Human-Centered Design Smart Clothing for Ambient Assisted Living of Elderly Users: Considerations in the COVID-19 Pandemic Perspective

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1 Introduction

The relationship between Design Research and older users has been deeply improved during the last decades [1] in the light of the worldwide constant growing of the average age of the populations, especially in the most developed countries [2]. The aging trend brings with it deep changes in the social scenarios across the world, regarding primarily the fields of social welfare and health assistance that require a continuously increasing engagement of the public and private sectors to conceive new assistance and welfare tools to guarantee fair and healthy aging to the largest possible amount of people all over the world [3]. Design Research is widening its boundaries to express its dimension related to the social improvement in different fields; in the light of the current scenario, one of the most significant and promising applications is Design for the Healthcare practice, a field where design becomes the interface between people and innovative technologies, combining multidisciplinary contributes to empower the user’s autonomy, monitoring health status and well-being improving quality of life [4]. The application of the design principles in the healthcare sector seems to be a promising tool to optimize strategies and investments, making them properly feasible and effectively responding to patients’ needs [5].

Design Research has always had a deep connection with the detection and satisfaction of people’s requirements, even if they were belonging to small niches of
users characterized by specific peculiarities not common to the rest of the population. Within the Design Discipline, there are many possible approaches to empower the design process to gain a more effective response to users’ needs and improve their quality of life, and one of the most popular and experienced ones is Human-Centered Design (HCD), developed to be an approach on problem-solving that involves the human perspective in each stage of the design project [6]. Literally cite the current standard, “Human-Centered Design is an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques. This approach enhances effectiveness and efficiency, improves human well-being, user satisfaction, accessibility and sustainability; and counteracts possible adverse effects of use on human health, safety and performance” [7].

Transposing this concept to the field of design for the elderly, HCD allows in developing design processes that consider the affections of the older person’s performances as invariants of the project, not making those a responsibility of the final user. To make the described approach, it is often accompanied by co-design, a design tool useful to directly and personally involve the users in the whole design process, making them active participants to the project and designing with them instead than for them [8]. The great importance of the users’ involvement in design project has been investigated from many perspectives and the co-design tool tries to explicit the good practices that can improve the results of the process by engaging the user in every single stage and collaborating with him for the definition of objectives and requirements, for the prototyping and testing phase, and in all the iterative design process phases [9].

The current technologies have a central role in developing human-centered solutions: their constant evolution creates continuous new possibilities of application and technology transfer. The concept of Internet is evolving from “a network of interconnected computers to a network of interconnected objects” (European Commission 2009), giving birth to the Internet of things, a platform including daily objects, devices, environments, and services. A growing portion of the IoT is dedicated to consumer applications, especially regarding the smart home, making possible a connection between different devices to help the user in improving his status of health and well-being. Referring to design for aging people, the Internet of things gives to designers a huge amount of new possibilities in creating smart solutions for the daily monitoring of the person in the daily environment, and the choice of a human-centered approach in those typologies of design projects seems to be useful in the expansion of the effectiveness of the conceived design solutions and addresses to specific users [10].

Based on the previous consideration, this chapter aims to study and discuss the current smart garment technologies based on HCD approach for Ambient Assisted Living (AAL) for monitoring and improving life quality, lifestyle and health of elderly users looking to the impact of the coronavirus (COVID-19) pandemic.
2 COVID-19 and Human-Centered Design for Older Users

Something tragic and unexpected has happened in recent months that has challenged many of the assumptions which are based on the current research practices related to the field of design for older people: that was the COVID-19 pandemic which has spread dramatically throughout the world, putting the current system in crisis in many different sectors.¹

The HCD practice and the co-design tool, applied to the design for the aging field, have always been based on several assumptions on needs and requirements taken as invariants for all the projects addressed to that typology of users, regardless of whether the projects concerned devices, services, or processes. Those assumptions are the ones regarding culture, personal status, diffused pathologies, daily habits, statistics on preferences, etc. Today, unexpectedly, the COVID-19 disease has deeply changed our society affecting our daily habits, instilling new fears, modifying the relationship with other people, and changing the perception of public and domestic environments. Those new feelings determined changes in human relationships, routines, future programs, and expectations creating a new context, with new rules and new ways of interaction between the person, the objects, and the environment.

Particularly, in Europe, elderly were the hardest hit category because of their past pathologies that made them more vulnerable to the virus, and in many cases because of their necessity of personal assistance or hospitalization, which makes them more exposed to contact with healthcare professionals who may have been infected by other patients. The previously achieved balanced condition between the typical diseases of old age and good quality of life is today questioned by the current context [11].

Regardless of when the situation will be resolved, and we hope it will happen as soon as possible, it is not too early to notice that that event’s consequences will significantly impact on the world’s balances even in the medium and long-term perspective.

Containment measures taken to combat the virus, such as the mask and social distancing, have given rise to new behaviors, new ways of interaction and new reasons of satisfaction and frustration. The paradigm in which we operated has profoundly changed and requires today to be read again and interpreted especially concerning the requirements of users as the elderly. In HCD, we used to explicit requirements and collect needs to set the project’s specifications: We used to analyze project invariants related to issues regarding available technologies, ergonomics, biometrics and all the information on the user category that is deductible from his targeting; and combine them with the project variables, determined by the personal goals and frustrations, the specific physical and health conditions, habits and preferences of the specific user. Both human project invariants and variables were then summed to obtain the human project specification. COVID-19 is challenging our usual practices because as our basic assumptions seem to be less effective: There is

¹https://www.who.int/health-topics/coronavirus#tab=tab_1.
much information we used to take for granted that today are not reliable anymore, requiring the hardest work of collection and interpretations of the human diffused and personal behaviors.

Just to make some examples, here are some statements that could be taken as granted before COVID-19 but now are not so reliable; the statements are referred to older users living in their own home and not needing constant assistance from a caregiver:

- Older users need to frequent their relatives as much as possible, especially the youngest ones.
- It is good for older users to attend different places to socialize and interact.
- Older users need to carry out different activities independently, to decide their favorite lifestyle feeling autonomous.
- Traveling, meeting new people, and undertaking new hobbies are effective stimuli to keep the person active.
- Personal assistance always reassures the elder’s relative on his safety condition.
- The older person needs to go regularly at his doctor’s office for effective monitoring of his health status.
- It is useful for the older user to be involved in each stage of the design process.
- The best strategies to collect the needs of a specific user are to interact with him in person.

In the light of the pandemic, those statements, that before were human project invariants, today shift to the list of the human project variables, which the designer and the multidisciplinary research team need to investigate project by project referring to a specific context and a specific group of users, because Design Research literature referred to COVID-19 now is not yet exhaustive enough to suggest good practices for HCD processes (Fig. 1).

3 The Impact of COVID-19 in Ambient Assisted Living (AAL)

As we can say that the virus has removed certainties from many established practices, so we can assert that it already suggests new certainties about what the post-COVID-19 world will be. It is already pretty obvious that public investments on health and welfare tools will be empowered that hospitalization modalities need to be rethought and that the personal assistance for the elderly could be not as safe as it should be.

The authors work in the field of HCD for AAL that is now facing the impact of the virus on its methodologies on design processes.

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2 The statements were collected in the PhD research of Silvia Imbesi, “Inclusive Design for the elderly”.
AAL involves the use of smart devices, wireless networks, software applications, computers, and sensors that, thanks to the Internet of Things, modify the user’s environment to make it safer, healthier, and more adaptive to the specific person’s needs. The possibility to transform the place where the user lives, making it adaptive and personalizable autonomously depending on the received inputs, opens to many chances. Especially for the elderly, being autonomous in daily habits, feeling independent, and not a burden for the family, keeping the health status constantly monitored and postponing hospitalization, are all elements that can significantly improve the quality of life of that category of people.

Considering the current pandemic, something has changed in the way people perceive their own home that has become a sort of safe haven in which to shelter to escape the virus, but at the same time even a prison where you were obliged to stay during the worst phase. That new condition makes necessary a strong improvement of the activities that the elderly should carry out while staying inside the house, avoiding where possible to expose themselves to the risk of infection by leaving the house or attending other people. In the light of this context, AAL takes huge importance as a tool to protect the person by letting him stay at home but without any decrease in the services offered and the degree of protection.

4 Smart Clothing for Elderly

Smart clothing is becoming an essential tool in Ambient Assisted Living for monitoring elderly at home in an ecological approach and in a non-intrusive way, Fig. 2.
There is an intersection between ambient assisted living and smart objects, generating the field of Smart Clothing.

Smart clothing as other IoT-based device can be used in different scenarios such as in industry, for Defense and Public safety (military), for Ambient Assisted Living in cities and home but also as a tool for personalized care.

Especially, they can be used for monitoring biosignal (physical, biochemical, and physiological), daily life activity, and localization in vulnerable group such as elderly as represented in Fig. 3.

We can distinguish “active,” “passive” and “very smart” garments [12]. Passive smart clothing can only sense the environment; active can sense and react to external stimuli and finally “very smart” where they can sense, interact, and adapt to environment and stimuli [12]. According to Rantanen and Hännikäinen (2005) [13], the human system integration is made by different layers. An inner one is between the human and the textile. Moreover, an outside layer is between the garment and the environment. Between these layers, the communication is made by interface as a fastener that serves to support the process unit such as an electronic board that contains battery and IMU sensors for physical monitoring. Between these layers, the communication is spatial, external, and internal. Human system integration and interaction are affected by the wearability of the user. Gemperle (1998) defined the guidelines for wearability composed by 13 items [14]. Between them, body placement, form language (body shape), and accessibility are the main items that should be more considered in designing smart clothing for elderly care. Cho 2009 [12]
Fig. 3 Scenarios for IoT-based devices

describes body position sensors for biosignal monitoring such as physical (movement) and physiological (electrodermal, electromyographic, electroencephalogram activity, impedance, respiration, body temperature, blood pressure, pulse, blood gas) (Fig. 4).

Furthermore, some of these signals can be integrated into a smart garment for monitoring elderly health and well-being.

An example textrode made of conductive fabric positioned at the chest level is used for electrocardiogram (ECG) and heart rate monitoring by transthoracic electrical bioimpedance measurements [15–17] captured by two fasteners connected in the front with the process unit that contains also IMU sensors or accelerometer for activity detection such as body posture (sitting, laying down,...) or falling. This is connected to a server that communicates by Bluetooth to a dedicated app that allows monitoring of the data in real time or storage of them for successive analysis. This information can be provided to the cardiologist for remote cardiac monitoring (Fig. 5).
Besides, Guan et al. 2017 [18] proposed a system that integrates the smart clothing with a home gateway and home server for remote patient ECG monitoring. The device proposed is a smart shirt that contains three lead ECG monitoring and three-axis accelerometer for body states as walking and falling.

The signals are sent from the smart cloth to the home gateway by Bluetooth (low energy). Then, after processing and compression, these signals are sent to a healthcare server developed on the WAMP platform and are transplanted onto the Ali Cloud platform. Elderly can scan a QR code present on the smart cloth through a camera to connect themselves with the home gateway. Successively after login, four different modules such as monitoring center, health records, connection, and system setting appeared, as figure [18]. A similar device is proposed by Huang et al. 2019 in Fig. 4 [19]. Data is collected through the smart shirt and the body tag and a smartwatch. Successively, data is updated to the service that in the case the signal is abnormal send an emergency message to an app to inform the caregiver. Lin et al. (2018) [20] proposed a similar system where the smart shirt is connected by Bluetooth to a network that is connected to the cloud where the data is presented in Web mode to the mobile device of the caregiver or the doctor. The smart clothing device operates
for surveillance (indoor localization “anti-lost,” tracking physical and physiological status and fall detection).

As MagicIC shirt presents a similar network, the smart shirt is used for home monitoring of cardiac subjects. The smart shirt is connected to a telecommunication system (UMTS) dongle for data transmission to cardiologists. Every patient normally performs three sessions of 3 min telemonitoring for 30 days [21, 22].

Lu et al. 2018 [23] presented a similar network using a smart shirt front zipper with a pocket with a sewn electrode. The proposed system is used for physiological function training, activity domain monitoring, fall detection, and emergency help.

As an alternative to the smart shirt, Burns et al. [24] proposed a bra for monitoring ECG and activity of older walkers through the city. Yeung et al. [25] proposed smart socks for monitoring step count, cadence, and velocity in older and neurological patients as Parkinsonian. As a while, Najafi et al. [26] proposed smart socks for
monitoring plantar temperature and pressure and joint angle in patients with diabetic peripheral neuropathy.

Kim et al. 2012 proposed a smart glove for hypertension composed of an inner and outside glove [27, 28]. The inner one contains electrodes stimulating sites for Transcutaneous Electrical Nerve Stimulation (TENS), while the outside protects the inner part. The transmission bands are connected then with an arm band with the tens. The gloves were applied on 12 patients demonstrating a reduction of blood pressure from $142.58 \pm 9.90/82.46 \pm 4.45$ mmHg to $119.83 \pm 9.23/75.79 \pm 4.90$ mmHg in systolic blood pressure.

Likewise, Yang et al. 2018 [29] proposed an e-sleeve for FEM simulation, training software and Kinect sensor testing them in eight stroke survivors.

5 Smart Clothing Acceptance

Smart clothing presents the capability to monitor elderly through the city without affecting their performances, improving assistance and their family caregiving [30–39]. Tsai et al. (2020) [31] proposed a technology acceptance model for investigating 50 elderly perceptions regarding the use of a smart vest for monitoring posture (Fig. 5). Several variables with different items were investigated as shown in Table 1.

Material resulted in one of the most problematic issues affecting the user. In fact, they prefer cotton fabric ant-allergic comfortable and breathable. These conditions revealed an issue that reduced their anxiety.

6 Discussion

Design, aesthetics, and technological issues need to be considered in the functional co-design process for designing smart clothing for elderly. Our suggestion is to use a washable smart garment with breathable fabric with seamless technology. The smart garments need to present front or lateral zip (with easy-grasp pull) easy to dress also if you are sitting or lying down. The smart garment should present a fastener in the front for connecting the cloth with the process unit that can be removed during wash. Besides, these clothes should be connected using QR code or beacon to a dedicated app for remote patients care and monitoring. We suggest avoiding smart bra or shirt that is needed to pull them over the head. In addition, a fall protection pad should be entered in removable hidden pockets. Also, anthropometry and 3D body shape analysis should be considered for designing personalized cloth for elderly monitoring [17].
| Table 1 | Technology acceptance model as described by Tsai-Hsuan Tsai et al. [31] |
|---------|---------------------------------------------------------------------|
| Variable                      | Items                                                                 | Description                                                                 |
| Technology anxiety            | TA1                                                                 | I feel apprehensive about using the smart clothing system                  |
|                                 | TA2                                                                 | I hesitate to use technology for fear of making mistakes that I cannot correct |
|                                 | TA3                                                                 | I am afraid that the equipment may suddenly stop functioning               |
|                                 | TA4                                                                 | I do not want other people to see me wearing smart clothes                 |
| Perceived ubiquity            | PB1                                                                 | A smart clothing system that provides healthcare information “anytime and anywhere is crucial |
|                                 | PB2                                                                 | The smart clothing system provides me with anytime and anywhere communication and connectivity |
|                                 | PB3                                                                 | I will use the smart clothing system very often for health purposes        |
| Resistance to change          | RC1                                                                 | I do not want the smart clothing system to change the way I deal with related problems |
|                                 | RC2                                                                 | I do not want the smart clothing system to change the way I keep myself healthy |
|                                 | RC3                                                                 | I do not want the smart clothing system to change the way I interact with other people |
|                                 | RC4                                                                 | Overall, I do not want smart clothing to change the way I currently live   |
| Perceived usefulness          | PU1                                                                 | Using smart clothes will improve my life quality                            |
|                                 | PU2                                                                 | Using the smart clothing system will make my life more convenient.         |
|                                 | PU3                                                                 | Using the smart clothing system will make me more effective in my life     |
|                                 | PU4                                                                 | Overall, I find the smart clothing system to be useful in my life          |
| Perceived ease of use         | PEOU1                                                                | I find the smart clothing system to be clear and understandable             |
|                                 | PEOU2                                                                | I find that the smart clothing system does not require a lot of mental effort |
|                                 | PEOU3                                                                | I find the smart clothing system to be easy to use                         |
| Attitude                      | AT1                                                                 | I think that using the smart clothing system is a good idea                |
|                                 | AT2                                                                 | I think that using the smart clothing system is beneficial to me            |
|                                 | AT3                                                                 | I have a positive perception of using the smart clothing system            |
| Behavioral intention          | BI1                                                                 | I intend to use the smart clothing system in the future                    |
|                                 | BI2                                                                 | I will always try to use the smart clothing system in my daily life        |
7 Conclusions

Coronavirus (COVID-19) pandemic is changing many aspects of our lives: we are experimenting new daily habits, new ways of interacting with other people, a new perception of the environment, and a new relationship with our home spaces and objects. Considering this unexpected modified context, it is important to protect the most fragile categories of users as the older people, who were the most severely affected by the virus. Human-Centered Design smart clothing in Ambient Assisted Living revealed to be a promising IoT device for monitoring elderly health care and well-being in a society that is becoming more a smarter eliminating borders enhancing a new vision of quality life and care. Several smart garments already exist in our society. But some of them are not responding to the requirements of device fit for the purpose of the elderly user’s care. Our suggestion is to use HCD approach for design smart device that is washable, easy to wear, and comfortable without limiting elderly user movement enhancing and improving life quality, lifestyle, and health. In the next future, it is necessary to research and invest more energy in this domain for improving the health and welfare where humans are the protagonist. By 2030, we will have more elderly than youngers, and aging will affect more and more human being of a smarter society. Future perspective needs to be addressed to empowering Ambient Assisted Living where Human-Centered Design smart clothing will become an essential tool for protecting senior citizens.

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