Addressing Rapidly Aging Society Challenges Through Health 4.0

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Abstract. People in the world are living longer than ever before, a major achievement of modern science and healthcare. Older people make up a growing proportion of the population, as well as an increasing contribution to society. However, an aging population might lead to the presumption that there will be an increased need for health and social care services. The reality, however, is more complicated. Without significant improvements in healthcare, the aging population will increase the number of people with ill-health and disabilities. Chronic conditions, and multiple morbidities at the same time will increase in numbers common. This, in turn, will put additional pressure on public services and care providers. To meet this demand, there is a need to adapt digital health and care systems and support for elderly as well as their informal caregivers. Currently, digital technologies are advancing at a rapid pace, with promising achievements that will have a relevant impact on the healthcare field. These advanced digital technologies (robotics, artificial intelligence, cloud computing, internet of things, or virtual-augmented reality) are grouped under the concept of Health 4.0, which fosters the use of cyber-physical systems to transform the current hospital-centric care delivery toward a more ubiquitous, smart, preventive, and personalized approach. This paper explores how health and care need change with age and how this need can be accommodated using Heath 4.0 technologies. We contribute to the Health 4.0 literature by offering a synthesis of the benefits and challenges that elderly people deal with when using Health 4.0 technologies.

Keywords: Health 4.0, aging society, connected health, Robotics, AI, IoT, Cloud Computing, Virtual Augmented Reality

1 Introduction

All over the world now, people are living longer thanks to the developments in health care. In most countries, people are living to the age of 60 and well beyond. Hence, there is a growth in the size of the population and the percentage of older people in the population. According to the WHO, 1 in 6 people in the world will be aged 60 years or over by 2030. Accordingly, people aged 60 and above will increase in their numbers from the current size (1 billion) to 1.4 billion by 2030 and projected to be 2.1 billion by 2050,

while the number of people aged 80 and above is expected to triple by the year 2050 to reach 426 million. Such increments will be distinctly occurring in high-income countries, for example, in Japan 30% of the population is over 60 years. However, low- and middle-income countries will be experiencing the highest change making up for two thirds of over 60 population living in such countries [1]. For example, in England, the number of people older than 85 will double to 2.6 million in the next 25 years.

Older people can experience physical and mental decline in capacities at different levels, hence the healthcare system should address a wide range of people's needs and care. As older people have an increasing chance of becoming frail and dependent, this increases the need for care provision, which implies economical costs. The European Economic and Social Committee (EESC) has pointed out that there is an urgent need for stronger state involvement and effective action at national and European level to regularize the precarious situation of both caregivers and care recipients. With demand for long-term and live-in care work continuing to increase due to demographic change and the aging of the European population and rising chronic health needs, the state will not only have to invest heavily in the care economy to subsidies it in the near future, but it will also have a crucial role in the regulation and professionalization of care work, the report said [2].

Digital technologies have emerged as a promising solution to fulfil the need of elderly people to address access, ease of use, and availability of assisted systems without the need to have the advanced technical knowledge to set up and use them. The most recent digital breakthroughs are envisioned to revolutionize the healthcare environment under the concept of Health 4.0, which leverages technologies like Artificial Intelligence, Robotics, Internet of Things, Cloud Computing, or Virtual and Augmented Reality. This paper aims to show how Health 4.0 and its technologies can improve healthcare outcomes for older adults and provide more personalized and efficient care.

This paper is structured as follows: Section 2 describes Health 4.0 and its evolution over time. Section 3 highlights the main application fields of Health 4.0 with an emphasis on the new technologies. Section 4 discusses the main benefits of Health 4.0 in relation to the aging population. Finally, Section 5 draws conclusions.

2 Health 4.0

In the incoming years, and specifically by 2030, we are likely to see dramatic shifts in how healthcare is delivered. Enabled by increased access to data, additive AI, wireless and mobile technologies, miniaturized wireless sensors, and wearable and implanted devices to monitor our health, new paradigms of healthcare have emerged at three different levels sensing [3], data fusion [4], and data interpretation [5] [6]. Healthcare will be delivered as a seamless continuum of care, away from the clinic-centered point-of-care model and with a greater focus on prevention and early intervention toward personalized, proactive, and predictive health [6].

This evolution of health technologies and services encompasses the so-called Industry 4.0, which advocates the use of Cyber-Physical Systems (CPS). CPS refers to the merging of computational elements, including the digital realm (such as computers and the Internet), with physical processes via computer networks. In the healthcare industry,

CPS has evolved beyond simply connecting medical devices, to become a crucial component in the management of large-scale medical data systems. A CPS designed for medical purposes combines intelligent medical devices, embedded software, and remote networking capabilities [7]. Industrial technology's advances have been reflected in healthcare in successive stages from Health 1.0 to 4.0 [8] as shown in Figure 1.

Health 4.0 could be defined as a continuous but disruptive process of transformation of the entire healthcare value chain ranging from medicine and medical equipment production, hospital care, nonhospital care, healthcare logistics, and healthy living environment to financial and social systems, where a vast amount of CPS are closely combined through the IoT, intelligent sensing, big data analytics, AI, cloud computing, automatic control, autonomous execution, and robotics to provide digital health services as Figure 2 shows [9]. In such a system, not only the health care organizations and facilities (e.g. hospital, clinics, and long-term care facilities) are connected; but also all the equipment and devices, as well as the patients' home and communities are linked together [10].

3 Health 4.0 Technologies

In the context of aging society, Health 4.0 allows the shift from traditional hospital-centric to a distributed and integrated care by heavily leveraging some pivotal digital technologies like:

- ***Robotics***: With the increase of the aging population, the demand for home care services is escalating and is pulling the transformation towards personalized assistance and support where robots play a fundamental role in supporting elderly in their daily activities [11].
- ***Artificial Intelligence***: AI empowers the Health 4.0 CPS systems with the capability of analyzing complex health or medical data to be used as the second body of expert doctors and professional caregivers, offering elderly an enhanced and personalized disease prediction, assisted diagnosis, assisted therapy, and assisted rehabilitation [6]. Medical professionals, having the ability to wirelessly and non-invasively

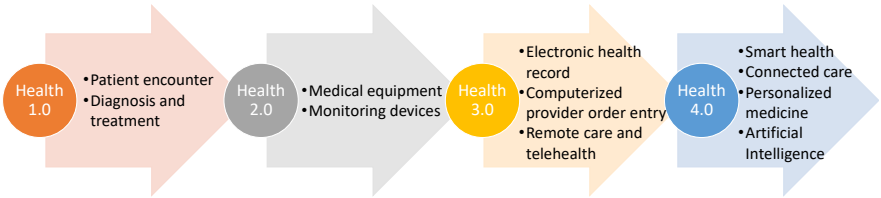

Fig. 1. Historical Evolution of Health Care 1.0 to Health Care 4.0 adapted from [8]

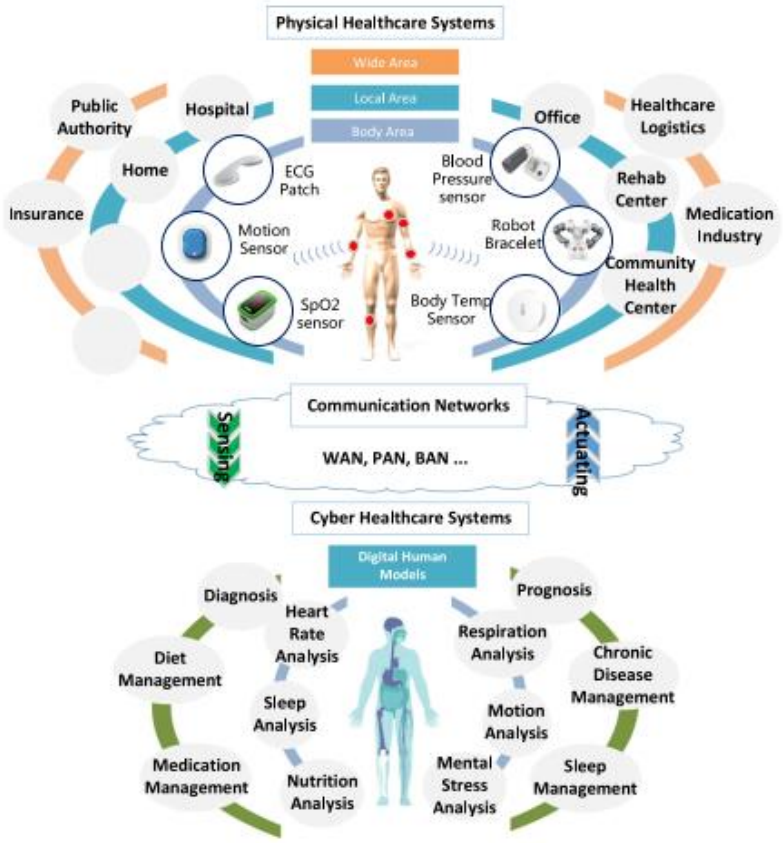

Figure 2: Illustration of the concept of Health 4.0 based on CPS [9]

gather a plethora of data from the subject, would be able to construct a remote "digital twin" of the subject's body and make interventions in real-time by exploiting such data with AI.

- ***Cloud computing***: Currently, 4G and 5G networks allow to access enriched services on the cloud that guarantees quality of service (QoS), seamless integration, very low latency, large bandwidth, scalability, large number of connected sensory devices, faster data generation and processing. All these features will act as the basic infrastructure for the rest of Health 4.0 technologies and services allowing a transition from reactive care to a patient-centric and proactive care that benefits in the way the elderly access the entire healthcare services [12].
- ***Virtual and Augmented Reality***: With the recent improvements in computational power and advances in visual and haptic display technologies, Augmented Reality (AR) and Virtual Reality (VR) are transforming the practice of healthcare by providing powerful and intuitive methods of exploring and interacting with digital

medical data. Older people can benefit from this technology through more natural and interactive virtual experiences that traduces in enhancement of quality of care [13]

- ***Internet of Things***: The tremendous growth in mobile devices, sensors, wearables and applications able to monitor physiological signs, are promoting the Internet of Things (IoT) as a main pillar of Health 4.0 solutions capable of providing older adults with a more comprehensive and personalized care and support.

Table 1 shows the groups of services or applications aimed at elderly people that can be implemented by each Health 4.0 technology, as well as their benefits and challenges identified in their implementation.

Table 1: HC 4.0 technologies, applications, benefits and challenges.

Technology	Services and applications examples	Benefits	Challenges
Robotics	-Inside/on body robots: exoskeletons or robot orthoses for physical rehabilitation. -Outside robots: social assistive robots, health monitoring robots, fall detection/prevention robots. -Robots and exoskeletons to support healthcare staff (lifting, transport, medication distribution).	-Enhancement of user's social interaction. -Support of activities of daily lives performance. -Increases well-being and performance of healthcare staff.	-Elderly can be excessively attached to the robot and miss out real social interaction. -Ethics about user's autonomy and dignity. -Cost-effectiveness robot adoption. -Clinicians' fear of being replaced by robots. -Expensive.
AI	-Aided early diagnosis and therapy selection, intervention planning. -Patient risk stratification. -Clinical recommendation for patient empowerment. -Personalized medicine -Motivational tools -Exploration of large databases to discover new knowledge.	-Use of a high underutilized volume of health data. -Unveiling association between patient's attributes and diseases features. -Reduction of medical errors. -Prediction of trajectory of medical	-Biomedical data as input (high-dimensionality, sparsity, noise, bias, missing values, unstructured). -Interpretability and trustworthiness of the AI results. -Confidentiality of patient data.

	-Chatbots and related tools to take over routine tasks.	conditions and early prevention. -Allowing staff to concentrate on actual demanding work instead or routine tasks.	-Clinicians' fear of being replaced by AI. -Many possible forms of biases in the trained models. -Ethical issues in data collection and data handling
Cloud computing	- Supporting the rest of Health 4.0 technologies' services with high capability connection (Telesurgery, real-time telemedicine, in-home health monitoring).	- High data transfer capability. - Ubiquitous services. - Seamless connectivity.	- Coverage in rural areas. - Low penetration of 5G devices. - Low adaptation of newer devices between elderly people.
IoT	- mHealth for remote monitoring and personalized treatment. - Ambient Assisted Living for supporting aging and individuals with disabilities. - Medication and treatment adherence control. - Monitoring falls or other emergency situations. - Sleep and daily habits monitoring.	- Increasing patient empowerment, adherence and satisfaction. - Better health self-management and awareness. - Higher user acceptance, availability, and comfort.	- Security vulnerabilities about medical data accessing and sharing. - Patient data privacy and confidentiality. - Lack of interoperability due to heterogeneity of data sources and devices. - Medical devices regulation and certification.
VR/AR	- Cognitive support for patient mental or cognitive problems. - Rehabilitation of psychological as well as physical disorders. - Pain management. - Patient education. - Training of healthcare professionals.	- Hands-free usage of a device. - Higher levels of interpersonal trust between therapists and patients. - Real-time performance feedback. - Involvement of patients in the	- Technological limitations to ensure a fully immersive experience. - Poor ergonomics of haptics and head-mounted displays. - Over-informed users that lead to distractions.

		decision making or preoperative process.	

4 Discussion

Currently, we are in the beginning of the fourth industrial revolution coined by the term ‘Industry 4.0’, which is characterized by principles like interoperability, virtualization, real-time capabilities, or cyber-physical systems. Industry 4.0 standards has contributed enormously to the development of e-health and Health 4.0 principles. This implies adopting and understanding new opportunities as well as challenges. Technologies such as IoT and AI are unregulated as of yet in most countries, and overseeing rapid development in the field which makes the adaptation of such systems a challenge due to the ethical issues and dependability in the health sector, which is rather difficult to pass due to the high standards thresholds. As a result, AI ethics in the framework of Healthcare 4.0 should consider aspects such as patient privacy, bias (including algorithmic, data-selection, optimization criterion biases), informed consent, and decision-making transparency in the healthcare settings with those stakeholders involved (e.g. patients, doctors). Additionally, the regulation and certification of medical devices that use AI algorithms, including software services, bring the necessity for collaborative efforts between regulatory bodies, healthcare providers, industry stakeholders, and researchers to establish clear guidelines, standards, and evaluation frameworks. Scalability is also a challenge to be addressed for interconnected devices using IoT. Furthermore, IoT security is a serious concern that needs to be addressed requiring a holistic cybersecurity framework to cover the different layers of the system.

While cloud computing is an established and secure system, its adaptation for healthcare systems is a challenging issue due the capacity which can become limited at certain conditions such as high demand by the public and domestic sectors, that results in poor bandwidth, unacceptable latencies, and packet drop. This requires better communication protocols and more reliable communication infrastructure with redundant systems.

In general, cloud systems allow cross platform compatibility, however, third party’ hardware and software might cause issues with connection and security. Such devices and services that are provided by other manufacturers must meet certain standards and should be thoroughly tested in terms of reliability, safety, serviceability, and power consumption.

Having set the standards for highly reliable and secure devices, the complexity of such devices will be high, this will not only increase the unit price, but also increase the power consumption, and affect the usability of such devices by older people who might have limited technological knowledge. In addition, the size and weight of such devices could be a deterrent for not taking them on board, as well as utilizing them in wearable formats.

The use of AI and big data analytics present another challenge due to the reliability, credibility, and legal consequences. Due to the utilization of new machine learning

algorithms and large amounts of data, this can cause problems when dealing with health, and life related decisions. The lack of transparency of AI and Big data has been raised by many researchers in relation to regulation and innovation.

5 Conclusions

The various aspects of Health 4.0 make healthcare devices interesting but also challenging. However, the technological advances in Health 4.0 are reshaping the future of healthcare systems to become ubiquitous and personalized medical services. The utilization of IoT, wearable devices and big data are the most pivotal developments of such systems. This will have an impact on the wellbeing and quality of life for elderly patients. On the other hand, AI is unveiling many hidden features and knowledge that can be extracted from data allowing patterns to be collated and exploited for advanced health care.

The challenges that still need further research and developments are security, privacy, ethical issues, complexity and opaqueness of systems, and adaptability, in particular by the elderly.

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