altice labs

Digital health: current trends and applications on innovative care

Healthcare; E-health; Digital health; Medigraf; SmartAL

White paper

Version 1.0, July 2023

Introduction

Traditional healthcare is moving towards a new scenario of digitally connected care ecosystems. A driving force is emerging that can help move from reactive to proactive strategies, improving patient interaction and transforming the digital sector [1]. Digital solutions have the power to address current health challenges, namely, an increasingly aging population, the enlarged prevalence of chronic diseases, the shortage of health professionals, and the remaining disparities in access to health services.

Digital technologies can shape the future of global health, having great potential to accelerate human progress and develop knowledge societies. An innovative health ecosystem is being shaped, creating a continuum of care that surpasses the traditional time and space barriers. It's a new scenario that also faces challenges, as the developed solutions must be guided by ethical, safe, secure, reliable, equitable, and sustainable principles. Transparency, accessibility, scalability, replicability, interoperability, privacy, security, and confidentiality are also imperative guiding points [2].

Several trends, like remote monitoring applied to different levels (diagnosis, consultation, and surgical), internet of things (IoT) devices, data analytics, and artificial intelligence (AI), can leverage a new paradigm of preventive medicine and help to reduce pressure and costs on healthcare systems.

Recently the World Health Organization (WHO) launched a first step towards the definition of an action plan for 2023-2030 considering digital health in Europe [3].

Topics like equity, solidarity, and human rights are transversal to the proposed strategy, which is anchored in four strategic priorities: (i) setting norms and developing technical guidance; (ii) enhancing country capacities to better govern digital transformation in the health sector and advance digital health literacy; (iii) building networks and promoting dialogue and knowledge exchange; and (iv) conducting horizon-scanning and landscape analysis for patient-centered solutions that can be scaled up.

Among other dimensions, the WHO identifies international cooperation as a critical issue, underlining the importance of platforms like the e-health Network [4]. **Figure 1** depicts the five guiding principles that are presented to support the sustainable adoption of digital health [3]:

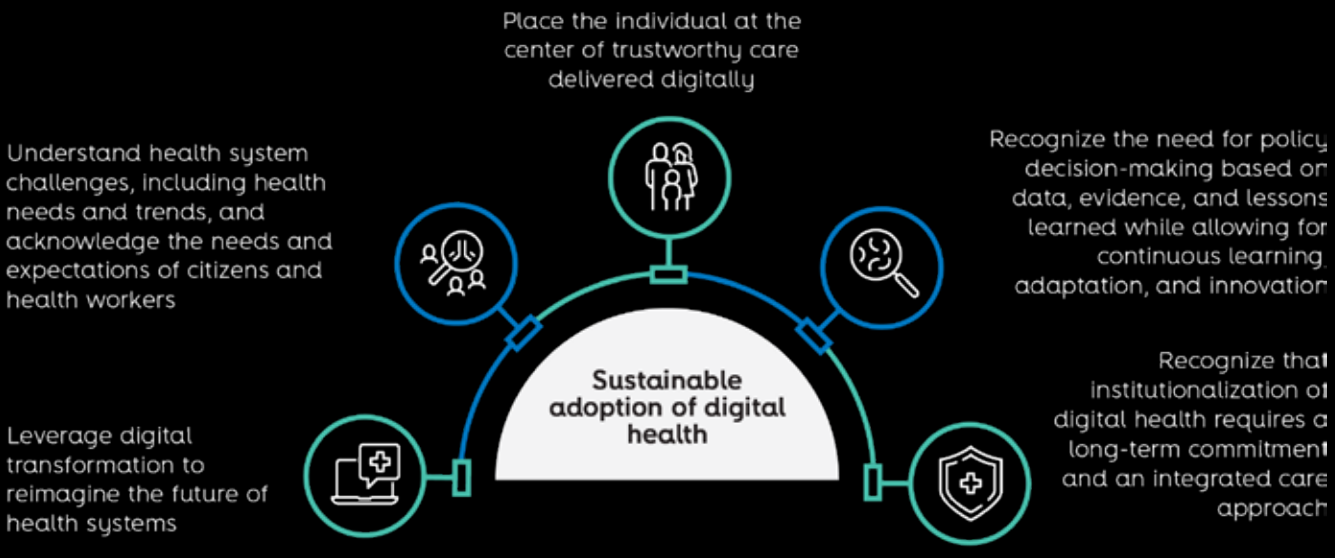

Figure 1 – Guiding principles to support the sustainable adoption of digital health

Critical health scenarios

As portrayed during the last years, health emergency situations are increasingly prevalent. The COVID-19 pandemic created a unique scenario, speeding up digital transformation and creating new opportunities to reconfigure both patients and health professionals' digital experiences. Now it is time to scale out both the innovative digital care delivery models already in place before the pandemic and the new ones brought up in the last two years, enabling the consolidation of more consistent integrated care models.

Different benefits of this recent transformation have been consensually described [5]: breakdown of geographical and time barriers, reduction of waiting lists and crowding in healthcare facilities, and saving on national healthcare budgets. However, despite those positive effects, bureaucratic and regulatory issues remain as potential barriers, as well as users' skills and attitudes (like patients' literacy or health professionals' commitment). The COVID-19 pandemic underlined how critical it is to: strengthen the resilience of health systems; pay special attention to vulnerable populations; analyze the impact of isolation on mental health; better listen to end-users; and develop person-based approaches [6].

The pandemic reinforced the idea that digital health can help to better understand and reduce disparities, while conventional channels failed to respond to current needs. Digital health solutions proved to be able to orchestrate resources to improve health equity [7].

Notwithstanding this equalitarian view, policies and strategies must be designed carefully. Despite the benefits that digital health brings to both patients and professionals, it may also stress inequalities regarding accessing health care services. Therefore, health literacy should be carefully considered to avoid deepening existing health inequalities and better promote patients' readiness to adopt digital health solutions [8]. The lack of digital literacy is a big challenge when developing easy-to-use digital solutions.

Active aging and chronic conditions

Older adults, chronic patients, or individuals in fragile situations, such as post-operative, clinic recoveries or prolonged treatments, should not be institutionalized longer than the absolute necessary for a number of reasons, including clinical, economical, and most importantly, human reasons. Instead, these people can remain in the comfort of their homes, as long as they are frequently monitored and maintain remote communication with their caregivers. Patients should be as autonomous as possible, actively engage on getting healthier, and feel safe. Telemonitoring and teleconsultation tools can help both patients and professionals in their daily lives. Caregivers can use these tools to schedule important tasks and provide reminders to the patients about their responsibilities, such as attending teleconsultations, measuring vital signs, taking their medication, and perform physical activity. Altice has developed a telemonitoring platform called SmartAL to help institutions, their staff and patients with all these daily routines.

Surgical care in vulnerable sites

Vulnerable sites (e.g., remote areas, developing countries, military settings, or emergencies) can benefit from virtual and augmented technologies, which can extend real-time collaboration between experts, namely in the fields of surgery and radiology. Besides training and support for less qualified health professionals and streamlining resources, these solutions can also reduce long-distance travel for surgeons and radiologists. Altice's long-standing experience in regularly providing teleconsultation services (offered by Medigraf [9]), connecting specialized hospitals in Portugal to other institutions located in countries like Cape Verde and Angola, has been possible due to the availability of reliable connectivity.

The existence of a robust infrastructure, especially during global health emergencies and in the face of real-time requirements, is a primary condition. The ubiquitous adoption of 5G technology (ensuring low latency, high reliability, and high bandwidth) is of great importance, considering scenarios involving robotic surgery and immersive virtual simulations, where haptic feedback and virtual control of critical medical procedures demand high connectivity for effective operation.

Rescue scenarios

For remote monitoring and evaluation in critical scenarios, solutions like the ones enabled by drones can be a gateway to increase the quality of healthcare services. Despite some current challenges related to safety and security and the involvement of local authorities, important results have already been described when using drones to support innovative healthcare approaches [10].

When associated with 5G networks, drones can be part of an innovative health approach to support critical communications scenarios: complementary monitoring solutions provided by rescue teams can communicate with drones, while these can enable the aerial observation of an accident scenario and facilitate real-time rescue operation. This is particularly relevant when considering public protection and disaster recovery situations.

Altice Labs has already set up demo scenarios associating teleconsultation, monitoring, and aerial observation

via a 5G infrastructure to show its potential. In September 2019, Altice Labs conducted a public protection and disaster relief (PPDR) simulacrum to demonstrate the potential of 5G technologies, involving the Aveiro City Council, the local Civil Protection Authority, the Public Security Police, the Baixo-Vouga Hospital Center, the Military Health Center of Coimbra, and the two Aveiro volunteer fire corporations. Rescue teams – security, fire brigade, and emergency medical teams – were mobilized to provide aid to a driver involved in a simulated car accident. A drone was used to scan the area and collect information about the tactical means necessary for the firefighter to carry, and sensing vests were used to monitor the vitals of the firefighters and police officers involved. Also, teleconsultation services were in place between the ambulance and the hospital to ensure the best healthcare assistance possible (as depicted in **Figure 2**). This year, a similar exercise took place in Funchal, Madeira, using the commercial 5G network from Altice, with remarkable success. The use of 5G-enabled healthcare applications in emergency situations, especially in difficult access places like ravines, is extremely important for local authorities. Also, this year, a real-time streaming operation using virtual reality devices took place at the Champalimaud Foundation, in Lisbon, and was visualized remotely, in Aveiro, via 5G. These are just some interesting scenarios where technology is a major triggering factor.

Figure 2 – PPDR simulacrum (Aveiro 2019)

Emergent technologies

Big data, analytics, and AI

Big data and analytics in healthcare allows for better collection and analysis of patient data, enriching prevention, monitoring, diagnosing, demand management, and fostering innovation and research. Contributing to the digital health scientific domain requires the implementation of open, secure, and robust policies regarding health data. For example, big data processing is of paramount importance in the epidemiologic field, as it can give epidemiologists a better understanding of diseases' evolution and allow them to prevent worst-case scenarios or at least anticipate actions and mitigate their consequences.

When looking at the services level, an integrated and interoperable approach to health data is needed. For instance, an application to be used by patients with respiratory problems needs to interoperate smoothly with environmental data on pollution [11], and apps designed for people with diabetes must be integrated with real-time glucose monitoring devices. Data is currently being collected from innumerous types of sources, like clinical devices, wearables, questionnaires, exams, images, etc.; the challenge, however, is to guarantee that it is 'good quality data'. Analytics and machine learning (ML) algorithms do not run well on poor-quality data, meaning non-reliable or less meaningful data. In this case, inferences, conclusions, and recommendations may lead to results with potentially dangerous consequences for the patient.

AI has also been described as a potential tool to improve e-health literacy and combat misinformation/disinformation phenomena (such as the COVID-19 infodemic): AI-augmented lifelong learning, AI-assisted translation, simplification, and summarization, and AI-based content filtering are currently important fields of innovation [12].

Cross-wising these benefits, security challenges must be kept in mind, as confidentiality and data privacy will always have to be protected.

In collaboration with external entities and universities, Altice Labs is currently working on the analysis and development of ML algorithms to support the diagnosis and give recommendations to patients suffering from retinopathy, an eye condition that can cause vision loss and blindness (often a complication of diabetes), and chronic diseases such as hypertension and diabetes.

Ambient sensing and connected technologies

Digital technologies can support healthcare providers to better deliver care at home. In this area, the COVID-19 pandemic also revealed new opportunities to accelerate the creation of new models of hospital-at-home care and prevention and follow-up.

Wearable biosensors have an important role in collecting and monitoring a wide range of physiological parameters that, when combined with other data (for example, electronic health records, EHR), can support clinical decisions, expanding care beyond hospital walls. It's a new approach that can improve outcomes, reduce costs, and offer more convenient care, namely for minor illnesses, recovery stages, age ailments, chronic diseases, etc. Besides physiological data, psychological, social, and environmental parameters can also be collected, extending the patient monitoring to other complementary layers, such as the emotional one.

Ambient sensing and connected technologies have great potential, for example, in assistive healthcare robots. But despite having shown early promise, they revealed some fragilities as their value did not prove to be able to support their costs. Nevertheless, Altice Labs has adapted its telemonitoring application SmartAL [13] to one of these robots [14] as part of its job to create new and inventive solutions running on different devices and interfaces to serve different types of people. Robots seem to have great potential as quick healthcare enablers to help elderly patients or, generically, people with limited mobility in their daily lives. Simple things, such as watching a video or answering a questionnaire, can be performed via a robot interface. Also, tasks scheduled by healthcare professionals using the SmartAL web interface or the mobile app may be presented to the patient in a friendly way. For example, when the time comes, the robot may talk to the user using an encouraging sentence and remind him or her to stand up and walk slowly for the next ten minutes, or say "*Please take your medication. It is not a big deal, just takes 1 second!*". The robot can also ask the user to measure the blood pressure at specific moments since it has a Bluetooth interface that allows automatically collecting vitals from several clinical devices. Furthermore, it responds to voice actions, is capable of face recognition, and maps indoor locations after a pre-learning scanning process. So, it may become handy to send it to some predefined locations (e.g., living room, sleeping room) and ask it to collect a box of pills or scan the entire house looking for an informal caregiver to hand over a thermometer to perform a daily measurement.

Despite some still prevalent barriers regarding users' privacy, security, and policy issues, ambient sensing and connected technologies can also ensure the surveillance of residential users. Behavioral analytics can be used through unobtrusive monitoring and real-time situational data, promoting patient safety and detecting abnormal behaviors. The IoT paradigm leveraged important trends, namely the ones related to assisted-living environments and smart homes, supporting vulnerable residents to live longer independently in their own homes [15].

In this context, the SmartHome [16] solution developed by Altice Labs is tailored to control the environment in the house (e.g., lights, plugs, heating) and ensure security (e.g., motion, fall and opening/closing doors and windows detection), but it can also provide precious complementary information to the SmartAL assisted living ecosystem, since all this IoT data may be used to learn more about the habits and routines of the residents and infer anomalous and risky situations, in terms of the state of health and well-being.

Besides IoT, mobile and wearable technologies (e.g., smartwatches and smartbands) are increasingly being used to collect physiological, contextual, and environmental measurements. Also, low-intrusive technologies such as contactless devices (e.g., contactless portable respiratory rate monitors, thermometers), wearable sensing solutions (e.g., flexible sensors and electronics, textile sensors, etc.), technology integrable into daily objects (e.g., capacitive sensing integrated into chairs), and implantable devices are being used to collect data. On top of this, AI and predictive analytics can translate data into knowledge, providing real-time insights valuable to make better-informed decisions and automating and streamlining work processes to reduce the burden of providing care in accordance with every patient situation. Using these approaches, patients can be monitored completely transparently with reduced intrusiveness.

As for teleconsultations, these can have the potential for non-emergency care, symptom triage, and improving access to healthcare services for those with mobility challenges. It is a scenario that can reduce the number of unnecessary trips to emergency rooms and be a part of the patient's care continuum, including prevention and follow-up. This is particularly relevant for patients with chronic conditions. Assessing the condition of patients before face-to-face consultations is a significant benefit, enabling the monitoring of at-risk patients.

This partnership between empowered patients-at-home and physicians is creating new scenarios of participatory health, in which patients are true partners of the process, being of utmost importance to include them in the design of healthcare models [17].

As a part of this vision, Altice Labs developed two products already mentioned in this article, Medigraf, and SmartAL.

Virtual and Augmented Reality

Healthcare paradigms are evolving, placing the patient at the center, developing a continuous process and shifting the care from a hospital-driven approach to a home-driven or pervasive approach. In this context, the wide adoption of new low-cost and patient-adaptive technologies for remote patient management is enabling trustful, transparent, and minimally intrusive monitoring. These technologies harness effective pHealth solutions – personal, personalized, predictive, preventive, pervasive, and participatory.

Cognitive and physical rehabilitation based on Virtual Reality exergames is just a fraction of the broad potential of emerging Extended Reality and AI technologies applied to this new context.

We have been unlocking a powerful ecosystem around SmartAL's task scheduling and monitoring capabilities, which may play a significant role in our aging society. This ecosystem will provide patients, relatives, and caregivers a balanced set of XR tools to support particular rehabilitation needs, as well as prevent their occurrence through regular monitored activity. The goal is to maintain and improve individuals' physical and cognitive capabilities, for a better assisted life.

Altice Labs' e-health solutions

Medigraf

Medigraf [9] is a teleconsultation and clinical data-sharing solution that allows healthcare professionals to work together remotely on a given clinical case. It offers a collaborative web environment over internet access to conduct medical appointments using audio and video conferencing tools. During the conference, it is possible to share real-time streaming information coming from medical devices (e.g., ultrasound images) as well as medical imaging information and data (digital imaging and communications in medicine, DICOM) or simple files (e.g., photos/images or analysis/pdf).

In 1998, the strategic purpose of developing this tool was to bridge the lack of specialized healthcare professionals in remote areas and offer patients better diagnoses and treatments. Also, it was important to bring more comfort and reduce costs from the constant travel of patients from peripheral regions to central hospitals (where the medical specialists are usually located) and medical specialists that need to assist other professionals on more complex cases. To fulfill this gap, Medigraf allows healthcare professionals to work remotely as a team, regardless of the distance between them. Over the years, this platform has become an everyday tool for healthcare institutions, responding efficiently to the needs of physicians, favoring collaboration, and enabling the implementation of a new paradigm of communication and cooperation. Besides regular teleconsultations between healthcare professionals in different institutions, Medigraf also allows one to schedule and perform teleconsultation appointments directly with the patients, which proved to be an extremely important feature during the pandemic (**Figure 3**).

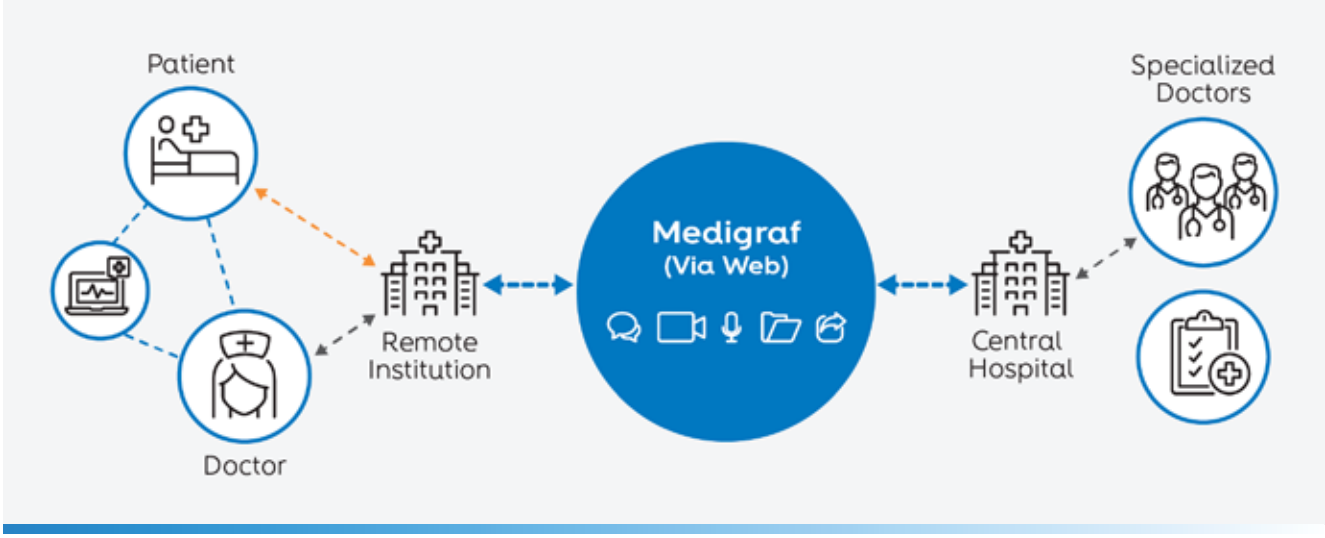

Figure 3 – Medigraf: teleconsultation doctor-doctor and doctor-patient

Currently, the Medigraf solution is the key supporting tool of a regular teleconsultation service between specialists at the Central Coimbra Hospital (Centro Hospitalar e Universitário de Coimbra - CHUC) and doctors in remote hospitals from Portugal's central and northern regions. Moreover, it provides a similar service to hospitals

in Portuguese-speaking African countries, like Angola and Cape Verde, and private institutions of public utility, as in the case of Instituto Marquês Vale Flor (IMVF) [18] in several medical specialties. This institute plays a very important role in medical cooperation with São Tomé and Principe and other Portuguese-speaking countries.

SmartAL

SmartAL [13] is a technological ecosystem that aims to simplify people's daily lives from both a clinical and social point of view. It was designed as a flexible solution to meet various assisted living use cases, from seniors to children, from care for chronic diseases to home care, and from social prevention to clinical follow-up of people in a state of fragility or isolation. This tool helps people with their daily care needs, as well as their families, professionals, and health/social care organizations.

SmartAL is a telemonitoring and teleconsultation tool where end-users (patients, family members, and caregivers) may follow in real time the health status of the patients while other ecosystem participants may assist with several complementary actions **(Figure 4**).

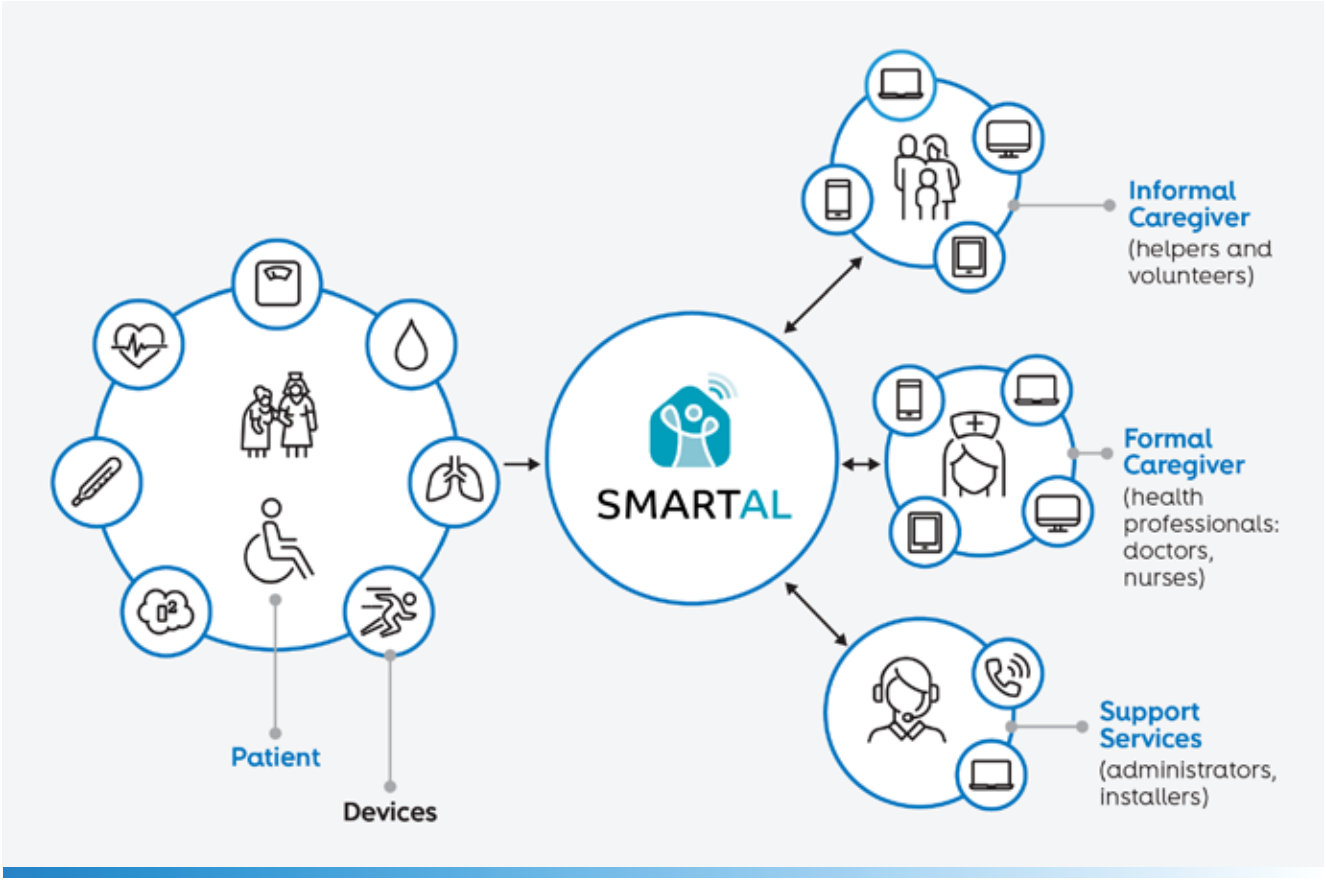

Figure 4 – SmartAL ecosystem

The core functionality of this tool consists of collecting information from clinical (e.g., oximeter) and non-clinical devices (e.g., personal band) and making it available to both patients and caregivers to have an overview of the patients' vital signs (**Figure 5**). The collected data is compared with the thresholds previously set by health professionals, and if values are outside the limits, notifications are immediately sent so that actions can be taken (e.g., schedule a teleconsultation).

Figure 5 – SmartAL clinical and non-clinical devices (wearables)

From the patients' perspective, the key concepts that guide and sustain their daily activities are tasks and plans (groups of tasks); tasks are usually scheduled by caregivers to keep track of the users' daily duties and to remind them when to perform them. There are predefined types of tasks, such as collecting clinical measurements, taking medication, and participating in teleconsultations, but there is also a free type that allows professionals to add new activities on the fly (e.g., take a five-minute walk, drink a glass of water every day). A task may be assigned to one or more patients and configured by defining the time interval in which it should be executed and who should be notified in case the task is or is not executed.

In addition to telemonitoring and teleconsulting, SmartAL also allows for the inclusion of simple questionnaires to assess the general state of well-being of the patient, and videos, to help him or her in the use of clinical equipment, how to deal with his/her illness or give incentives and recommendations about nutrition and other healthy habits.

SmartAL is based on different services and technologies, aiming to serve everyone in the friendliest way possible. It is multilingual and supports multiple user interfaces so that it can be adapted to the needs of each customer (see **Figure 6**). It can be accessed via smartphone, tablet, PC/web browser, or TV (as an interactive IPTV mediaroom application or on Android TV). The caregiver/professional can access a complete front office via PC or tablet. The platform provides all the configured services and manages the scheduling of each user, generating

automatic alerts and notifications that can be sent to both end-users and caregivers on multiple interfaces. SmartAL allows end-users to achieve a high degree of independence, autonomy, and dignity, feeling safe both inside and outside the home, as they have a friendly tool that helps them manage their daily lives and prevent risky situations.

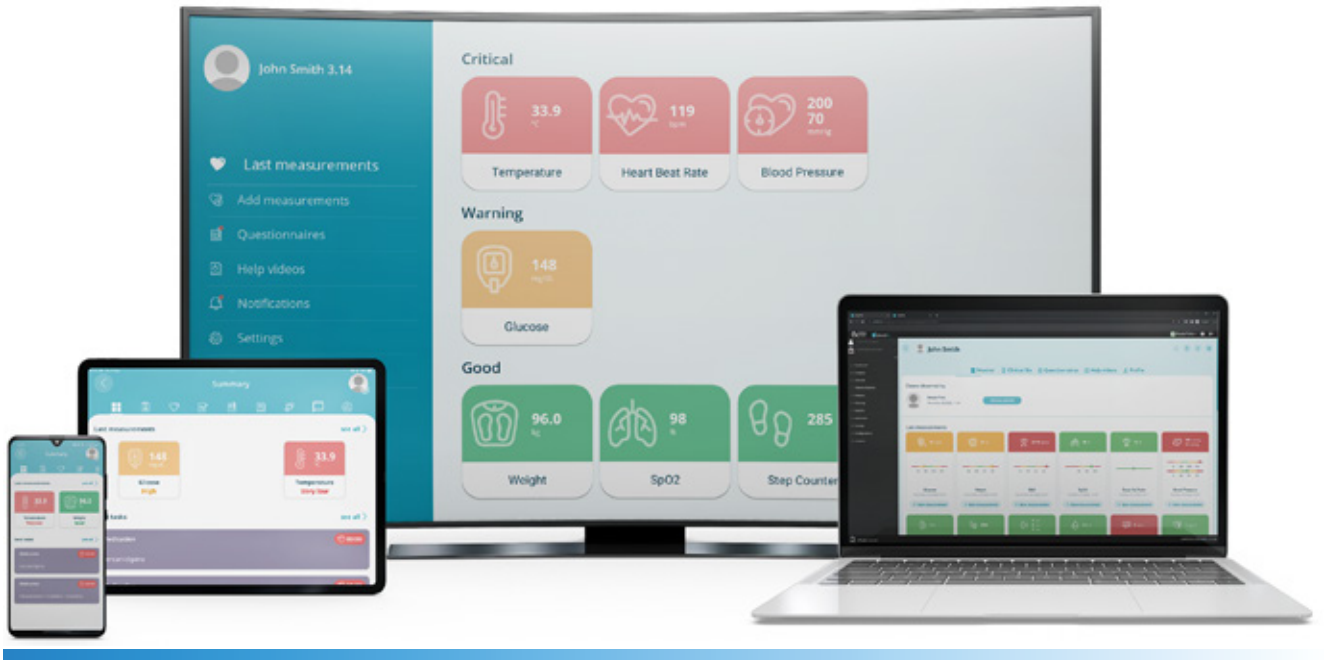

Figure 6 – SmartAL user interfaces

In summary, SmartAL is capable of serving multiple target audiences with various benefits to both end-users and professionals, while it is foreseen to have a stronger impact on several clinical and social aspects, such as: extending the time people can live in their preferred environment by increasing their autonomy, self-confidence, and mobility; supporting the maintenance of health and functional capabilities of end-users, namely old adults; promoting a better and healthier lifestyle for individuals at risk; improving 'always-on' interaction between each person and his social ecosystem, especially with their caregivers, preventing social isolation and increasing their feeling of personal security; and finally, stimulating the growth of supported clients (more revenues), for individual professionals and institutions.

Valuing person-centric health experiences

Digital tools can empower a person-centered healthcare approach. Current trends show the importance of creating positive end-user experiences when designing digital health services. Easiness, comfort, and scalability are critical issues when designing health interfaces, enabling:

For the end-users, an immediate sense of the product value and available features, reduced screen time, and low-level skills to understand how to interact with systems.

For the development teams, no need to add new layers of complexity every time a new product or service is presented, supporting the rapid deployment of new applications.

Such a strategy can help scale up new solutions, deliver better user experiences adapted to all, and ensure patient engagement and loyalty. This new approach can leverage people-care and value-based care strategies.

For those in vulnerable situations, it is even more important to develop community-based participatory approaches, namely when researching user needs to inform interface design. Differentiating life situations, motivations, and e-health expectations is the basis for developing digital health solutions adjusted to end-users' daily lives [19].

Person-centric healthcare delivery models underline the importance of looking at digital engagement as a driving force for the enhancement of patient experiences. It is necessary to deepen attention to the development of solutions that can leverage the creation of trusted digital relationships and prioritize access to empathic, comfortable digital experiences. Poor user-centered design can lead to low digital adoption.

Health professionals are also first-level beneficiaries of a more enriched and person-centric approach to interface design. Among other reasons, health professionals' burnout has been described as caused by poor EHR usability. A well-designed interface can reduce the time and effort required to use EHR. This is particularly relevant considering clinical data's growing complexity and volume.

In this context and as part of its evolution strategy, SmartAL is being restructured following, on the one hand, new usability guidelines and accessibility principles and, on the other, standards [20][21] to shape a new EHR able to store all the relevant patient data and ensure communication with other health care systems and databases. Also, engagement and gaming techniques (some involving virtual reality) are being developed and incorporated into the application as incentives for the users. Games will be considered in different contexts, such as cognitive training, physical exercise, physiotherapy, entertainment, and socialization, since they are proven to be a determining factor in recovery.

Conclusions

Digital health is a strategic approach meeting the need to provide health care to an increasingly aging and often isolated population and those who need continued care without needing to be institutionalized (e.g., chronic patients). Technology can accelerate care delivery in these cases, transforming and optimizing healthcare.

Despite the recent developments described, data, interoperability, trust, credibility, and security challenges should be addressed at all stages of the development process. Each stakeholder involved in creating digital health solutions must be aware of the importance of consent, data ownership, privacy issues, and legislative compliance, namely with the European Union General Data Protection Regulation and Medical Device Certification. Working towards surpassing interoperability challenges is also necessary.

To retain the loyalty of consumers and support future developments, it is necessary to deepen knowledge of patient engagement strategies. To ensure such an approach, it is necessary to engage with early adopters and better scale-up pilots, advancing from trials to more sustainable development models.

It is also of the utmost importance to establish strategic partnerships with diverse stakeholders, exploring, among others, opportunities in social responsibility with vulnerable populations. Use case diversification can be a path to enlarging the view of the broad spectrum of populations and scenarios that can benefit from the developments that digital health has brought to the scientific community, the industry, and the market.

Further attention must be put in looking into evaluation and impact measures, namely through health technology assessment approaches [22]. These can be an instrument to provide evidence, determine the value of digital health solutions, and inform guidance to support future innovations.

A continuous commitment to this evolution cycle is needed, creating sustainable and integrated strategies [23] able to be the catalyst for the improvement of technological, social, and human development, and in which the ‘experience of care’ is valued as one of the most important dimensions to support the design of innovative approaches in what concerns digital healthcare.

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Acronyms

AI	Artificial Intelligence
Android	Mobile operating sustem developed by Google
CHUC	Centro Hospitalar e Universitário de Coimbra (Central Coimbra Hospital)
COVID-19	Coronavirus disease 2019
DICOM	Digital Imaging and Communications in Medicine (the standard for the communication of medical imaging information and related data)
EHR	Electronic Health Records
IMVF	Instituto Marquês Vale Flor (a foundation for development and cooperation across portuguese speaking countries)
IoT	Internet of Things
IPTV	Internet Protocol Television
ML	Machine Learning
PC	Personal Computer
PPDR	Public Protection and Disaster Relief
TV	Television
WHO	World Health Organization

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