today's older people are also more diverse, better educated, and work longer (Czaja et al., 2019). Despite this, the aging of the population implies a necessary increase in the levels of care and assistance, both formal and informal, both at home and in special facilities, and influences the ways in which this is delivered and the actors involved (formal caregivers, informal caregivers, services, social-health facilities, etc.). In fact, as age increases, so do chronic diseases, comorbid conditions and, often, a partial or total impairment of autonomy and independence or simply an inability to perform the most basic daily activities independently. This is very evident especially in countries with a high rate of elderly people such as Italy. In the latter country, the latest report on Equitable and Sustainable Welfare (Istat, 2023) notes that the number of people with multicronicity or severe

limitations is 49% for those over 75. More fragile health status conditions affect women more (54.7% compared to 40.9% for men) and increases with age: in fact, for those over 85 it reaches 60.9%. Based on these considerations, it is clear that the overall effects of aging on the health and welfare system are considerable.

HOME CARE AND TELEMEDICINE

One of the distinguishing features of the new generation of the elderly is the approach to new technologies, a significant factor that can greatly expand the possibilities of access to care and assistance, communication and information services (Istat, 2019). Indeed, digital technologies represent a resource to support care and assistance at home. In this sense, to ensure, as far as possible, the continuity of care and assistance that people need, telemedicine services can ensure safe and efficient care pathways while maintaining a strong patient-doctor relationship.

Telemedicine is defined as the use of telecommunication technologies for diagnostic, monitoring and therapeutic medical purposes when distance and/or time separate participants (Hers et al., 2006). Telemedicine services can be summarized into three categories: store-and-forward, home-based and office/hospital-based. As defined by Hers et al. (2006) "*Store-and-forward telemedicine* involves the collection of medical data and then their transmission for subsequent interpretation. (…) *Home-based telemedicine* services enable health professionals to monitor physiological variables, test results, images and sounds. The information is usually collected in a patient's home or a nursing facility. (…) *Office/hospital-based telemedicine* services are usually real-time, clinician-patient interactions that conventionally would require face-to-face encounters between a patient and a health professional. Examples of office/hospital-based services that might be delivered by telemedicine include office visits, hospital visits, consultations and home visits, (…)".

Studies in the literature regarding *Store-and-forward telemedicine* services show that some of the areas for which it is used are: teledermatology (Barnard & Goldyne, 2000; Taylor et al., 2001), ophthalmology (Gomez-Ulla et al., 2002; Baker et al., 2004), cardiology, gynaecology and gastroenterology (Ferris et al., 2003). While regarding the *Home-based telemedicine* service some of the application areas are: asthma (Chan et al., 2003), congestive heart failure (CHF), hypertension and pulmonary diseases (Benatar et al., 2003; Rogers et al., 2001; Maiolo et al., 2003). Finally, regarding *Office/hospital-based telemedicine* service some of the application areas can be summarized as follows: ophthalmology, dermatology, rheumatology (Leggett et al., 2001), vascular surgery (Endean, 2001), otolaryngology (Mashima et al., 2003) and psychiatry (Ruskin et al., 2004; Nelson et al., 2003).

The overall state of scientific research underscores the benefits of telemedicine interventions and suggests that the spread of telemedicine should continue. Of course, there may be situations where the use of telemedicine is most highly justified, when care would otherwise be impossible to provide.

These are remote rural areas or other places where medical care is not available locally and the patient, for whatever reason, is unable to travel to a place where it can be obtained.

Telemedicine: Access Requirements, Service Types, and Current Status

Patient/caregiver eligibility for access to home care services is assessed on a case-by-case basis. In detail, at least two elements are required:

- the ability of the patient/caregiver to access technological systems and infrastructure that meet at least the minimum technical requirements for proper and safe use of the service;
- the minimum skills and abilities that the patient must possess in order to use the technological platforms appropriately, also taking into account any additional support he or she may receive from the caregiver.

In addition, there are a number of minimum requirements for the activation of home care pathways: (1) adherence by the person concerned to the home care pathway and activation of the telemedicine service in which multiple professionals can operate; (2) identification, suitability and training of the patient and/or caregiver(s); (3) adequacy of the social aspects of the family environment, home environment and support network; and (4) structural suitability of the living environment related to the clinical picture also in relation to the use of equipment. So, through digital communication systems between doctor and patient/caregiver, a variety of different kinds of health care services can be delivered. The main home care services through telemedicine, spread globally, are shown in Table 1.

Table 1. Main services provided through telemedicine and related technological supports.

Type of Service	Description	Technological Supports
Telehealth	Telehealth is a health care act in which the physician interacts remotely with the patient, even with the support of a caregiver, and may result in the prescription of medications, or further clinical investigation. This act allows the transfer of health information without moving the patient, thus ensuring continuity of care.	Basic technological equipment for video calling supplemented by tools for consulting clinical documentation (reports, images, etc.) is necessary. The ability to exchange clinical data, medical reports, audio and video images in real time must be guaranteed.
Medical teleconsultation	It is a medical act in which the practitioner interacts remotely with one or more physicians to converse, including through a video call, regarding a patient's clinical situation, based primarily on the sharing of all clinical data, reports, images, and audio-video regarding the specific case. It can also take place in asynchronous mode.	Basic technology equipment for video calling supplemented by tools for consulting and sending clinical records (reports, images, etc.) is needed. Patient information must be available in the home record.

(Continued)

Table 1. Continued

Type of Service	Description	Technological Supports
Teleconsultation medical health care	It is a health care activity, not necessarily medical, that takes place at a distance and is performed by two or more people who have different responsibilities. It consists of a request for support during the performance of health care activities, which is followed by a video call in which the addressed health care professional provides guidance to the other for decision making and/or proper execution of patient-facing care actions.	The basic equipment that enables video calling is supplemented by the tools that serve to document the clinical conditions that are the source of the consultation query: devices for data and image management and exchange, devices for monitoring, for rehabilitation, etc.
Teleassistance	It is a professional act pertaining to the relevant health profession (nurse/physiotherapist/logopedist/etc.) and is based on the remote interaction between the professional and patient/caregiver by means of a video call, to which the sharing of referral data or images can be added if necessary. The purpose is to facilitate the proper performance of care activities, which can be performed mainly at home.	Devices for recording, data and image storage, media for data and image exchange, video and vital parameters, fixed and/or mobile devices that provide for easy use, medical devices and sensing sensors; accessible APPs, videos and information and/or training materials.
Telemonitoring	Enables remote sensing and transmission of vital and clinical parameters continuously by means of sensors that interact with the patient (biometric technologies with or without applied parts).	A set of certified technology devices connected to a central platform for receiving and storing collected data is needed.
Telecontrol	Medical telecontrol enables remote monitoring of the patient. It is characterized by a cadenced series of contacts with the physician, who places the progress of the clinical picture under control, by video call and with the sharing of clinical data collected from the patient, before and during the same video call.	Remote monitoring takes place through a set of certified technological devices connected to a central platform for receiving and storing collected data.
Telerehabilitation	It consists of the remote provision of benefits and services intended to enable, restore, improve, or otherwise maintain the psychophysical functioning of people of all age groups with disabilities or disorders, whether congenital or acquired, transient or permanent, or at risk of developing them. It is a health activity pertaining to health professionals, may be multidisciplinary in nature, and, when it is beneficial to the patient, may require the collaboration of caregivers, family and non-family, and/or teachers.	Basic instrumentation that enables video calling is supplemented by devices for data and image management and exchange, primarily through the use of CE-marked medical devices, including mobile and wearable devices, sensors, robotics, serious games, and will be provided by the health care company in the same manner as in-person intake pathways.

TELEMEDICINE AND HOME CARE SERVICES: THE STATE OF THE ART IN ITALY

Before the Covid-19 health emergency, the level of deployment of telemedicine services was limited. The Mckinsey report (2020) shows that in the U.S. states alone in the first eight weeks of the pandemic, implementation of digital solutions accelerated, which normally occurs within five years. Even in Italy the use of this type of service was just over 10%; during the emergency it tripled, exceeding 30% for many. The most widely used Telemedicine service is Tele-consultation with specialist physicians (47% of specialists and 39% of GPs use it), which also attracts the prospective interest of 8 out of 10 physicians. It is followed by Tele-visit (39% of specialists and MMGs) and Tele-monitoring (28% specialists and 43% MMGs) (Digital Health Observatory, 2021).

Research Methods and Objectives

The Human-Centred Design (HCD) approach, applied to all phases of the design process, can play a crucial role both in understanding the needs of the elderly population and in translating these needs into more suitable and relevant digital products. For these reasons, the early stages of activities conducted as part of the "THE - Tuscany Health Ecosystem" project included a literature review of the most relevant home care and telemedicine services both nationally and internationally. The research aims to highlight the opportunities offered by telemedicine at the national level. The literature review was conducted from January 2023 to March 2023 and followed an exploratory process. The search was mainly performed on online databases such as PubMed, the IEEE digital library (Xplore), the ACM digital library, ProQuest, JSTOR, Science Direct, Web of Science, Google Scholar, Scopus, Web of Science, Researchgate, dedicated websites such as WHO.int, UN.org, commission.europa.eu, aal-europe.eu, lavoro.gov.it, and famiglia.governo.it. No restrictions were applied to the date of publication. Databases were selected primarily for their indexing of international publications and accessibility by the University of Florence. First, keyword searches were conducted to identify potentially relevant studies in the Italian context. Second, for those studies deemed most interesting, the method and results achieved were evaluated. The keywords searched, covered users (e.g., frail elderly), objectives (e.g., data on aging population, elderly home care, telemedicine services), and general topic (telemedicine, home care technologies). The research identified the main telemedicine services for home care nationwide and highlighted the features the innovative elements proposed by these services.

RESULTS

Telemedicine Services: Italian National Findings

In Italy, before the Covid-19 health emergency, the diffusion of telemedicine services was very limited. The Covid emergency greatly accelerated the diffusion of telemedicine applications and services, especially in to the difficulties

of performing health care services in presence and minimizing hospital admissions when unnecessary. Telemedicine services, which have developed in Italy in recent years, differ in their objectives, patients involved and technologies used.

Since the goals of the THE-Tuscany Health Ecosystem project are aimed at limited implementation in the territory of the Tuscany region, only the research results at the national and regional levels are reported below. The findings are summarized in Table 2 and shown in full below.

Table 2. Main telemedicine services in Italy.

Service Name and Region	Major Outcome	Study
TreC Pediatria (Trentino-South Tyrol)	Support to health care providers by an innovative, effective and safe service for all patients.	Trentino Salute 4.0, 2020
COReHealth (Apulia)	Reduced hospitalizations, greater equity of access to health care and better quality of care.	AReSS Puglia, 2020
ASP Golgi Radaelli (Lombardy)	New practices and improvements for the quality and effectiveness of care (e.g., tele-rehabilitation pathways, use of exoskeletons).	Fosti et al., 2022
Tel.Te.Covid 19 (Tuscany)	No hospitalizations or deaths for the monitored patients, reduced impact on the National Healthcare System.	Panicacci et al., 2021
Pensami (Tuscany)	Collection of multiple data to obtain a predictive model of clinical and nonclinical events.	IFC-CNR Pisa, 2020
Air Cardio (Tuscany)	Optimized timing of outpatient visits and hospital admissions.	European Commission, 2020

- Platform TreC Pediatria (www.trentinosalutedigitale.com): it is a digital solution that enables communication and information exchange between the patient's family and the pediatrician. Through a medical dashboard and mobile application, integrated within the TreC platform, physicians can deliver services to their patients remotely, avoiding assemblages at clinics. The platform integrates several functions: televisita, which allows the pediatrician to prescribe and perform a remote visit with the patient's family; a pediatrician-activated chat channel, which allows asynchronous, two-way communication between doctor and patient; and a secure area for sharing multimedia files (images, PDF files, etc.);
- COReHealth: it is the Regional Operations Center for telemedicine of chronic conditions and clinical networks. The service provides that people with chronic conditions can be treated at home, thus in a comfortable environment, thus reducing hospitalizations and visits to outpatient clinics. In fact, it allows for self-management of one's illness and the possibility

of being constantly followed, monitored and treated even at a distance or with timely interventions. The Central Unit provides the care team with a cloud (backoffice) platform for the telematic management of their patients by offering, among the main services: personalized patient monitoring paths (telemonitoring), telehealth, tele-consultation and telecare services, digitized services for taking charge, customization and management of patients' care plans, logistics management/warehouse of medical device kits. The medical team, based on the specific need, provides the patient with the medical device kit (tablet, saturimeter, multiparameter, scale, etc.) aimed at real-time detection and monitoring of salient parameters. If these are not in the normal range, an automatic alarm system is triggered, leading to immediate action. An app, available for Android and iOS, allows patients to stay in touch with their specialist physician and caregiver (video calls and chats), consult the schedule of scheduled televisits with their care team, view their treatment plan and the entry of vital parameters that are communicated to the physician in real time; it also facilitates the measurement of compliance with the treatment pathway (medication intake, lifestyle);

- ASP Golgi Radaelli (Fosti et al., 2022): it works on the use of technologies in rehabilitation with the aim of expanding activities at the patient's home, initiating tele-rehabilitation pathways, and introducing new tools (such as exoskeletons) that can lead to new practices and improvements in the quality and effectiveness of care. During 2020 and 2021, following the closure of day and outpatient services related to Covid-19, ASP Golgi Redaelli started some experiments for remote and home-based activities that are now being developed thanks also to investments in technological and digital equipment. The strategic goal is the expansion of rehabilitation-related activities, both by seeking an increase in volumes but also by expanding the range of services offered and thus the cases that can be treated;
- Tel.Te.Covid 19 (Panicacci et al., 2021): it is a telemedicine system, consisting of a mobile application for internal collection of vital parameters and a cloud platform that allows physicians to monitor them remotely. The project targets patients with heart failure and in remote monitoring of heart rate (HR), oxygen saturation (SpO2), blood pressure and weight according to a decided and customizable personalized care plan. The system consists of three modules: (i) the multi-access, multi-profile cloud platform provided on the Web. It features a graphical user interface (GUI), which allows care team members to enroll patients, customize the monitoring plan (i.e., the number and type of measurements) and thresholds that generate events and notifications, and displays the progress of collected measurements; (ii) The home kit, delivered to an individual patient. It consists of a set of Bluetooth sensors and an Android tablet with an app installed. The latter sends notifications and guides the patient in performing self-measurements of vital parameters by means of the sensors. It is also responsible for transmitting the collected values to the web platform to make them available to the care team; (iii) the professional kit, for nurses and caregivers. It is designed to support professionals during home visits to responsible patients or to manage multiple patients within

the same healthcare facility. It consists of a set of Bluetooth sensors, which are usually more professional than those in the home kit, and an Android tablet with the professional app installed;

- PENSAMI (www.ifc.cnr.it): the project aims to develop a predictive model of clinical and nonclinical events for the purpose of improving chronic disease management and prevention in children and adolescents, improving patient outcomes and compliance, and ultimately, optimizing therapeutic strategies;
- AIR CARDIO (www.italy.representation.ec.europa.eu): the project aims to develop a digital platform that helps physicians in Tuscany remotely monitor the health status of children with congenital heart disease. The platform helps bridge the gap between specialized health care services, which are often located in densely populated areas, and patients who are in remote areas. The platform offers an e-Health Advanced Care Centre (e-HACC) module that collects and processes incoming data. A biomedical sensor in the form of a patch is applied to patients' chests to transmit their vital signs via Bluetooth. It has a built-in electrocardiogram function that can detect an irregular heartbeat for several minutes. The data received from the sensor is synchronized with the e-HACC so that doctors can assess the condition of the patient under examination. In case of technical or medical problems, an automatic alarm signal alerts physicians and caregivers, setting in motion direct communication with them. An integrated decision support system indicates the examinations and diagnostic procedures that can be considered by physicians based on the clinical condition of the patient under observation. The system provides advice and alerts on potential drug interactions, dosages, and allergies and also measures the possibility of developing any side effects.

CONCLUSION

Digital and information systems are responsible for connecting healthcare professionals with the patient. In this sense, home automation, defined as the intelligent use of medical technologies and instrumentation, plays a key role. The overall state of scientific evidence underscores the benefits of telemedicine interventions and suggests that the spread of telemedicine should continue. Of course, there may be situations where the use of telemedicine is more warranted, when care would otherwise be impossible to provide. These are remote rural areas or other places where medical care is not available locally and the patient, for whatever reason, is unable to travel to a place where it can be obtained.

In addition, the increasing deployment of these services will present many challenges, including equitable accessibility, ethical and regulatory barriers, and digital literacy among the elderly. Future developments of this research plan to make a contribution in this regard by developing best practices for the design of integrated telemedicine services, starting from people's real needs.

Next Steps

The research conducted so far has enabled the collection of critical issues, possible developmental elements and data for the development of guidelines

for telemedicine service products and interfaces for diagnosis and treatment for neurodegenerative diseases. On this basis, the research project plans to carry out the following research activities in the near future: (1) phase 1: application of the HCD approach to the analysis of the needs of primary and secondary users at the regional level with respect to telemedicine services currently in place (ongoing); (2) phase 2: conduction of two focus groups with medical doctors active in telemedicine services and formal and informal caregivers in order to highlight and define critical issues in current telemedicine services; (3) phase 3: application of User Experience (UX) and Inclusive Design (ID) principles to the development and elaboration of preliminary and final guidelines for the design of services, interfaces and products for telemedicine services in digital diagnosis and therapy for patients with multimorbidity.

AUTHOR CONTRIBUTIONS

Scientific director of the research F.T.; Research planning M.P. and C.B.; All authors contributed to the draft and accepted the published version of the manuscript.

FUNDING

Research was pursued within the "THE - Tuscany Health Ecosystem" project (European Union NextGeneration EU, Ministero dell'Università e della Ricerca, CUP I53C22000780001).

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