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MAIN SECTION

Habitat Project: Proposals for an Autonomous, Independent and Inclusive Life for Self-sufficient and Non-self-sufficient Elderly People

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ABSTRACT

Growth in the global elderly population necessitates a review and redesigning of the social care system in order to reduce operating costs while maintaining a high quality of life for individuals. On this basis, an academic/industrial research pool has developed the Habitat project (Home Assistance based on the Internet of Things for the Autonomy of All), a research project funded under the POR FESR 2014-2020 initiative of the Emilia Romagna regional authority. The main goal of Habitat is to develop a digital, open, inclusive and flexible platform, utilising advanced technologies—such as the Internet of Things, radio-frequency identification, wearable devices, sensor networks and artificial intelligence—and embedding them into commonly-used objects, such as an armchair, a belt, a radio or an *applique* lamp. The interface of these smart objects is totally transparent and non-invasive. This allows customizable configurations for domestic or community spaces (RSA – residential care facilities, day-care centres, etc.) giving the elderly more autonomy and independence, while monitoring their movements, checking their posture or warning them of health-related events. These activities are fully personalized as each smart object can recognize the individual and thus conform to their specific needs. The project lasted two years and ended in July 2018.

KEYWORDS
elderly; user-centred design; HABITAT; co-design; Internet of Things

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Introduction

Over the last decade, global life expectancy has increased significantly due to several factors, including developments in the fields of medicine and diagnostic technology, greater awareness of health and a healthy lifestyle and greater attention to healthy nutrition.[1-2-3] However, the concept of life expectancy must be distinguished from the concept of quality of life because it would be undesirable to increase the former by drastically reducing the latter.

According to the World Health Organization (WHO), by 2050, the population aged over 65 years will exceed the number of children under the age of 14.[4]

We are therefore facing—and increasingly so in the years to come—an epochal demographic transformation that will necessarily have great repercussions on the economic, social and cultural structures of our society.[5]

In order to deal with this, the WHO has introduced the concept of active aging[6]. Possible strategies to promote healthy aging include fostering healthy lifestyles and disease prevention, trying to make people as autonomous as possible, increasing their self-esteem and independence.

To date, many dependent seniors, and those who are self-sufficient but with mild cognitive or physical impairments, rely on health facilities for their selfcare. Others seek to remain and live in their domestic settings, where professional caregivers are required. However, both solutions present obvious disadvantages and, unfortunately, the former cannot continue in the long term. If the current population growth trend continues, either there will not be room for everyone in healthcare facilities or social and healthcare costs will not be feasible for the economy. In addition, seniors who are cared for in nursing homes have been shown to suffer more frequently from loneliness, depression, and social isolation.[7]

As for assistance provided by caregivers (or family members who apply

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1 Vince Thomas et al., "Estimating the Prevalence of Dementia in Elderly People: A Comparison of the Canadian Study of Health and Aging and National Population Health Survey Approaches," *International Psychogeriatrics / IPA* 13 Supp 1 (February 1, 2001): 169–75, https://doi.org/10.1017/S1041610202008116.

2 Carol T. Kulik et al., "Aging Populations and Management," *Academy of Management Journal* 57, no. 4 (August 2014): 929–35, https://doi.org/10.5465/amj.2014.4004.

3 WHO Are you ready? What you need to know about ageing. Accessed July 07, 2020, https://www.who.int/world-health-day/2012/toolkit/background/en/

4 Elena Borelli et al., "HABITAT: An IoT Solution for Independent Elderly," Sensors19, no. 5 (12 March 2019): 1258, https://doi.org/10.3390/s19051258

5 Reports and data Available online. Accessed July 07, 2020, https://www.aihw.gov.au/reports-data

6 Rocío Fernández-Ballesteros, *Active Aging: The Contribution of Psychology* (Hogrefe Publishing, 2008).

7 Thomas J. Mattimore et al., "Surrogate and Physician Understanding of Patients' Preferences for Living Permanently in a Nursing Home," *Journal of the American Geriatrics Society* 45, no. 7 (July 1997): 823, https://doi.org/10.1111/j.1532-5415.1997.tb01508.x.

for continued work leave to try to look after their loved ones), it must be noted that this carries an important cost for the families, which not everyone can afford.

Therefore, from a quality-of-life perspective for seniors, trying to age in place,[8] while limiting further expenses, would be more efficient.

On this basis, the paper aimed to find solutions that increase people's independence in their own homes by enhancing inclusiveness and accessibility of services, without altering or lowering quality of life. Specifically, the paper describes a precise methodological process that led to the conception and realization of an IoT platform and several interoperable smart objects with the aim of fostering safe, healthy and inclusive aging for both self-sufficient and dependent people in their domestic settings or day-care centres.

HABITAT project presentation and objectives

A multidisciplinary research group, established by many universities and companies, worked to discover new strategies to develop inclusive solutions for the elderly and their families. This was the purpose behind the HABITAT project (Home Assistance Based on the Internet of Things for the Autonomy of All).[4] The project was funded under the POR FESR 2014-2020 initiative of the Emilia Romagna regional authority (Italy) and aimed to develop and test an Internet of Things platform that could allow creation of assistive and reconfigurable environments by implementing, improving or redesigning certain everyday objects. The two-year project ended in July 2018.

The project began by considering many complex and varied objectives. Thus, right from the start, a strategic partnership was established to foster solutions across technical fields by sharing multidisciplinary knowledge and a multitude of strategic tools[9]. Specifically, the authors of the paper are a member group of the Tecnopolo of Ferrara - TekneHub Laboratory accredited by the Rete Alta Tecnologia network, and are specialized in human centred design. The authors' project task was threefold: the group had to design the smart objects and interface of the HABITAT platform, test all prototypes of the assistive environment, and define the final technology readiness level as required by the initial proposal.

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8 Hardison D. Wood, *The Pros and Cons of Nursing Homes* Hardison Wood Legal Blog. Accessed July 07, 2020, https://www.hardisonwood.com/blog/the-pros-and-cons-of-nursing-homes/

9 Elena Borelli et al., "HABITAT: An IoT Solution for Independent Elderly," *Sensors*19, no. 5 (12 March 2019): 1258, https://doi.org/10.3390/s19051258.

Project partners[10] collaborated with companies in Emilia Romagna from various sectors, which offered their design know-how and technical resources for creation of some of the prototypes.

The primary users considered by the HABITAT project were the elderly. The project focused on designing smart-home solutions for seniors starting to face aging-related issues but who are still able to live in their homes without constant professional care, living with their partner or with a relative or alone. The quality of life of these individuals can be significantly improved by enhancing their level of autonomy, prolonging independent living in their own homes and postponing the need for hospitalization.[11] The majority of people in this category of users are not actually confident with the use of smart devices because of differences from more traditional products and difficulties interacting with smart interfaces that are not always truly intuitive in practice. The secondary users considered in the HABITAT project were those people who provide formal or informal care to the main users, such as medical staff, family members, relatives, friends, and so on. Considering this, while the system was not primarily conceived for them, their needs were included in research to facilitate their tasks. The stakeholders considered for the project were people or institutions that do not have direct interaction with the system or with the primary users but were involved in its development or were of particular interest to it.

Based on the above considerations, the aim of HABITAT was to produce many flexible and accessible solutions to promote active and healthy aging of the target audience. In particular, the choice of developing an interoperable IoT platform was due to new and increasingly effective technologies that enable users to personalize and customize the system according to their preferences.

Furthermore, the project produced several interconnected smart objects. According to the purposeful vision of the partners, HABITAT's initial proposal outlined the development of a set of smart devices—such as an indoor localization system equipped with indoor locators, smartwatches and wearable tags, an armchair, and an intelligent multipurpose radio—which were conceived to fulfil the objectives of the entire project.

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10 The other partners of the project are: CIRI-ICT of the University of Bologna, Interdepartmental Center for Industrial Research in Information and Communication Technologies, which cooperated for the definition and the design of the ICT infrastructure for HABITAT life scenarios; CIRI-SDV of the University of Bologna, Interdepartmental Center for Industrial Research, Health Sciences and Technologies, which cooperated for the selection and engineering of sensors and actuators part of the various smart objects; ASC-Insieme, Azienda Servizi per la Cittadinanza - Azienda speciale Interventi Sociali Valli del Reno, Lavino e Samoggia, which cooperated for the definition of requirements, specifications and application scenarios of HABITAT by providing its great expertise gained in the home care sector, specifically managing several Day Care Centers; and lastly Romagna Tech, a member of the Emilia Romagna Rete Alta Tecnologia, which cooperated for the dissemination of project results.

11 Taha Zahari and Ruhaizin Sulaiman, "Ergonomics Consideration in the Design of Products for the Elderly Population", in *Proceedings of the 9th Asia Pacific Industrial Engineering & Management Systems Conference* (APIEMS2008), 2008, 309.

However, during the process, the design strategy changed following direct involvement of the users, which provided new research insights, explained in the next section.

Ten similar devices, available on the market, were compared to each other through a competitive benchmarking.[12]

The results highlighted both advantages and disadvantages of each device relative to users' needs as expressed during previous focus groups with the target audience. The emerging considerations are highlighted by the following points:

- the smart objects must target the real needs of the users;
- the smart objects must be conceived as interoperable elements that can communicate with users through a simple and comprehensible language;
- the final solutions must match users' needs not only in terms of quantitative requirements but also qualitative and emotional needs.

As an example, the wearable devices were criticized by the users involved in the co-design workshops. Consequently, some operating strategies or functionality embedded into the smart objects were confirmed as proposed while others were completely changed.

Methodology

The HABITAT project was developed through user centred design (UCD).[13] The UCD approach was considered perfectly suited for design research related to the Internet of Things because it places great importance on the users' specific characteristics and personal requirements[14]. This allows the design team to develop products, services and systems based on the specific needs of a certain niche category—such as the elderly in the HABITAT project—who have specific abilities and often struggle with usability of some products widely used by the majority of the population.[15]

Regarding the methodological approach, the early stages of the project involved a user analysis to collect as much information as possible on the different users. The multidisciplinary project team conducted surveys, direct interviews and questionnaires with users to collect data on their

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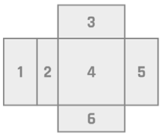
12 Giuseppe Mincolelli et al, "Internet of Things and Elderly: Quantitative and Qualitative Benchmarking of Smart Objects,", in *Advances in Design for Inclusion*, ed. Giuseppe Di Bucchianico, vol. 776, (Cham: Springer International Publishing, 2019), 335–45 https://doi.org/10.1007/978-3-319-94622-1_32.

13 Giuseppe Mincolelli, *Customer/User Centered Design. Analisi di un caso applicativo* (Santarcangelo di Romagna: Maggioli Editore, 2008), 115.

14 see ISO 9241-210:2019 Ergonomics of Human-System Interaction — Part 210: Human-Centred Design for Interactive Systems.

15 Giuseppe Mincolelli et al, "Design for the Active ageing and Autonomy: the Role of Industrial Design in the Development of the 'Habitat' IOT project," *International Conference on Applied Human Factors and Ergonomics* (Springer, 2017), 88.

QUALITY FUNCTION DEPLOYMENT



	RELEVANCE OF NEEDS	% RELEVANCE OF NEEDS	1. PROCUT SPECIFICATION	2. PROCUT SPECIFICATION	3. PROCUT SPECIFICATION	4. PROCUT SPECIFICATION	5. PROCUT SPECIFICATION	6. PROCUT SPECIFICATION	7. PROCUT SPECIFICATION	8. PROCUT SPECIFICATION	9. PROCUT SPECIFICATION	10. PROCUT SPECIFICATION	1. COMPETITOR	2. COMPETITOR	3. COMPETITOR	4. COMPETITOR	5. COMPETITOR
1. COSTUMER NEED	4	6%	0	9	0	0	0	3	1	0	0	3	2	1	3	3	3
2. COSTUMER NEED	1	1%	0	3	0	0	0	3	0	3	0	0	2	1	1	2	3
3. COSTUMER NEED	5	7%	0	3	3	0	1	3	1	3	3	1	5	3	4	2	4
4. COSTUMER NEED	3	4%	0	3	0	1	0	3	0	1	0	1	2	1	1	3	4
5. COSTUMER NEED	3	4%	0	3	0	9	0	3	0	1	1	3	2	3	3	3	4
6. COSTUMER NEED	2	3%	9	3	3	3	3	1	3	3	3	1	1	1	2	1	2
7. COSTUMER NEED	1	1%	0	3	3	1	1	3	1	3	3	1	1	2	2	3	1
8. COSTUMER NEED	2	3%	0	1	1	1	1	1	0	1	0	1	2	2	3	3	3
9. COSTUMER NEED	4	6%	3	3	3	3	3	1	3	3	3	1	3	3	2	4	5
10. COSTUMER NEED	5	7%	0	9	0	0	0	9	0	1	0	1	3	2	3	4	5
ABSOLUTE TECHNICAL IMPORTANCE			65	280	188	142	68	216	72	164	129	87					
% TECHNICAL IMPORTANCE			5%	20%	13%	10%	5%	15%	5%	12%	9%	6%					

FIG. 1 An example of a QFD matrix. Source: S. Imbesi, 2019.

daily habits and the goals or frustrations they perceived in their routines. Each requirement identified was then sorted by user type and rated by recurrence and importance, in specific cells.

Next, this information was used for the Quality Function Deployment[16] matrices **[Fig. 1]**, completing one for each smart device. In order to facilitate management of the QFD outcomes for the multidisciplinary team project, each QFD matrix was filled in with 20-25 user needs linked to a specific smart object and 20 measurable technical characteristics linked to the same device. Within the QFD matrices, user needs and technical characteristics were matched to evaluate their degree of correlation by using the 0, 1, 3, 9 rating scale, derived from the QFD algorithm, to obtain the classification of the most impactful characteristics that could satisfy the most important needs.

After the stages described, the project team had enough information and data to prepare a project brief for each smart object. From the prepared documentation, some common requirements emerged for all smart objects:

- a clear and simple interface that would allow the elderly to easily use technology instead of being overwhelmed by it;
- interoperability and capacity to operate autonomously on the basis of data gathered from the domestic environment;

16 Yoji Akao, *Quality Function Deployment: Integrating Customer Requirements into Product Design* (Taylor & Francis, 1991).

- return of such information in an intelligible form that can be undestood by a self-sufficient senior rather than a caregiver or an operator.[17]

The smart objects were designed, prototyped and tested through an iterative UCD process, as described hereinafter.[18]

The first object is a sort of physical 'frame' containing a monitor and a free space usable as a notice board. The shape of the object was chosen to improve usability by avoiding the perception of something too technological and complicated but rather fostering the idea of very intuitive and accessible use.

The second HABITAT smart object is a smart armchair, which has been designed for both self-sufficient and non-self-sufficient seniors, and can even be used as an alternative to the wheelchair. The smart armchair is comfortable for various seated activities, and it offers different configurations to ensure the best sitting posture according to the physical abilities or disabilities of a particular person.

The third smart object is a wearable device enhanced with inertial and gyroscope sensors, capable of constantly monitoring body motion for movement analysis in both indoor and outdoor spaces.

The fourth smart object is another wearable device, conceived as a tag for an indoor locator. It is associated with an RFID reader that locates the tag. The wearable tag has different fixing options and it should be worn on the upper body. The reader should be installed on the wall at a specific height in all rooms of the home according to a modular and scalable layout that allows coverage of the areas where the seniors spend their day. The fourth smart object was conceived to be perceived as a lamp rather than a medical device in order to be more appropriate for a domestic environment.

In order to develop an inclusive solution that could improve accessibility for individuals and their autonomy in domestic environments, the research adopted a co-design approach. This allowed the research to include the main users throughout the decision-making and concept-generation processes, which was fundamental in defining the technical and morphological aspects of the smart objects. The users played the role of experts during idea generation and concept development, while the researchers acted as facilitators by supporting people in giving form to their ideas, providing prototyping tools for ideation and expression.[19]

The participatory activities were structured into two main co-design workshops, both involving the same people as in the first phase of the user

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17 Giuseppe Mincolelli et al, "Inclusive Design for Ageing People and the Internet of Things: Understanding Needs," in *Advances in Design for Inclusion*, ed. Giuseppe Di Bucchianico and Pete F Kercher, vol. 587, (Cham: Springer International Publishing, 2018), 98–108, https://doi.org/10.1007/978-3-319-60597-5_9.

18 Mincolelli et al, "UCD, Ergonomics and Inclusive Design: The HABITAT Project," 824.

19 Elizabeth B.-N. Sanders and Pieter Jan Stapper, "Co-creation and the New Landscapes of Design," *Co-Design4*, no. 1 (2008): 5–18.

FIG. 2 First workshop setting. Source: GA. Giacobone, 2017.

analysis and both organized with the contribution of the public elderly day-care organization ASC Insieme. All the participatory activities were held at the ASC Insieme's headquarters in Casalecchio di Reno (Bologna), Italy. The workshops involved 12 elderly families over 65 years old, including self-sufficient and non-self-sufficient seniors. Each family included either an informal caregiver (a relative) or a formal caregiver (a professional health operator). The scope of the two workshops was to contribute to generation of the final prototypes of the smart objects through co-design. This collaboration supported the co-design process in gathering numerous insights from the perspective of elderly people, as fundamental insights to properly define specific solutions focused primarily on specific needs of the elderly people.[20]

The first workshop was used to develop the initial project concepts, specifically defining their expected functionality and appearance [Fig. 2]. In order to facilitate the idea-generation process, the workshop was divided into three participative round tables—with both users and facilitators—each associated with one of the smart objects resulting from the research. The activities analysed the needs of older people through their everyday living experiences, which were thoroughly explored by using a brainstorming section and by creating several user-journey maps. Furthermore, the use of an empathy map collected the emotional aspects of all members of the families—such as conditions of fear, frustration, satisfaction and pleasure—which in turn became specific insights to improve the quality of the overall project. Subsequently, all of the user data was utilised to design the functions and morphological aspects of the smart objects in the form of raw prototypes, focusing particularly on the level of acceptance of the inertial sensor and the usability of the interface.

20 Karin Slegers, Pieter Duysburgh, and Niels Hendriks, *CoDesign with People Living with Cognitive and Sensory Impairments* (Taylor & Francis, 2015), 11

Following the first workshop, the early concepts were refined and improved with the most important considerations drawn from users' expectations. After this, the second co-design workshop was organized to evaluate correspondence of the updated prototypes with the expectations of the seniors. The activities involved observing the elderly while interacting with the smart objects and the interface to improve their usability, accessibility and desirability. This method allowed some needs to be elicited from their behaviour.[21] At the end of the second workshop, any friction encountered during interaction between the elderly users and the artefacts was reviewed and resolved by developing a working version of the overall project. In order to estimate the technological maturity of HABITAT, another conclusive usability test was conducted by an external expert in a simulated environment and with real users, in order to assess and formally validate the technology readiness level of the smart objects.

Results achieved

The outcomes of the overall research generated a multidisciplinary project that promoted development of solutions across technical fields to support 'aging in place'. The synergic collaboration among all partners produced an assistive domestic environment through a modular and scalable IoT-based platform, which provides a customizable and adaptable healthcare service to residents.[22] The overall HABITAT platform is composed of a family of four interoperable smart objects that can support elderly people's everyday activities and simultaneously monitor their health, improving their quality of life. This is done through predictive analysis of their daily behaviours or biological parameters. The smart system is meant to fade into the domestic background and act only when required by the needs of the seniors. To achieve this, the four smart devices are everyday objects equipped with digital capabilities (sensors, actuators, wireless connection and information computing), that can detect, record, and react to data streams produced by the elderly people in the domestic environment. Three smart objects (a smart chair, an indoor localization system and an inertial sensor) repeatedly collect data from the indoor environment. The information gathered is processed by the IoT cloud system and displayed through a digital interface. This takes operative decisions based on both health status and indoor position of the users. HABITAT not only has medical purposes for healthcare but also aims to provide psychological stimulation for the elderly through an entertaining and enjoyable experience[23], to preserve their social identity, sense of

21 Tim Brown and Barry Katz, *Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation*, vol. 20091 (HarperBusiness: New York, NY, 2019).

22 Giuseppe Mincolelli et al., "New Domestic Healthcare. Co-Designing Assistive Technologies for Autonomous Ageing at Home", *The Design Journal* 22, no. sup1 (2019): 504

23 Angelika Dohr et al. "The Internet of Things for Ambient Assisted Living," in 2010 *Seventh International Conference on Information Technology: New Generations*, Las Vegas, NV, USA: IEEE, 2010), 804–9, https://doi.org/10.1109/ITNG.2010.104.

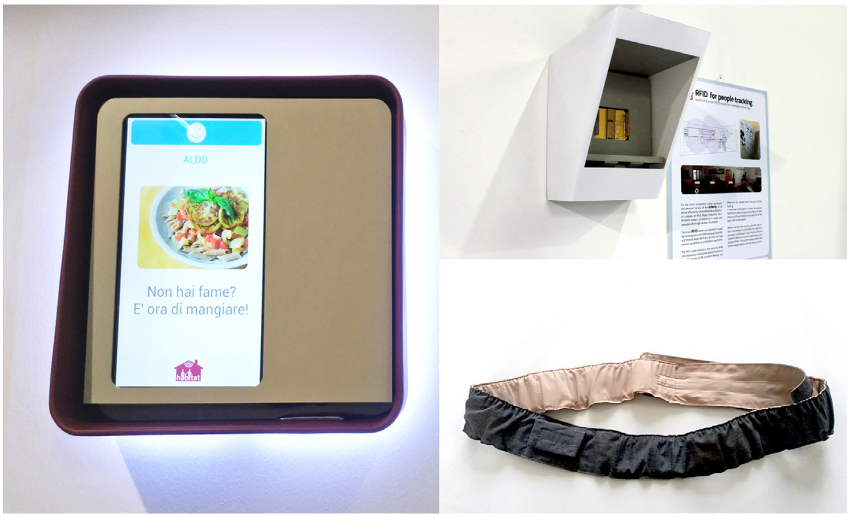

FIG. 3 The digital interface (left); the reader lamp of the indoor localization system (top-right); the wearable inertial sensor for tracking elderly people's movements (bottom-right). Source: M. Marchi, 2018

personality and a level of independence while aging in the home[24] The system also provides remote support to families and health operators to ensure monitoring of their parents/patients through the IoT network. In addition, the beta version of HABITAT was developed to configure each smart object to operate either as a stand-alone device or together as a full assistive ecosystem. This means that the artifacts can adapt to different stages of aging, underlined during the testing phase under three specific categories: self-sufficient senior, partially self-sufficient senior, and non-self-sufficient senior.

The first smart device is the digital interface, which is designed in the form of a picture frame that fades into the domestic background as an element of home furnishing **[Fig. 3]**. The physical prototype features a communication system to connect the device to the other smart objects and a wide touch-screen to interact with the caregivers through visual notifications. Meanwhile, the software monitors and improves the daily activities of seniors through integrated analysis of data collected by other smart objects. During the analysis of the elderly person's state of living, the communication of either suggestions or advice about particular health conditions is displayed through simple instant messages designed to be readable and intelligible for all. Specifically, the layout of every message is structured in three parts: on the top, a coloured bar identifies the message category; in the centre, a large image refers to the figurative meaning of the communication; and at the bottom and below the image, a simple phrase indicates the specific purpose of the notification. Blue and green divide the notifications into two categories. Blue indicates temporary advice, which encourages the elderly person to do an action such as drinking, eating, walking, changing posture or sleeping. Green identifies interactive

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24 L. N. Gitlin, "Conducting Research on Home Environments: Lessons Learned and New Directions", *The Gerontologist* 43, no. 5 (1 October 2003): 43, https://doi.org/10.1093/geront/43.5.628.

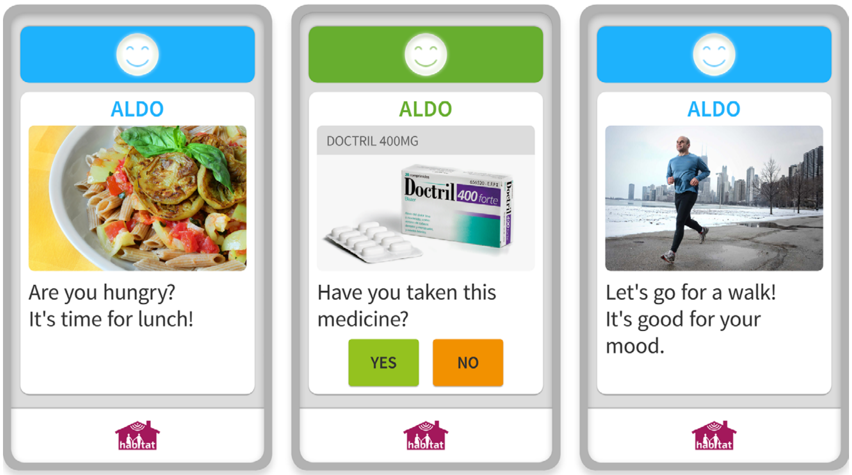

FIG. 4 Some screens of the HABITAT interface. Source: GA. Giacobone, 2018

messages, which are used to gather information about the elderly person's daily routines, such as whether they have already taken medicines at certain times **[Fig. 4]**. In particular, green indicates a specific activity requested at the end of the day, which prompts the elderly people to rate the quality of their everyday lives on a level from one to five, according to five specific parameters: nutrition, mood, health, rest time and interpersonal relationships. The digital interface also provides a mobile version, which extends the service outside the domestic environment in order to help caregivers to remotely monitor the elderly person everywhere and in real-time. More specifically, the mobile version displays health parameters of each senior monitored by the IoT system and it supports caregivers with specific warning messages (in red) in the event of critical issues involving one of their patients.

The second smart object is a conventional armchair with several load cells embedded in different locations—under the feet, the seat frame and the backrest—which provide real-time monitoring of sitting posture and the amount of time seniors spend seated. A computational board collects the data and sends it to the cloud system. Here it is processed to offer strategic decisions for the elderly people to improve their health in the form of personal advice. Information is visible on the digital interface, which displays recommendations for physical activities (e.g. walking), achieving proper back posture while seniors are sitting in the armchair.[25]

The third smart object is a wearable device equipped with an inertial sensor that monitors **[Fig. 3]** dynamic motion of seniors inside and outside the domestic environment. Like the smart chair, the inertial sensor analyses both active and passive time of the elderly people to monitor their daily activities. Furthermore, if there are critical events, such as falls, the wearable device is also able to warn the caregiver in real-time by working with the indoor localization system. The smart object is developed to be

25 Ergotek, which is the industrial partner specialized in ergonomic seats for older people, provided its know-how to develop the physical prototype.

FIG. 5 The image shows the functioning prototypes of the HABITAT system: the digital 'frame' interface (top-left); smart chair; and indoor localization system inside the lamp (top-right). Source: M. Marchi, 2019

worn on the back at waist level, at the height of the L5 vertebra, in order to perform correct motion tracking.

The fourth smart object is the indoor localization system [Fig. 3], which is based on Radio-Frequency IDentification (RFID) technology and has two components: localization readers and recognition tags.[26] The localization readers are embedded into wall lamps or shelves to conceal technology in the surroundings and they monitor the position of the tags in the domestic environment. The tags are integrated into the other smart objects or worn by the elderly people on the upper body to facilitate identification. The indoor localization system is developed to prevent undesirable access of the elderly people into areas declared unsafe (for example the bathroom) and when a problem occurs, the system can warn caregivers in real-time with alerts.

Finally, specific desirability and usability tests were conducted for all smart objects and for the whole HABITAT system regarding the technological readiness level (TRL). To do this, the project team selected an external consultant. The study on usability and desirability of the HABITAT project lasted about one month and was carried out in two different locations:

- the first, was the ExpoSanità International Fair (BO). This is an international exhibition for the healthcare and assistance sector. On this occasion, the HABITAT project had the opportunity to exhibit the smart

26 Paolini et al, "Human-Centered Design of a Smart 'Wireless Sensor Network Environment' Enhanced with Movement Analysis System and Indoor Positioning Qualifications," in *2017 IEEE MTT-S International Microwave Workshop Series on Advanced Materials and Processes for RF and THz Applications* (IMWS-AMP) IEEE MTT-S, Pavia: IEEE, 2017, 3, https://doi.org/10.1109/IMWS-AMP.2017.8247434.

objects in a dedicated pavilion. The Fair allowed practical demonstrations to gather considerations on usability and interaction between people and the devices [Fig. 5];

• the second was at a day-care centre managed by the partner ASC Insieme. Nineteen participants were involved, including self-sufficient and non-self-sufficient elderly people and caregivers to whom the HABITAT system was explained for the first time, including the objects and the smartphone applications. Specifically, tests involved:

7 self-sufficient elderly people

2 caregivers of semi-self-sufficient elderly people

2 semi-self-sufficient elderly people

4 caregivers of non-self-sufficient elderly people

4 non-self-sufficient elderly people.

The goal was to quantitatively evaluate usability and desirability of the HABITAT system and its individual components: the wall lamp, necklace and identification pin, wall screen, smartphone application for self-sufficient elderly people, smartphone application for caregivers, armchair and belt. At the end of this cognitive process, the external consultant positively evaluated the project and assigned it a technological readiness level of 5. All users were able to conclude their test session without interruptions. Furthermore, the consultant drafted a technical report in which some suggestions for improving device-user interaction and the graphical interface of some applications were highlighted. These suggestions arose from the many interviews and tests that were performed with users.

Critical discussion of results

On the basis of the experimentation performed within the HABITAT project, several observations can be made. Firstly, it is crucial to work in synergy with the research and development team in order to structure and implement complex projects, both for user involvement and for high-level technology. The fields of investigation are distinct from one another (in terms of language, skills and design repercussions), therefore, assuming and developing a common inclusive methodology can drastically reduce the margins of final error in terms of time and quality. Specifically, the HABITAT project has followed human-centred design approaches that have led the entire research project to significant outcomes based on the real needs of users. Adopting participatory methodologies, listening to people and planning the development process with them right from the very first project choices considerably increased the quality of the overall results.

Secondly, the lack of accessibility to spaces, services and products by people with specific needs—such as children, the elderly or those with disabilities—will certainly be a dominant theme in coming years, as demonstrated by trends in demographic data. For this reason, it is essential to immediately start planning a different approach to social assistance, much better aligned with the reality and needs of people. The HABITAT project has tried to propose new solutions that would give people greater autonomy and independence through development of a completely open and inclusive IoT platform and the design of smart objects equipped with AI.

A final reflection on managing and mastering new technologies:

they are—and continue to be—important tools for increasing the quality of people's lives, creating inclusive urban and environmental realities. However, keeping the individual at the centre of the creative project is fundamental. New technologies must continue to be conceived as tools and not goals. Empathic and emotional aspects—together with pleasing use and aesthetics—must remain essential elements of a project. The HABITAT project has confirmed these aspects.

Conclusions

The field of design for ageing people is constantly increasing in importance in the light of the great contribution it can make from a social perspective. Satisfaction of the requirements expressed by the elderly in order to increase their quality of life can be a strong welfare tool in the reduction of public expenses related to personal assistance and health services.

Recent technological innovations are opening up scenarios that were unthinkable a few years ago, allowing multidisciplinary groups to design devices, services and processes related to IoT that can be integrated into the everyday environment of target users.

In this context, Design Research has the important role of acting as a bridge between technology and potential use of the product by users, as a tool to set the project's specifications in order to satisfy requirements regarding usability, ease of use and accessibility, which make a difference to the effectiveness and feasibility of the design project.

Integrating objects or products, encouraging different ways of socialization and proposing different daily habits, are all actions that are not easy for seniors to understand. People have different needs and it is not always easy to build discussion and change their lifestyle and habits for the sake of greater well-being and daily security. Therefore, it is necessary to adopt extreme sensitivity in order to change the lifestyle or integrate certain objects or products within daily habits. The goal is therefore to produce interconnected and smart objects with very simple, customizable and flexible interfaces based on individual user profiling. Furthermore, it is crucial to carry out an inclusive process for knowledge and purchase of the individual devices. The elderly have to get used to new habits, being able to choose the most suitable technology for their characteristics and ability; only with these conditions can technology to encourage active ageing be usable, accepted and inclusive.

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