Universal Access in the Information Society (2024) 23:305–328
https://doi.org/10.1007/s10209-022-00940-5

LONG PAPER

Toward improved co-designing home care solutions based on personas and design thinking with older users

Renata de Podestá Gaspar[1] · Vinícius P. Gonçalves[2] · Geraldo P. Rocha Filho[3] · Julio Cesar dos Reis[4] · Ferrucio de Franco Rosa[5] · Rodrigo Bonacin[5]

Accepted: 25 October 2022 / Published online: 12 November 2022

Abstract

The ability of human beings to live longer is an outstanding achievement of science in the 21st century. New technologies and innovations have an essential role in ensuring the well-being of the new generation. By adopting Internet of Things (IoT) technologies, it is possible to improve autonomy, security, and quality of life. However, designing IoT solutions for Home Care and older users brings new challenges to the Human–Computer Interaction field. Older users are heterogeneous and critical users of technology and interactive solutions. In this context, it is necessary to promote the participation of older users in the design process aiming at considering their specificities, intentions of use, and individual preferences and necessities. We propose a co-design method based on Design Thinking and Personas. Our research contributes to methods and a case study assessment regarding IoT-based Home Care solutions' co-design. The proposed approach considers older users' wishes and needs in an iterative, creative, and participatory way. We tested the proposed method in a case study with nine older adults. Results indicate the effectiveness and difficulties of involving older users in the design process. Our results contribute to a better understanding of how to carry out participatory activities with older adults in the context of Home Care.

Keywords Home care · Older users · Personas · Internet of things · Design thinking

✉ Rodrigo Bonacin
rbonacin@cti.gov.br

Renata de Podestá Gaspar
repodesta@gmail.com

Vinícius P. Gonçalves
vpgvinicius@unb.br

Geraldo P. Rocha Filho
geraldof@unb.br

Julio Cesar dos Reis
jreis@ic.unicamp.br

Ferrucio de Franco Rosa
ffrosa@cti.gov.br

1 UNIFACCAMP, Rua Guatemala, 167, Campos Limpo Paulista, SP 13231-230, Brazil

2 National Science and Technology Institute on Cybersecurity, Electrical Engineering Department, University of Brasília (UnB), P.O. Box 4466, Brasília, DF 70910-900, Brazil

3 Computer Science Department, University of Brasília (UnB), P.O. Box 4466, Brasília, DF 70910-900, Brazil

4 Institute of Computing, University of Campinas, Av. Albert Einstein, 1251, Campinas, SP 13083-852, Brazil

5 CTI Renato Archer and UNIFACCAMP, Rod. D. Pedro I, km 143, 6, Campinas, SP 13069-901, Brazil

1 Introduction

According to the World Health Organization, Home Care includes health and social support services on the client's residence [58]. In the context of older users care, such services allow them to stay longer in their own homes. New technologies, such as the Internet of Things (IoT), can lead to advances in quality and boost home care solutions. IoT technology aims to connect things used daily to the Internet [3]. In the context of Home Care, IoT can assist in the development of solutions for the older users [18, 21].

Involving different views in the design process is critical for innovative solutions in older users Home Care. These views avoid unilateral solutions proposed by designers [62], especially when the older users, who are those most affected by the solution, are not involved in the design. Older users are not a homogenous group. In this sense, they do not live in the same places and do not have access to the same resources as well as do not have the same capacities [8].

The literature points out older users among the most critical stakeholders when seeking solutions in Information and Communication Technology [30]. A change in their homes

is a threat to a pre-established equilibrium and hence causes uncertainty and resistance [28]. It is necessary to understand and consider older users' needs, as well as the requirements of the entire supporting network (*e.g.*, family, caregivers, and health care professionals) [20]. However, the participation of stakeholders is often hampered by the complexity of smart solutions for Home Care.

Design Thinking (DT) [11] consists of user-centered techniques and tools that can assist an iterative process to find creative solutions to real problems. However, there is a lack of studies to address the question of how older users take part in co-design activities involving complex areas, such as IoT for Senior Home Care. According to a previous systematic literature review [48], most studies are failing to employ specific methods, practices, and techniques to encourage user participation. They are unclear about how older users and family members are involved in the project and how they perceived different views of the design problem. The concept of IoT is rarely adopted, and as a result, there is a need for an in-depth investigation of the subject in question.

Our main objective is to investigate and set out a method, based on DT, so that a co-design can be obtained for IoT elderly Home Care services. To this end, we propose the use of Personas [61] to support co-design in a set of workshops that include older users, their families, and health professionals. In our view, there are few studies that make use of Personas to represent the full range of the needs of the older users.

Personas are fictional characters, designed from a synthesis of users' behavioral patterns, including their motivations, desires, expectations, and needs [61]. The Personas technique is used in our method to stimulate empathy and discussion about various needs and views during the workshop sessions.

Our main contributions are twofold:

- The IoT Participatory Method for Home Care Solutions (called IoT-PMHCS) is based on DT and Personas. This includes guidelines for good practices, ideas, and suggestions to co-design Home Care systems with the older users. This method provides an alternative to include older users in the DT process.
- Our proposal shows results of the application of the method in an original case study, with the aim of assessing the benefits derived from the inclusion of older users, and other stakeholders, in the design processes. Our findings show the advantages of the method. We discuss drawbacks and research challenges raised.

The remainder of this article is organized as follows: Sect. 2 describes the concepts and background on Home Care, Ambient Assisted Living (AAL), DT, and Personas. This section contextualizes our proposal by presenting studies on older users' co-design and Participatory Design (PD); Sect. 3 details our developed approach, including the IoT-PMHCS method; Sect. 4 presents a case study conducted with older users co-designers and reports on the obtained results; Sect. 5 discusses the findings in light of existing literature studies; Sect. 6 wraps up the conclusions and points out further research.

2 Background

This section presents the theoretical and methodological foundations by including concepts related to Home Care and its technologies (Sect. 2.1); key aspects of DT (Sect. 2.2); the Personas concept (Sect. 2.3); presents and discusses studies on older users co-design in Home Care (Sect. 2.4).

2.1 Home care, AAL, IoT, and health smart homes

According to Spinsante et al. [57], most of the older users ideally present the following values: live in their residences; be as autonomous as possible (independence); stay healthy (well-being); be part of the daily life of their family, neighbors, and community (social); be able to move and exercise (mobility). The residence is the first place in the live of the older users because it is closely linked to their identity and self-expression [52]. Home is also the emotional center of the older users's life, being more than a place to live [37].

AAL and Home Care are closely related concepts [7]. AAL includes intelligent environments with sensor networks aiming at providing solutions that require little effort and user interaction [1].

IoT allows to remotely control objects and characterizes them as service providers, by making them intelligent objects. By combining the concept of AAL with IoT technology [57], assistive IoT technologies have emerged as a powerful tool to increase the independence of older users [39]. However, additional research is required to adequately relate AAL and IoT technological resources to the needs of older users and expectations for Home Care.

The purpose of the IoT framework is to enable the design process to answer questions, such as those related to how people can interact with this new technology [5]. Koreshoff, Leong, and Robertson [34] adapted the core concepts of this framework to Human–Computer Interaction (HCI). This involved: *Things*, HCI with IoT technology which can be added to everyday objects and the effects on their use; *Internet*, the average rate for transferring data among things; and *Semantics*, the way HCI methodologies involve people in the design process to provide sensory information on the models and interaction approaches aligned with a semantic domain.

Health Smart Homes, or Health care in Smart Homes, has developed from the integration of IoT and Information

Systems with telemedicine. Health Smart Homes use smart devices (e.g., wearable technologies) in the support of users and caregivers [53]. The literature in Health Smart Homes points out the need for research on alternative methods of design and evaluation [14, 59], such as those that promote the participation of users in the design process. It is necessary to study specifics on the design and adoption of Health Smart Homes for older users because they may have different attitudes than younger users. This includes, for instance, different concerns about privacy, ease of use, and amount of control [25]. Older users do not necessarily present tight resistance to the adoption of technology, as shown in [13], as long as there is a suitable design. In this sense, the literature has shown advances in understanding how to design technological artifacts for older users [19]. However, the participation of older users in design [2, 41] and the constant technological changes (such as those regarding IoT) pose open challenges to the universal access research community.

2.2 Design thinking

DT is an approach focused on the human being using multidisciplinarity, collaboration, and tangibilization of thoughts and processes, leading us to innovative solutions [61]. Therefore, the DT technique is a collaborative approach, consisting of a structured process in several steps that uses user-centered techniques.

According to Vianna et al. [61], the DT process is organized into four phases: i) immersion, ii) analysis and synthesis, iii) ideation, and iv) prototyping. The DT approach is a promising tool for identifying innovative solutions for the older users. DT is composed of a set of user-centered techniques combining concepts of insight, observation, and empathy. According to Brown [11], using only traditional techniques such as focus groups or surveys in interviews rarely leads to important insights, as they usually ask people what they want, not what they need. On the other hand, DT is based on our ability to be intuitive, recognize patterns, develop ideas that have an emotional meaning beyond the functional, express ourselves in media beyond words or symbols [11].

We argue that DT can be a valuable approach to encourage participation and brings older users, experts and family closer to the proposed solution. In our view, participation can be promoted by using techniques such as exploring Workshops' scenarios in all development phases. This encompasses elicitation of requirements and specification, design, implementation, and validation of prototypes. One key differential of our study is that it uses and organizes in a process multiple methods, through the DT steps with several stakeholders (including older users, health professionals, and family), to avoid an unilateral view.

2.3 Personas

Personas are a concept increasingly used in the development of technological systems. They can be used during all development phases of an innovative solution. Personas may be used to support the participatory process, as they drive users to practice empathy by directing them to think from different perspectives and assisting collaborative decision-making during the design process.

According to Cooper [15], creating Personas consists of making a composition of demographic, biographical data, and imagined information, modeled to create a character that approaches the reality aimed during the design development of applications. According to Gonçalves et al. [22], for a complex scenario, such as the older users lifestyle, the standard Personas creation process is not enough [15]. It is necessary to involve various stakeholders (*e.g.*, Home Care professionals) and monitor them in real time to bring details to the fictional characters, approaching the specificities and needs of the target users.

2.4 Co-designing home care with older users

As presented by Haslwanter and Fitzpatrick [27], there are various causes of AAL design failures, such as difficulties to evaluate caregivers properly, use of not affordable technologies, and the adoption of a stereotyped view of the older users. To investigate existing design approaches, we conducted a systematic literature study about design approaches for IoT solutions for older users Home Care, such as PD, Personas, and Semiotics [48]. Gaspar et al. [48] presented details of this study. This section summarizes the only closer related studies, including DT and Personas's use in Home Care solutions' co-design.

The literature indicates DT as a promising tool for improving the effectiveness of the design of Home Care solutions. DT combined with other methods, can further develop the participation and engagement of the older users in the co-design process. Methods such as gamification can improve the engagement of older users in the design process and enhance empathy with design solutions [42].

Camilli et al. [12], for instance, combined cross-disciplinary approaches for enhancing older users' experience. Experience design techniques were used to consider interactions among the older users and the services or products; ethnography was used to learn about people and their social-technical context; lean startup was used to define short prototyping cycles; DT was used to obtain new ideas of services, processes, and products considering users' needs, preferences, desires, and behavior.

Several studies explored DT as a tool to deal with various aspects of Home Care design (Table 1), such as (1) Home Care educational practices [36] to promote the organization

Table 1 Studies that use DT as a tool for Home Care design

Refs	Context	Pers.	IoT	Participants
[36]	Education for child Home Care	No	No	Clinicians and Parents
[24]	Operators	No	No	Inst. actors
[33]	Active aging	No	No	Older users, Stakeholders
[29]	Psychiatric	No	No	Patients
[63]	Age-friendly design	No	Yes	Designers
This	*Older users ideas, values and challenges at Home*	*Yes*	*Yes*	*Older users, IT and Health professionals*

and innovation of clusters of Home Care operators [24]; (2) promotion of active and healthy aging [33]; (3) psychiatric home treatment [29]; (4) provision of age-friendly design [63]. Table 1 shows studies that point out the interest in the use of DT in Home Care solutions. However, solutions to provide effective participation of older users (last column of Table 1) in the Home Care co-design process are still open research issues. This table shows that our study differs in terms of context, use of Personas, IoT technology, and participants of the design process.

The systematic literature review [48] revealed that the involvement of the older users and family members in the PD process is of crucial importance to ensure empathy and improve the acceptance of new technologies, particularly in identifying Home Care. In the context of IoT, the involvement of IT professionals is essential for finding innovative solutions and making a detailed design of the system requirements using the IoT framework. Gaspar et al. [48] exposed methods that can be combined to obtain more consistent results.

We recommend employing Personas as a tool to improve communication and encourage the involvement of older users in the design process. In our proposal, the Personas technique is combined with scenarios to enable and encourage effective user engagement whereas adopting participatory practices [35, 47]. This involvement is particularly challenging in the light of emotional factors and sensitive questions, such as finance and health. In this sense, there is a need to adopt novel approaches and processes so that these factors can be handled appropriately.

3 A co-design approach relying on design thinking and personas

We present our original IoT Participatory Method for Home Care Solutions (IoT-PMHCS) based on DT and Personas. IoT-PMHCS includes a guide to best practices, insights, and suggestions to involve stakeholders in all stages. Section 3.1 presents a co-design approach for older users Home Care. Section 3.2 fully describes our proposal (IoT-PMHCS).

3.1 Framing a co-design approach for older users home care

This study was initially inspired by a previous work presented in [22], which proposed a method for designing Personas together with caregivers and professionals. Such work points to the potential of using Personas in the development of IoT-based Home Care solutions. It indicates the need for appropriate methods to conduct the design with older users facilitated by Personas, such as those methods proposed by PD.

PD research has promoted the participation of users in the design process since the 70's. In common with the User-Centered Design approach, PD incorporates users in the design process and is concerned to promote developing more democratic design processes with users [6]. Since the early years, PD has argued that everyone should have the opportunity to participate in decisions concerning his/her life.

The literature has proposed strategies to conduct participatory activities, practices, experiences, and methods to address the design with older users (*e.g.*, [38]). Whereas PD's social understanding is moved by the inextricability of design, political activism, and research, IoT-PMHCS gets inspiration in its design practices to promote the participation of older users. By articulating methods coming from other fields, such as DT, Personas, and IoT framework, the IoT-PMHCS aims to promote inclusive participation of older users in design [9] and the development of suitable products for Home Care in the face of new smart technologies.

IoT-PMHCS was conceived to encompass a set of consistent DT-based steps. The method represents an evolution of the existing methods because it combines co-design with several stakeholders in the process steps without losing the flexibility demanded by IoT solutions for Home Care. In our proposal, all stages and their respective suggested methods can be adapted.

Regarding the "pure" DT, IoT-PMHCS provides the following advantages: it adapts and uses DT to focus on how to promote innovations with the older users by combining methods and tools to facilitate the interaction. IoT-PMHCS aims to provide a valuable analysis strongly centered on Personas. The focus is on defining artifacts (*e.g.*, Personas), as well as techniques that allow effective participation (e.g., use of terms and tasks focused on older users). IoT-PMHCS provides, in the Prototyping stage of DT, a framework to design AAL solutions based on IoT, as well as for detailing requirements using User Stories.

Regarding the engineering process of the proposed method, first, a systematic review of the state of the art [48] was carried out to identify related research, and then, an initial version of the method was proposed. A preliminary case study was conducted to verify the feasibility of applying the PD and DT techniques. This preliminary case study was carried out with 10 Computer Science students from the Federal Institute of Minas Gerais, Muzambinho campus, Brazil, aged 18 to 22 years, in an 8-hour course on DT. The objective of the course was to present DT processes and their main methods. In each phase of the course, practical exercises were applied to identify and to prototype an IoT-based solution for Home Care for the older users.

From the preliminary case study, we obtained the following results: (i) we exercised the main DT methods that are part of the IoT-PMHCS; (ii) we evaluated the effectiveness of the DT methods; (iii) we evaluated the time and numbers of people that are necessary to carry out the process; and (iv) we evaluated commitment and participatory techniques.

As the focus of this research is on older users, we updated the specific aspects of the method, such as

1. as the activities with students were exhausting (even for young people), we proposed to adjust the duration of each task (*e.g.*., more breaks and a more significant number of sections) as well as the distribution of the task over time;
2. the used material/artifacts were adapted to the target audience (*e.g.*, older users and family), for example, low technology artifacts and slower (and longer) videos, with larger subtitles and less technical information were proposed for the activities with older users;
3. clarification of how to use norms [40] to support the choice of the priority Home Care solution for each Persona;
4. definition of how Personas can contribute to commitment and involvement. To this end, the Personas should model key elements to represent older users such as physical characteristics, psychological conditions, and experience with technology [22].

3.2 Participatory method for IoT home care solutions (IoT-PMHCS)

Figure 1 presents the phases, input, and output of the IoT-PMHCS method, which are summarized as follows:

- **Input**. *Challenge*: The input is a design challenge to be carried out, containing essential profile of the target audience and the IoT technology;
- **Phase 0 (Setup)**. *Exploratory Study and Planning*: A study is carried out with older users to investigate solution themes, understand the context and challenges, and plan the co-design processes;
- **Phase 1 (Analysis)**. *Mapping of Personas, Values, and Needs*: This phase identifies the values and needs of the solution's main stakeholders using participatory activities and the Personas concept. As the main result, the Personas mapping is developed;
- **Phase 2 (Mapping)**. *Mapping IoT Solutions*: After mapping Personas, we need to identify IoT technology alternatives in conjunction with older users. We choose the best alternative for each Persona, considering their values, needs, and preferences using standards;
- **Phase 3 (Design)**. *Design IoT*: This phase aims to design IoT-based solutions identified in Phase 2 by using the IoT framework. At this phase, we expect to obtain the development of a prototype. The process's conclusion takes place through experimentation and feedback from the older users;
- **Output**. *Prototype*: As the main result, we obtain prototypes co-designed with older users, including an evaluated IoT-based solution and requirements for the next prototype cycle.

3.2.1 Phase 0: exploratory study and planning

This phase aims at understanding the design problem, immersing ourselves in the main themes that guide PD activities' design and planning. The left side of Fig. 1 presents the activities to be carried out in Phase 0. This phase is supported by specific tools to conduct exploratory studies and planning with stakeholders.

Phase 0 receives as input a design challenge, which focuses on designing IoT-based solutions for the Home Care of the older users. These solutions must allow the individuals to prolong their lives for a longer time in their homes, with family members and professionals' control.

The process starts with the research activity, which includes exploratory research with older users, health professionals, and family members, as well as the desk research with IT professionals. The rationale is to include older users' views from the first activities, by providing their views on key aspects of the solution, such as the health-related issues.

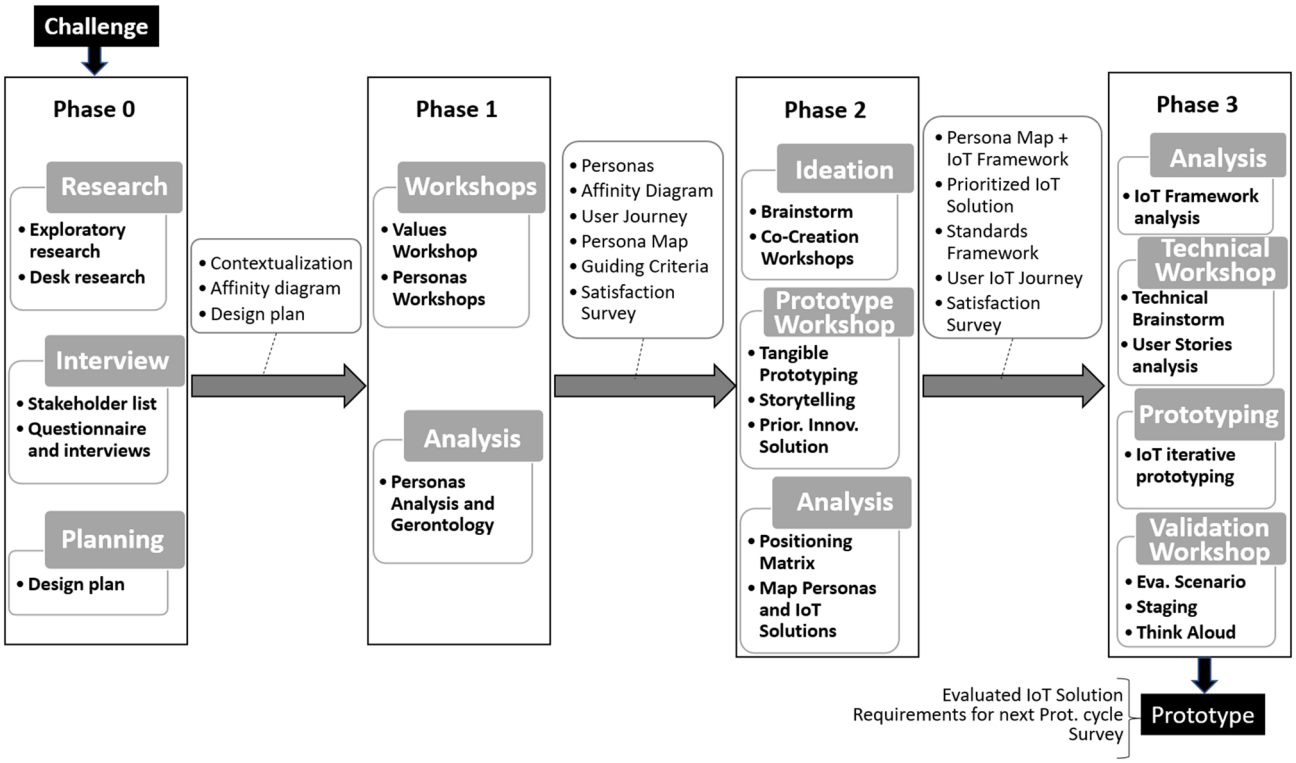

Fig. 1 Overview of IoT-PMHCS: phases, activities, practices and results

Table 2 Summary of Activities, Practice/task, Participants and Recommendations for Phase 0

Activity	Practice/task	Participants	Recommendations
Research	Exploratory Surveys	Older users, health professionals and family	Consider questions with health-related issues, behavioral aspects, economic and educational issues, and relationship with technology. Provide questions with language adapted to the public, large letters and multiple means of completion (e.g., online, mobile and paper based).
	Desk Research	Designers and IT Professionals	Consider state of art on articles, books and technology.
Interview	Stakeholder list	Designers	Use of Stakeholder Diagram [31, 51] as an starting point for identifying focus groups and stakeholders.
	Questionnaire and interviews	Older users, health professionals and family (and other selected stakeholders)	*Older users* follow a semi-structured script that addresses the issues mentioned in the exploratory surveys; *health professionals* follow a script with issues related to the problems regarding safety, behavioral challenges of the relationship, and the possible use of smart technologies in their daily activities; *Family members* follow a script that addresses issues related to life and health, values and needs, and technology and Home Care.
Planning	Design Plan	Designers	Based on research and interview, identify the following information for each PD activity: Phase of IoT-PMHCS; PD method; expected stakeholders; duration; location; and status.

Questionnaires adapted to the older users' needs are used to this end. Table 2 presents the participants and key recommendations for the activities, practices/tasks of phase 0.

Subsequently, interviews are carried out. It is necessary to identify and list the stakeholders, as well as to define their participation in the interviews. We aim to provide a broad

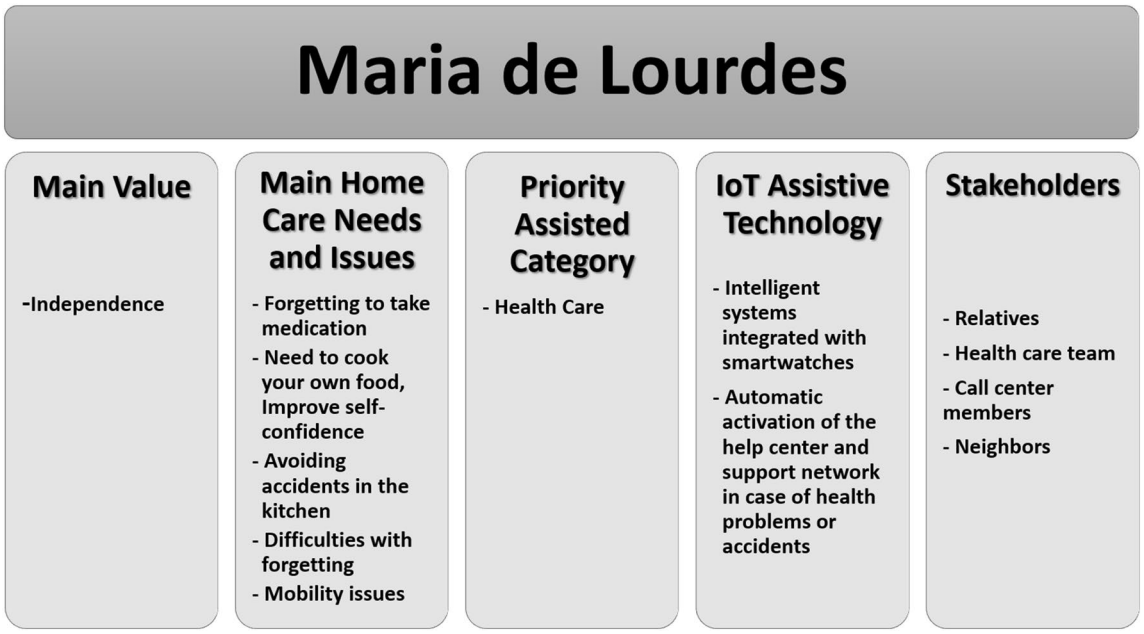

Fig. 2 Persona Map for "Maria de Lourdes" including Main Values, Main Home Care Needs and Issues, Priority Assistive Category, IoT Assistive Technology, and Familiarity with IT

view and promote the participation of those who impact or are impacted by the solution. We propose that at least older users, health professionals, and family participate in the interviews. As Table 2 shows, scripts must be adapted to the interviewees, as well as providing adequate accommodation, reduced time (if necessary), and promoting interaction with designers.

In this phase, designers must elaborate the design plan based on the results of the previous activities. This plan must be flexible and contain key definitions for the next phases. As outcomes of this phase (cf. Fig. 1), we expect Contextualization (better understanding), Affinity Diagrams with risks and challenges, and the Design Plan.

3.2.2 Phase 1: describing personas, values and needs

This phase aims at identifying stakeholders' values, challenges, and older users' needs, by carrying out PD activities, mapping Personas, developing the initial Persona Map, and identifying the Guiding Criteria.

In this phase, Personas should be created with a focus on reflecting the profile of older users in Home Care. Considering the context of the Brazilian older users, we suggest using the Personas proposed in [22]. These Personas were built based on extensive work with health professionals with experience in Home Care in the Brazilian context.

This phase starts with two workshops (Fig. 1): the Values Workshop is focused on techniques to identify older users' values, challenges, and needs; the Personas Workshop aims to complete the Personas information with older users. Generative Session and Brainstorm [61] techniques are used in the Values Workshop, and 'Empathy Map", "User Journey" and Brainstorm [61] in the Personas Workshop. Table 3 summarizes the recommendations for conducting the activities of this phase, including the Values Workshop.

The analysis activity consists of producing a Canvas, named Persona Map, to encourage collaboration, a discussion between the participants, and the co-creation process. As presented in Table 3, it is necessary to provide an easy alternative to visualize the project and build it with the participants. Figure 2 presents an example of a Persona Map, including the main value (independence), main home care needs and issues (e.g., forgetting to take medication), the priority assisted category (home care), IoT assistive category (e.g., intelligent systems) and stakeholders.

As the main outcomes of this phase, we expect Personas, Affinity Diagram, User Journey, Persona Map (initial), and Guiding Criteria.

3.2.3 Phase 2: mapping home care solutions

In this phase, we aim at identifying innovative IoT-based technologies to meet the needs of each Persona. Figure 1 presents the activities, inputs, and outputs of this phase.

This phase starts with the ideation activity, which includes a brainstorming section and a co-creation workshop. Both aim to provide innovative solutions focused on older users. This activity requires adaptation of the artifacts

Table 3 Summary of Activities, Practice/task, Participants and Recommendations for Phase 1

Activity	Practice/task	Participants	Recommendations
Workshop	Values Workshops	Older Users	Use of Generative Session and Brainstorm [61] to identify subjects' values, challenges, and needs. Consider needs, such as the local (must consider mobility limitations and provide a cozy and familiar environment), artifacts (that facilitates writing and reading by older users), registers (possible residence to video cameras) and duration (to avoid fatigue).
	Personas Workshops	Older Users	This Workshop should be carried out for completing the Personas by using adapted artifact to support understand and execution, such as "Empathy Map", "User Journey" and Brainstorm [61] in large blackboards or cardboard.
Analysis	Personas analysis and gerontology	Older Users and health professionals	Produce a Persona Map (Fig. 2) for each Persona containing: Persona Identification, main value, home care needs and family issues and priority assistive products as well as IoT assistive technology designed by the participants. This canvas should be used to encourage collaboration, discussion between the participants and co-creation. To this end, we recommend using a cardboard with postcards identified by colors during the workshop with participants. Larger postcards may be required by older users to facilitate the task.

Table 4 Summary of Activities, Practice/task, Participants and Recommendations for Phase 2

Activity	Practice/task	Participants	Recommendations
Ideation Workshop	Brainstorm	Stakeholders (IT professionals, older users, and their families)	Conduct a Brainstorm session aiming at proposing innovative solutions focused on older users. To ensure the participation of older users consider adapting the artifacts/material (to support reading and manipulation of people with motor and vision limitations), limit the number of participants, provide places with ergonomics conditions and ease of access, and limit the duration with breaks to avoid fatigue.
	Co-creation Workshop	Stakeholders (IT professionals, older users, and their families)	Use Co-Creation techniques (e.g., [61]) for the ideation of innovative solutions considering the conditions listed in the last item.
Prototyping Workshop	Tangible Prototyping	Older Users	Organize groups of 3-4 participants divided by Personas according to affinity. Use tangible objects to express the functionalities and concepts of the system. Use objects of daily use and well-recognized by older users.
	Storytelling	Older Users	Organize groups of 3-4 participants divided by Personas according to affinity. Use storytelling [46] and low fidelity prototyping of IoT assistive and health technologies.
	Prioritize Innovative Solutions	Older Users	To choose the solution to be used in Phase 3, the method recommends using the Guiding Criteria identified in Phase 1 as a reference. The choice can also be made considering the solution's preference and adherence by vote and consensus.
Analysis	Positioning Matrix	Older Users and IT Professionals	Relate Personas and ideas on a blackboard (or large cardboard), so that participants can give their opinion using post-its (one color for each Persona).
	Map Personas and IoT Solutions	Older Users and IT Professionals	Map each Persona with the respective suitable solutions and technologies. Standards Tables, based on [40], can be used to support the choice, once they address aspects related to perception, cognition, evaluation, as well as denotative and behavioral.

Table 5 Summary of Activities, Practice/task, Participants and Recommendations for Phase 3

Activity	Practice/task	Participants	Recommendations
Analysis	IoT Framework analysis	Designers	Describe the IoT Framework elements for the prioritized solution. This task is carried out in two instances: (i) before the Technical Workshop, providing a preliminary version with the main "things" and functionalities; (ii) after the Technical Workshop, with a more "stable" solution.
Technical Workshop	Technical Brainstorm	IT professionals	Focus on generating ideas to realize the functional and technical requirements previously identified.
	User Stories analysis	IT professionals (older users and other stakeholders)	Formalize user stories, feasibility analysis, and technical requirements to implement solutions based on the stories that arise in the co-creation workshop and storytelling.
Prototype	IoT iterative prototyping	Designers	Prototype a solution proposal considering the prioritized needs among the specified conditions, and plan scenarios for the Validation Workshop. Older users and other stakeholders should be consulted in this task. We highlight it may be necessary to adapt the solution to meet all types of Personas and respective users.
	Evaluation Scenario	Older Users	Describe scenarios with older users by using the prototypes.
Validation Workshop	Staging / Role-play	Older Users	Invite older users to role-play scenarios (last item) from their day-to-day situations using the prototypes. Preferably perform it in their own homes.
	Think Aloud	Older Users	Encourage users to verbalize what they are thinking during scenarios. Think Aloud protocol [60] can be used to this end.

and methods to enable the participation of the older users. Table 4 presents a summary of the recommendations for the activities of Phase 2.

In the following, the method proposes the prototyping activity, in which a set of practices are executed with older users in order to discuss, select and propose IoT solutions for Home Care. This includes the use of tangible objects to create prototypes, storytelling [46], and prioritization techniques. Personas are used to organize small groups of participants and to empathize with the older users (Table 4).

The analysis activity includes the collaborative construction of a positioning matrix to relate Personas and ideas, and the respective IoT solutions.

3.2.4 Phase 3: designing home care solutions

In this phase, we aim to prototype the IoT solution identified in the previous stages. Figure 1 presents the activities, inputs, and outputs of this phase, which is a prototype version.

This phase starts with the framework analysis, in which the designers must use the IoT Framework (see Sect. 2.1) to describe the elements of the prioritized solution. Table 5 presents a summary of the recommendations for the activities of Phase 3.

In the sequence, designers and IT professionals conduct technical workshops, which include brainstorming of the technical solutions according to the previously identified requirements, as well as the formalization and feasibility analysis of the User Stories. Next, the design and development team implements prototypes in an iterative manner. Older users and other stakeholders are consulted about the produced prototypes.

The last activity is the Validation Workshop, which starts with the description of scenarios focusing on the use of the prototypes in the users' own homes. Role-play scenarios are carried out with older users, where they act in situations that require Home Care assistance. Finally, the older users are invited to perform scenarios using the Think Aloud [60] protocol.

We obtain as results of the last phase a prototype, an IoT solution evaluated by older users, a survey, and requirements for the next prototype cycle.

4 Evaluation with older users and analysis of the results

We applied IoT-PMHCS to understand older users' participation needs, difficulties and impressions during the proposed activities (main focus), as well as to analyze the acceptance of market based solution and proposed prototypes. The studies with the older users presented in this work were approved by the Human Research Ethics Committee of the Brazil Platform, Brazil, Register No. 98684218.3.0000.5397. All participants signed an informed consent form.

Figure 3 presents an overview of the application of the IoT-PMHCS and evaluation activities carried out within its phases. This includes interviews and five workshops, as well as semi-structured questionnaires called "Participation

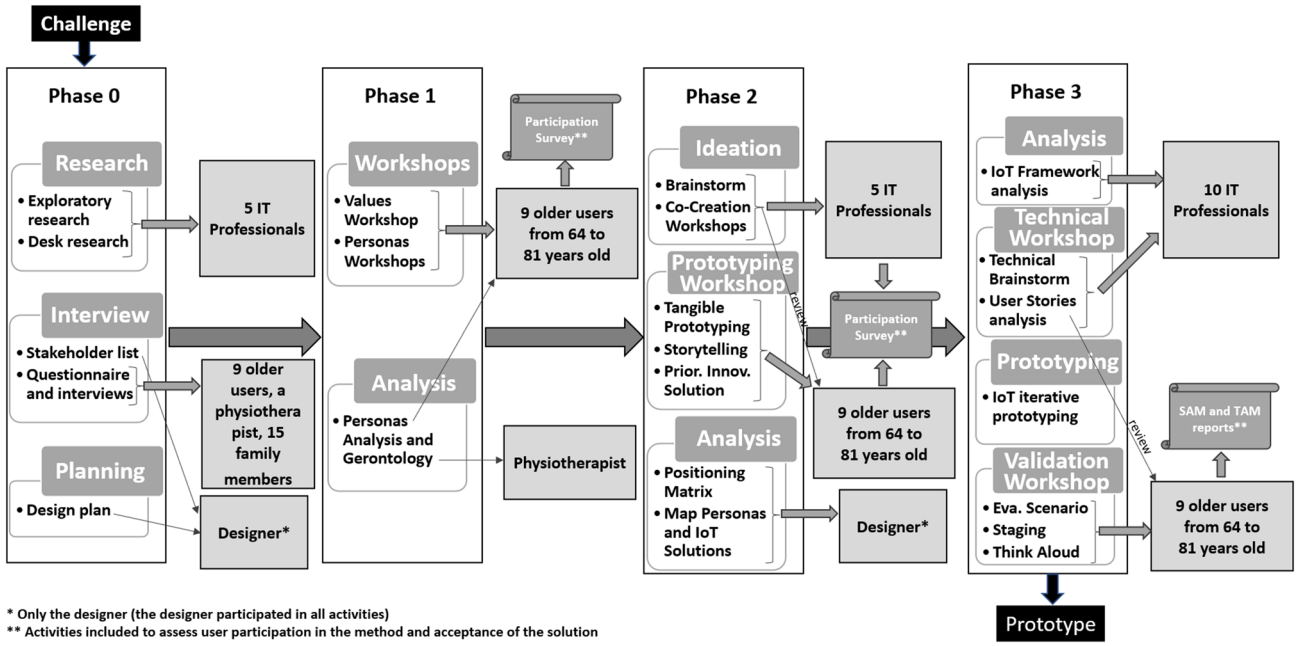

Fig. 3 Overview of the participation of the stakeholders in method and evaluation activities

Survey" applied at the end of three workshops to evaluate user participation. We also applied SAM (The Self-Assessment Manikin [10]) and TAM (Technology Acceptance Model [16]) techniques to evaluate the acceptance of the solution.

Section 4.1 presents how we planned and conducted the activities with older users, IT professionals, caregivers, and family. Section 4.2 presents the evaluation results of the IoT-PMHCS activities.

4.1 Planning and conducting the evaluation

This study followed the planning model conducted by Gonçalves et al. [23], which was designed to assess the way older users interact with Home Care systems. In the following, we present details regarding our study goals, its methodology, the participants involved in the study, materials, and devices.

Hypothesis: IoT-PMHCS is able to provide effective participation of the older users (and other stakeholders) in the design of Home Care solutions based on IoT technology. We also expect good user acceptance of the technology, once they participated in the process.

Study objective: To understand and evaluate the participation of older users in the IoT-PMHCS, including their needs, difficulties and opinions about the participatory activities. We also aims to evaluate the acceptance of prototypes developed using existing AAL devices (*e.g.*, IrisSenior[1]).

Methodology: A group of older users was invited to participate in the design (using IoT-PMHCS) and studies so that their behavioral responses could be analyzed in their homes (i.e., the design activities took place in the house of the participants), aiming to allow participants to act more naturally. The studies with the older users took place in the town of Muzambinho-MG, Brazil. Figure 4 shows some pictures of activities with the older users during the application of the IoT-PMHCS method. We followed the method recommendations for scheduling, execution, and sequence of tasks. Table 6 sets out the main participatory activities required for the method.

Due to practical restrictions, activities with designers and IT professionals took place in the city of Campinas, SP, Brazil.

The participants answered the "Participation Survey" at the end of the Values, Ideation, and IT professionals workshops (Table 6), which asks about their experience during the activities. We also carried out a final evaluation after using monitoring devices during the validation workshop using SAM and TAM (Fig. 3).

Participants: By using the stakeholder diagram [31, 51], we identified key responsible actors, namely older users, IT professionals, researchers, health professionals, as well as family members, and older users' friends. The following groups of participants were selected:

- Nine older users were selected due to the researchers' proximity and because they resemble the Personas selected in this work. Table 7 summarize their profiles.

[1] http://www.irissenior.com.br/

Fig. 4 Co-design Activities with Participants

Table 6 Participatory activities carried out in the conducted case study for the application of the IoT-PMHCS method

#	Event	Participants	City	Time	Method
0	Research and Interview	Health professionals, older users and relatives	Campinas and Muzambinho	16h	Forms on internet and semi-structured Survey
1	Values WS	9 older users - 60 to 80 yrs.	Muzambinho	3h	Generative Session and Brainstorm
	Ideation WS	5 IT Professionals	Campinas	3h	Co-Creation, Brainstorm
2	Prototyping WS	9 older users - 60 to 80 yrs.	Muzambinho	5h	Brainstorm, Storytelling, Norm table, User Journey
	Technical WS	10 IT Professionals	Campinas and Online	4h	Co-Creation, Brainstorm, User Jrne.
3	Validation WS	6 older users - 60 to 80 yrs.	Muzambinho	6h	Scenario, Staging and Think Aloud

Table 7 Older Users profile, including, respectively, pseudonym, age, gender, basic skills with (any) IT device, closest person (even if you live alone), educational level, profession, and whether you live alone or not

Pseudonym	Age	Gender	IT Exp.	Closest person	Educ. level	Occupation	Live alone
Bela	81	Female	No	Daughter	Second degree	Housewife	No
Teresa	75	Female	Yes	Husband	Second degree	Housewife	No
Beta	68	Female	Yes	Husband	Graduated	Housewife	No
Luiz	67	Male	Yes	Husband	Graduated	Manager	No
Noel	70	Male	Yes	Husband	Graduated	Retired	No
Edson	75	Male	Yes	Husband	Graduated	Layer	No
Zeze	68	Female	No	Son	Graduated	Retired	Yes
Elga	64	Female	Yes	Husband	Graduated	Dentist	No
Lucia	72	Female	Yes	Husband	Graduated	Retired	No

Interview results detailing its main characteristics are presented at the end of this section;

- Ten IT professionals, including: seven computer scientists, two computer engineers and one production engineer. Five professionals work in a transnational corporation that operates in several IT areas; another five participants were graduate students. Eight participants have previously developed IoT projects;
- One physiotherapist at the city of Muzambinho, selected by her experience with older users care;
- Fifteen family members of the older users, selected according to their proximity to them.

Materials: The used materials prepared in advance of the study: the consent form; the profile survey questionnaire; and the participant observation form. The profile survey questionnaire addressed social, cultural, and educational issues to develop a detailed profile of older users. The participant observation form contained notes regarding all participants, including the older users, professionals, family members, and researchers. Also, the workshops were recorded in the video for posterior analysis.

Devices: The older users were monitored by the call center of Home Telecare IrisSenior using a speakerphone; besides that, they used a bracelet and smart necklace[2] to monitor falls and heart risks. These devices were used in the validation workshop (Table 6). The participants used these devices at least two days before the final evaluation (SAM and TAM).

Initial activities and description of older users' profile. We carried out semi-structured interviews to understand the profile of older users. The interviews were individual and included 19 closed and open questions (available in [49]). These interviews focused on key elements, such as their lifestyles including habits and health, dangerous situations experienced at home including the main challenges and needs, and their relationship with technology and Home Care.

Regarding their profiles, most of the participants were female, over 70 years old, university graduates. Regarding their home-sharing, only one participant declared to live alone. The others live with their spouse or family members; however, they stay around four hours alone at home on average. Although we face practical difficulties related to the recruitment of participants, which led us to an unbalanced group in some aspects, this group matches our minimal selection criteria: to include (1) at least one participant between 60-69, 70-79, and ≥ 80 years old; (2) at least one female and male participant; (3) participants of different occupations, including at least one retired; and, (4) both participants that live alone and with their families.

The biggest challenges experienced at home were related to falls, forgetfulness, and fire. According to the interview reports, the situations range from moderate to severe and were rich to understand their Home Care needs. All participants who live with family members have already experienced dangerous situations during periods they stayed alone. This led us to believe that their previous experiences are valuable for the design.

When asked about health problems, the most common were those related to hypertension (55.5%) and hearing loss (50.0%). None of the respondents required intensive care or had a serious illnesses that made it unfeasible to participate in the workshops or to live alone. Participants who had better health conditions expressed their concern about foreseeing problems in the near future, and the need to plan their stay longer at home.

When asked about dangerous situations, eight participants reported that they would currently use their smartphone to call for help (seven participants would call the neighbor). Five older users reported that they use the device frequently. Only two participants said they had no difficulty with technology and like it a lot, two participants responded that they do not like new technologies, but when they get used to it, they start using it frequently. The others (five) reported difficulties with technology but they are open to using it in face of possible benefits. They were also asked "How do you imagine that technology can help you in dangerous situations at home?". Older users were willing (and some enthusiastic) to come up with ideas for using the technology in their homes and for health monitoring, which pointed out a positive posture in relation to participation in co-design activities. Although they related some difficulties with the technology, this preliminary result contradicts the initial idea of older users as a resistant group.

4.1.1 Participation surveys and final evaluation methods

The Participation Survey was applied after the Values Workshop and Prototyping Workshop to older users, and after the Ideation Workshop to IT professionals (cf., Fig. 3). The objective was to collect information about their experience with the workshop shortly after its execution. Details about the design of the questionnaire, results, and analysis forms are available in a Technical Report [49]. Table 8 presents the questions, which aim to evaluate the adequacy of the IoT-PMHCS workshops to older users.

After taking the "Participation Survey", the answers were discussed in a focus group; the researchers mediated the discussion and summarized the most relevant elements for analysis.

We also executed a final evaluation during the Validation Workshop, in which we simulated a dangerous situation, after prolonged use (15 days). We chose to use the SAM [10] and TAM [16] techniques twice: i) at the end of a simulated experience of using the IrisSenior device in self-assessment guided by the researchers, and (ii) after an experience of prolonged use. We aim to evaluate the acceptance and influences of prolonged use. As presented in Table 12, three participants made use of the solution during 15 days.

SAM was chosen because it is a qualitative and objective method that allows the subjective feelings of an emotional

[2] Bracelet and smart necklace were chosen as being integrated into the IrisSenior's technological solution, as well as having appeared as alternatives in the initial activities.

Table 8 Questions of the "Participation Survey"

#	Questions
Q1	Did you have enough time to complete all activities?
Q2	Did you feel prepared and comfortable with the workshop?
Q3	Were the artifacts used in the workshop adequate (Post-Its, Card-boards, Printed Material, Videos ...)?
Q4	Were the activities properly executed (even when some complexity is required)?
Q5	Was our group prepared for executing the activities?
Q6	Was the information provided by the mediator and the Personas' descriptions sufficient for the workshop?
Q7	Would you participate in the next stage of this research project?
Q8	Please, leave any comments or suggestions.

episode to be evaluated using pictograms. Emotional aspects are important in events involving health and can be crucial for the success of a Home Care solution. The use of pictograms proved to be viable in the context of the older users who participated in the study.

Resistance and acceptance of new technologies is one of the key design challenges we face in the development of solutions for Home Care. We chose to use TAM, since it is a is a method to assess the acceptance of technologies. The following factors are considered: perceived utility, perceived ease of use and external variables.

4.2 Evaluation results and findings

For each phase of IoT-PMHCS (Sects 3.2.1– 3.2.4), we describe the analysis of results and lessons learned about issues related to co-design activities with older users (and other stakeholders) as well as a brief summary of the produced design artifacts.

4.2.1 Results-phase 0

The older users participated in interviews and answered the exploratory surveys and questionnaires (see Fig. 3). In general, the activities took place as expected and all artifacts were properly produced, which indicates the feasibility of applying the method with stakeholders in a real-world context. Individual interviews took approximately one hour per person for both older users and health care professionals.

In the interviews with the older users, we took into account the main problems raised by Home Care. The results were initially divided into the AAL categories proposed in [39], adapted to the Brazilian context. All older users were open to answering the questions. One older user made a point of reporting problems with technology and difficulties that it brings (according to him) to his daily life. However, he was willing to discuss alternatives and give suggestions for creating an "easy to use" solution. Older users highlighted the importance of a break during the interview and declared a preference for it in relation to the questionnaire.

The main challenges of Home Care pointed out by the older users concerned the problem of falls (9 citations in 23, that is 40%) and forgetfulness (8 citations in 23, that is 35%). The main challenge presented by the health professionals is linked to falls (at night, on stairs, on slippery floors) and abuse suffered by the elderly due to the lack of preparation of caregivers.

A questionnaire was also sent by e-mail to 22 family members and answered by 14, with at least one family member of each older user. A key concern was related to fast communication in case of danger. Appendix 1 presents results with the "Affinity Diagram of Main AAL Suggestions" produced from the results with older users, physiotherapists, and family members.

4.2.2 Results-phase 1

As shown in Fig. 3, in this phase, older users took part in two workshops (Values and Personas). During the Values Workshop (Table 6), the participants were divided into three groups (refer to Table 9) according to the affinity with the Personas suggested in [22]. These personas were created by Home Care professionals, as described in [22].

Results from the "Participation Survey" show the main issues and lessons learned about the workshop planning and execution. The quantitative results are presented in Table 10. We summarize the following results based on the participants' feedback (qualitative and quantitative): (i) *time schedule*, the total duration of two hours was considered adequate by all participants; however, most highlighted that 10-minutes breaks every half hour are desirable to maintain focus and participation; (ii) *groups*, the division of the users in three groups (according to Personas) were considered satisfactory, only one participant requested to change the group, (iii) *material*, they reinforced the need of using printed content using large font size instead of digital files, and (iv) *process*, they emphasized the importance of providing step by

Table 9 Values Workshop: Home Care challenges prioritized by Persona

Group-Persona	Persona value	Categories in order of importance	Home care challenges	Additional challenges
Group 1 - Antonio: Luiz, Edson and Noel	Independence	Health, Mobility, Social Inclusion, Safety, Daily Facilities	Medicines control	Mobility, friendship, robbery, failure
Group 2 - Maria de Lourdes: Elizabete, Lucia and Teresa	Independence	Health, Social Inclusion, Safety, Daily Facilities, Mobility	Forgetting to take medication, taking care of feed, improve self-confidence, concern with cooker, forgetfulness, difficulty with mobility	Loneliness, robbery
Group 3 – Nair: Maria José, Maria Gabriela and Elga	Be Part of	Social Inclusion, health, Daily Facilities, Mobility, Safety	Need for company or caregiver, Control of medications, daily activities, food	Depression, difficulty seeing, forgetfulness, difficulty with mobility (Faith)

step explanations about the process, prior to the workshop, including the next phases.

All participants answered positively about participating in subsequent activities and assigned positive evaluations of the workshop such as *"It was an opportunity to go back to school and work as a group. It was fun"; "When asked about our values, we had to look internally for what was really important in our lives and this brought us great reflections"; "It was an opportunity to think about our current reality and our future"; "It was an opportunity to be with friends in a different manner"*.

Older users also emphasized some positive aspects of using Personas with Empathy Maps [17] in the proposed method. We identified a higher degree of identification between user groups and Personas regarding health conditions, their relationship with technology, and personal preferences.

The "Sense of Purpose" was the most significant value pointed out by the participants, followed by "Be part of" and "Independence". We also asked the groups to provide the main value for each Persona. Table 9 shows the results from the Values Workshop, summarized by Group - Persona. Fig. 5 shows the guidelines, which were used to stimulate the discussion. An example of this is that during the next phase, the participants (IT professionals and older users) were invited to propose innovative IoT measures to ensure security and independence.

4.2.3 Results-phase 2

As shown in Fig. 3, IT professionals participated in the Ideation Workshop while the older users participated in the Prototyping Workshop. Although our initial planning presupposes the participation of older users in the Ideation Workshop (see Table 4), practical issues such as geographic distance and the agenda of the participants did not make this possible. This led us to adapt the Prototyping Workshop to include an activity to present and review (by older users) the results from the Ideation Workshop.

Results from the Participation Survey (with IT professionals) after the Ideation Workshop show: (i) participants considered the material and activities to be adequate for carrying out the activities; (ii) they also considered the explanations sufficient to conduct the activities; (iii) the participants consider themselves capable of carrying out the proposed activities; (iv) most (67%) of IT professionals recommend the presence of older users and IT professionals in the same ideation session (as initially planned). The IT professionals suggested, in case it is not possible to carry out this activity in a group with older users and IT professionals together, to use tools to facilitate the co-creation of shared artifacts such as the Persona Maps and Canvas.

Qualitative results from the Participation Survey after the Prototyping Workshop (with older users) show: (i) participants considered the material and activities to be adequate for carrying out the activities, in particular they highlighted the importance of playfully artifacts linked to their daily lives; (ii) they considered the explanations sufficient to conduct the activities; (iii) they do not consider the presence of IT professionals necessary, and they believe it would even hinder or limit the activities with older users; (iv) most (about 89%) of the participants do not consider the presence of health professionals essential, and they believe health professionals may limit the practices and direct participation of the older users. Older users (even those under 70) reported

Fig. 5 Guiding criteria including main solution goals, criteria which define its successes and project' limitations

Table 10 Results of "Participation Survey"

#	Values WS	Ideation WS	Prot. WS
Q1	100%	100%	100%
Q2	100%	100%	100%
Q3	100%	100%	100%
Q4	100%	100%	100%
Q5	67%	88%	88%
Q6	88%	100%	100%
Q7	88%	100%	100%
Q8	Text	Text	Text

back and leg pain, as well as eye strain and tiring. The quantitative results are presented in Table 10.

The older users did not mention problems regarding tasks and artifacts. Older users highlighted the importance of the technology addressed and recognized the value. For example, one older user reported "... addressing a very current and necessary subject for the proposed age group", while another older user reported " ... the group was very homogeneous, showing a lot of interest in the excellent work, which was to benefit the lives of many people in the future".

We found relevant lessons learned from the workshops with older users, which can be used as directives for future Home Care co-design with older users:

- In general, older users did not report problems with artifacts, and as mentioned, they highlighted the importance of playful ones. We highlight the importance of using videos, images, and animations, as these can ease the understanding of innovative concepts (e.g., IoT and AAL);
- As shown in Table 10 (Question 5), some participants did not feel prepared to perform the activities. During the Values Workshop (see Sect. 4.2.2), they proposed using a sequential process (step-by-step) with a gradual evolution of complexity;
- The use of Personas was positively evaluated both from a quantitative (Table 10 - Question 6) and qualitative point of view. For instance, a user stated that "it is sometimes easier to talk about a health need of yours reflected in a Persona than it is to talk about yourself";
- The interactivity and constant feedback from older users supported us in providing a more adjusted process and the environment from workshops of phase 1 to phase 2. This allowed us to adapt the activities proposed in IoT-PMHCS to meet the specific needs and restrictions of the working groups;
- Once older users reported back and leg pain during the Prototyping Workshop, we suggest not exceeding two hours per participatory process session, recommend breaking activities down into smaller tasks and doing them on different days, as well as providing adequate accommodation such as ergonomic armchairs and adequate local for breaks.

Regarding the produced artifacts, the Ideation Workshop produced the following: (i) generation of ideas for each Persona and Positioning Matrix, including the criteria for choosing the best ideas; (ii) prioritized ideas for each Persona (Table 11); and (iii) updated Persona maps.

During the Prototyping Workshop, older users revised the IT professionals' ideas, proposed a substantial number of new ideas (56 ideas divided into 16 large categories), and prioritized the ideas (Table 11). These ideas were discussed using low fidelity (paper) prototypes. The Prototyping Workshop also produced a checklist table to support the selection of solutions in the next phases and updated versions of the Persona Maps and User Journey artifact.

The following assumptions for an integrated solution were defined: (1) assist older users' memory, mainly about taking medicines and buying them; (2) detect emergencies and facilitate communication when they occur; (3) collect and interpret updated health information; (4) be integrated to rescue services and trigger them as quick as possible; and (5) keep the entire support network up-to-date about emergency and procedures.

Table 11 Ideas revised and prioritized by older users

Persona	Ideas
Persona - Nair	(1) a device to control feeding and medicines, with alerts for caregivers; (2) an image recognition emergency system including video cameras at strategic points and monitors at family house or mobile; (3) a wearable device for monitoring pressure, heartbeats, and cholesterol, with alarms.
Persona - Antonio	(1) a chromotherapy system using light spots designed to improve sleep quality and adaptable to the time of day; (2) a set of devices designed to decrease the excitement rate before sleep; (3) a fall and stumble system.
Persona - Maria de Lourdes	(1) an online medicine box device that is able to recognize missing medicines and automatic purchase via the Internet; (2) an intelligent warning system integrating wearable devices and sensors; (3) an intelligent kitchen system to simplify food preparation and avoid risks.

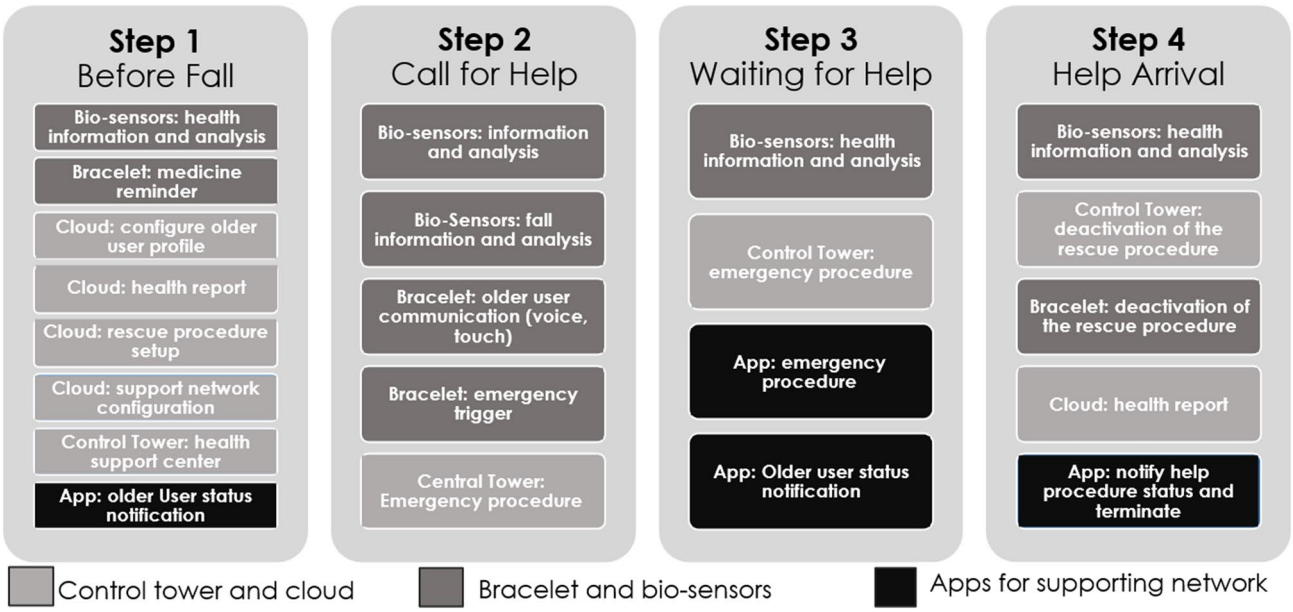

Fig. 6 Revised version (by older users) of Smart bracelet features according to the User Journey

4.2.4 Results-phase 3

As shown in Fig. 3, in Phase 3, 10 IT professionals participated in the analysis and technical workshop while the older users participated in the validation workshop.

The IoT Framework was analyzed and used to organize the tasks with IT professionals during the technical workshop. The IoT Framework was linked to the User Journey in order to develop the functional specification of the solution, resulting in (i) an *Integrated Solution Diagram*, which maps the components (or things) that are part of the IoT solution as well as how they exchange information, (ii) the *IoT Framework* including User Stories aiming to supports the detailing of "semantics-thing" relationships, and (iii) a *Features List* with scenarios using IoT solutions as described in the User Stories.

Figure 6 presents smart bracelet features specified according to the User Journey, that have been reviewed by older users. A hazard prevention worksheet (including a description of using fall sensors, oximeter, blood pressure sensors, environment CO2 sensors, to cite a few), constructed with the study results, was used in a new review of the IoT Framework.

We held a Validation Workshop employing different simulation scenarios. Table 12 presents the participants' profile and their scenarios, including: name (nickname), age, resistance to technology, familiarity with technology, group/persona, type of scenario, description of the scenario, and duration of the scenario.

As it was out of scope to build a new device, at this stage, we reused an existing device (IrisSenior equipment) in an adapted solution. We named this solution "AS IS" in the validation workshop (Table 12). In this scenario, the simulation took place with real-world devices, i.e., the user simulated a dangerous situation (cf. Table 12), activated the device, and the Central IrisSenior carried out the service as in a real and current situation.

The "TO BE" scenario considers the need for additional devices, such as activation by voice command, replacement of the bracelet by a smartwatch, biosensors, and integrated sensor analysis. Table 13 presents the relationships between results of participatory activities and the "AS IS" and "TO BE" scenarios, i.e., examples of how the values, challenges, and ideas have arisen with older users and IT professionals were considered in the evaluated solutions. We highlight the use of wearable devices, which facilitate communication with family, their own social groups, and other older users aiming to strengthen some key values such as belonging (be part of) and a sense of purpose. Independence is another value considered due to the lower need for intervention by health professionals via automation by biosensors. It is also noteworthy that in the "TO BE" scenario, sensors are incorporated to evaluate emotional and security reactions (which were emphasized by the participants in phase 0). Such issues were synthesized in a list with 21 user stories for the "TO BE" scenario, which is detailed in a Technical Report [49].

SAM and TAM were applied during the Validation Workshop with all participants and after 15 days (prolonged use) with three participants of the Validation Workshop (Table 12) in order to measure the acceptance of the proposed solution. The results supported the definition of refinements and adaptations in both prototype and method.

Table 12 Validation Workshop: Organization and description of scenarios and participants

Pseud.	Age	Resistance to technology	Familiarity with technology	Group-Persona	Type of scenario	Description of the scenario	Use period
Elizabete (Beta)	68	No	No	Maria de Lourdes	TO BE	(1) Partial simulation, (2) Voice command activation, (3) Situation: health problem and fall, (4) Successful	15 Days
Lúcia	72	No	Yes	Maria de Lourdes	AS IS	(1) Partial simulation, (2) Manual activation, (3) Situation: fall, (4) Fail	During the Workshops
Luiz	67	No	Yes	Antônio	AS IS	(1) Partial simulation, (2) Manual activation, (3) Situation: health problem, (4) Successful	15 Days
Maria José (Zezé)	69	Yes	No	Nair	TO BE	(1) Full simulation, (2) Voice command activation, (3) Situation: health problem and smoke, (4) Human Intervention	During the Workshops
Elga	64	No	Yes	Nair	AS IS	(1) Partial simulation, (2) Automatic activation by fall sensor, (3) Situation: fall, (4) Fail	15 Days

Table 13 Examples of relationships between results of participatory activities (with older users and IT professionals) with "AS IS" and "TO BE" solutions

Persona	Main value	Challenges	Ideas	AS IS	TO BE
Nair	Independence	Memory failures	Device to control feeding and medicines	Phone call support	Smartwatch with medication reminder app introduction of location sensors in objects (keys, glasses, wallet, purse)
Antonio	Independence	Falls in general, theft and robbery	Fall and stumble system	Manual activation in the smart bracelet or Iris-Senior device	Automatic activation via ambient monitoring sensors (falls, fire, etc) and voice control system (remote activation).
Maria de Lourdes	Be Part of	Loneliness, blood pressure and hearing	Intelligent warning system integrating wearable devices and sensors	Smart Bracelet (with biosensors and emergency trigger)	Multiples wearable devices (e.g., necklace and smartwatch) for communication and health monitoring (biosensors)

They showed the need to produce more flexible solutions as well as the possibility of extending the method to other purposes and groups.

Results of the SAM We highlight the following results of the SAM method: (i) Regarding "Satisfaction", 85% of users felt satisfied or very satisfied with the solution; (ii) Regarding "Ease of Use", approximately 72% considered the solution simple and easy; this encourages its use; (iii) Regarding "Motivation", 75% of the volunteers felt motivated to use the device in dangerous situations after the simulation. This motivation decreased after prolonged use; 28% declared to be less motivated, 29% declared to be indifferent, and 43% remained motivated. This is due to the fact that the volunteers gave up using intensively the device on average after 2 days of prolonged usage (15 days) since they did not need it or did not like its design.

By observing the use of the framework, we understand that the solution meets the expectations of the older users in most cases, especially in situations of immediate danger. With prolonged use (15 days), the solution presented

motivational problems after the second day; however, the SAM analysis does not make clear the reason for the lack of motivation. To identify the cause of the problem, the results of the TAM method were analyzed, as described below.

Results of the TAM Regarding "Perceived Utility", after simulating the use of the solution in simulated situations of danger, most users agreed that the device is useful, generates value, and provides tranquility for the older users and their families. Only 16% of the answers indicated the opposite (4 negative responses out of 24), with only one user believing that the solution does not improve the autonomy and that its resources are limited. However, when the questionnaire was applied after prolonged use, the number of negative answers to the solution increased to 38.89%.

When older users are faced with the question *"I would not use this device because it has many limitations."* in a simulated dangerous situation, 100% of the answers disagreed with it. However, after prolonged use, the majority of the users agreed with this statement. This leads us to infer that after prolonged use, the solution presents attractiveness problems. After prolonged use, 100% of older users answered that they would like more features in the device and 67% pointed out design problems. The following statement corroborates this analysis: *"It is ugly, I would use it if it had a more beautiful and modern design. In addition, there are no interesting features."*. We also collected new design suggestions, such as *"I wanted a solution similar to a Smartwatch, but with more features."*.

Regarding "Perceived Ease of Use", 100% of the answers (even after prolonged use) state that the device is simple, easy to use and does not cause anxiety in use. During the workshop, 1 of the 5 participants stated that they would not use it daily as compared with 2 of the 3 participants after prolonged use. However, all users stated that they were motivated in proposing changes that they could make use of the devices. When asked what features they would like and want to keep intact after 15 days of use, the older users mentioned: ease of use, call center, speakerphone, and action plan. One of the participants declared *"It makes me feel more secure, it is like not being alone."*, and another older user highlight: *"I really liked the 'Help me Iris' voice command. The response time ..."*.

Regarding "External Variables", 100% of the answers indicate that the instructor has a good level of knowledge about the device. This outcome could be related to the perceived ease of use since 100% of the answers state that the device was simple and easy to use. Regarding the support offered by the IrisSenior Service Center, 71.43 % state that the Service Center provides good service and that its action plan is efficient.

5 Discussion

This section discusses results from our research and the conducted case study in the application of IoT-PMHCS with older users. Section 5.1 focuses on our study in view of co-designing of IoT-based solutions for Home Care with older users, including aspects related to the use of Personas and strategies for addressing participation and creativity. In Sect. 5.2, we analyze the results obtained by the developed solution. Section 5.3 discusses the trade-offs and limitations, as well as open research challenges.

5.1 Co-design of IoT for home care with older users

In accordance with the vision of Leonardi et al. [37], in which home is a "territory of meaning", our study emphasized the relevance of better understanding older users "territory", their challenges, and especially how staying in their homes for as long as possible is important for the extension and quality of their lives. Although participants reported difficulties in their daily lives, results from our Values Workshop (Table 9) reinforced other studies (*e.g.*, [57]), by showing that older users prefer to: live in their own homes and be as autonomous as possible (independence); have a good life condition (health and well-being); be part of the daily life of their family, neighbors, and community (social inclusion); move and exercise (mobility).

As Table 11 shows, our study demonstrated the need for proposals and solutions that go beyond the use of smartphones. Thus, the communication concept needs to go beyond the current mobile computing scenarios based on the use of smartphones, *i.e.,* it must evolve into connected everyday objects, incorporating intelligence into this context [26].

This research presented the need for a suitable design method to guide designers in the construction of IoT-based Home Care technological solutions. In the case of older users, a comprehensive IoT-based solution that meets users' different needs and preferences is required. As argued by [44], values are a key factor in co-design with older users [38]. Our solution focused on addressing older users' values (e.g., Table 13) to further promote better acceptance, which were evaluated using SAM and TAM.

The IoT-PMHCS gets inspiration in PD, and articulated methods coming from other fields, such as DT, personas, and IoT framework, in the context of Home Care for older users. Each of these had a specific role in designing with older users for IoT solutions for Home Care, which we discuss in the following.

Participation and respect for older users are the basis of our proposal. The obtained results indicated that older

users were open to cooperating with the design tasks. Our preliminary results (Sect. 4.1) presented the older users disposition on cooperating and, as presented in Sect. 4.2, older users remained open to cooperating during all the workshops. Even those who reported difficulties after the 15 days study (Sect. 4.2.4) remained open to cooperating by customizing the solution. This contradicts the initial idea of older users as a technology-resisting group. One hypothesis (to be explored in future studies) is that when called to participate in the design, the technology makes sense to them, removing the barriers of resistance to using the solution.

As discussed by [32], we emphasized that DT can contribute to innovative design solutions and human-centered health solutions for older users. In accordance with [50], several adjustments were necessary to enable and promote the participation of PD activities with older users, such as (1) *adjustments to schedules*, for instance (Sect. 4.2.2) frequent 10-minute breaks were suggested by older users; (2) *accommodations*, due to complains of back and leg pain in the prototyping workshop; (3) *artifacts*, for instance, the older users preferred playful tangible artifacts (Sect. 4.2.3); and (4) *process adjustments*, such as to provide step-by-step explanations, with a gradual evolution of complexity.

The co-design of IoT devices with older users and IT professionals is another key aspect in IoT-PMHCS. As presented by [2], the design of IoT with older users falls into complex issues related to their situated passions, environment, and objects, personal relationships, as well as the need for orchestration to realize an IoT prototype. At IoT-PMHCS, we used the IoT framework [5, 34] as a means for structuring, understanding, and addressing the gathering of IoT requirements. During the study, we used the IoT Framework to analyze and organize the tasks in the technical workshop; in particular to support IT professionals in the detailing semantics-thing relationships using user stories produced by older users.

In view of developing Home Care services as a strategy for humanized Health Care [54], such as those proposed by relational technologies that indicate the reception, bonding, listening, respect, and dialog with the health service users [45], the IoT-PMHCS brings, via the unprecedented composition of consolidated approaches to co-design with older users (DP, DT, and Personas), a path to propose Home Care solutions based on the perception of the older users themselves.

Empathy is another aspect to be considered in the co-design process. There are approaches and frameworks used to empathize with users during the co-design process [55, 56]. The literature points out Personas as valuable tools to create empathy with users in the design process [15, 22, 42].

Previous studies by Gonçalves et al. [22] have underlined the need for the participation of older users in the IoT-based solution design process for Home Care using Personas. Their results are not strictly comparable to our current contribution because this previous study was concerned with creating Personas (used in this study). We highlight some positive and negative aspects of both studies. Gonçalves *et al*. [22] refer to the participation of health care professionals in the design, which has resulted in a flexible description of the Personas, including their physical characteristics and psychological conditions. Our current investigation explores this question in a higher depth because we address several aspects of the design process with older users, including the issues related to the challenges of their everyday lives (Table 14) and values (Table 9). It also involves technological issues, as well as the validation of a functional solution. The inclusion of older users in the process leads to issues and solutions being included that may not have been predicted by health professionals and designers. However, this might incur additional costs and require more time to investigate the process, since the participation of health professionals was only examined in our study in a limited manner when compared with Gonçalves et al. [22]. Further studies are necessary to tackle how to carry out activities with health professionals and older users together.

We emphasize that IoT kits can be used to enable creativity and facilitate the design in further research with IoT-PMHCS. By focusing on the experience of people using the IoT elements in this context [2], studies on the use of IoT kits (e.g., Un-Kit), in the specific context of Home Care, can help with prototypes and consider the creativity of older users in the co-design activities.

5.2 Analysis of the developed solution and user acceptance

The IoT-PMHCS was conceived to provide requirements and to support the specification of innovative IoT-based solutions. With regard to the main requirements raised by users during the design, which were considered in our prototype, we highlight: (i) assisting older users in preventing danger; (ii) providing additional technological resources, such as a clock, alarms to avoid forgetting medicines, communication with family members and a medical support network, etc.; and (iii) being ubiquitous and pervasive whenever possible.

As shown in Table 13, our method allowed to take into account the values, challenges, and ideas of the participants (Older Users and IT professionals) in the solution. Some system features such as simple interfaces, memory support (to avoid forgetfulness), and communication capabilities can support key values such as *independence* and *be part of*. We opined that this would have a positive influence on the acceptance of the solution. The SAM and TAM methods were used to assess acceptance.

As presented (Sect. 4.2.4), during the Validation Workshop both SAM and TAM reported positive results regarding older users' sentiments and acceptance. Such aspects were better perceived and valued in simulated dangerous situations. However, with prolonged use, the solution presents attractiveness issues, just as users were likely to use the solution with customization. This indicates the need for studies on long-term use to increase motivation (and comfort), according to the individual preferences [4]. Future research should address the need for adaptive Home Care solutions, including the emotional aspects [43].

5.3 Trade-offs, limitations and research challenges

Despite positive feedback in various situations during the application of IoT-PMHCS, we identified the following limitations of our study: (i) The prototype does not implement all the proposed requirements; (ii) The proposal was applied to 3 Personas, despite Gonçalves & Bonacin [22] recommend 5 Personas, due to the unavailability of the participants.

We highlight that the choice of the bracelet and smart necklace may have influenced the proposition of innovative solutions. These choices were made due to the limitations of technologies available, because they are integrated into the IrisSenior solution, as well as due to they appeared in the preliminary studies. This influence was minimized in sessions that led to imagining the "TO BE" solution (not considering technological and financial limitations at the time). In this sense, replacement of the bracelet by a smartwatch, biosensors, and integrated sensor analysis was proposed.

Due to the limited time and availability of users, it was not possible to fully assess the "TO BE" solution in aspects related to the values elicited by the method (*e.g.*, be part of and sense of purpose). Such an assessment demands long-term production and operation, as well as additional research on these aspects. In fact, our results show that although we have good results in the short-term, in-depth studies and the continuous improvement of the solution in the long-term are essential for research on technological solutions for Home Care.

We highlight the limitation of our study with regard to the number of participants. These participants brought valuable feedback. Further studies with a higher number of older users, as well as professionals from other fields related to Home Care could complement our results and improve the process.

Although the IoT-PMHCS has phases and some general activities that can be applied to other contexts, the method remains limited in terms of the domain (Home Care), technology (IoT), and users (older users), since its templates, artifacts, and activity dynamics were built for specific purposes. For instance, the template of "Persona Map" focuses on care needs and assistive categories, the IoT framework is a key and integrated part of Phase 3, and the dynamics of the activities and artifacts used in it were elaborated to allow co-design with older users. For example, the duration and intervals of activities, the construction of artifacts that are easy to see and manipulate, as well as the preparation of the environment for considering mobility limitations were produced thinking of older users. Future research on possible changes to the method for use in other contexts is needed. Such research involves the reformulation of central elements of the method, as well as an evaluation in other contexts.

6 Conclusion

Providing a real-world IoT-based solution in Home Care for older users is a challenging design task. This research dealt with key issues in the co-design activities of these solutions with older users and other stakeholders, such as IT professionals, family members, and health care professionals. We hope to create an enabling environment for older users' participation in the design process, aiming to build solutions that consider the values, challenges, and ideas brought by stakeholders.

We presented the IoT-PMHCS Method relying on DT and PD methods. Our proposal is strongly oriented by the concept of Personas to generate commitment and empathy. We emphasized capturing stakeholders' values, using the IoT framework as a supporting tool. We pushed the boundaries of participatory techniques by generating innovation in the context of IoT in Home Care with a focus on older users.

We identified and discussed key aspects of the design process in a study with older users. We detected fundamental requirements for IoT-based Home Care solutions relying on the results from participatory activities. We discussed lessons learned, users' acceptance, and proposed requirements for future Home Care solutions.

As future work, we aim to define Personas to represent all stakeholders of the solution (*e.g.*, family members, health professionals, etc.) and expand each profile's analysis within each phase of the method. We propose researching adaptive solutions focused on long-term use. Such solutions can increase the motivation for using more attractive devices according to the individual perspective and provide Home Care features customized and flexible to each user's needs and preferences.

Appendix -affinity diagrams

See Tables 14, 15 and 16.

Table 14 Results of the affinity diagram regarding the main challenges in Home Care and AAL suggestion based on interviews with the participants (older users)

Category	Detail	Challenges	AAL
Safety and Security	Burglaries, robbery and Fire	High occurrence of theft and robbery in the home of the older users; Fire	Sensors and face recognition could identify strangers; Monitor caregivers to avoid mistreatment; Activation of alarms using voice command; Use of mobile devices to provide danger alerts for family members.
Daily task facilitation	Forgetfulness	Memory failures	Sensors to locate important items using voice commands (e.g., keys, mobile, glasses, wallet, bag, medicine); Activation/deactivation of electric and electronics devices.
Mobility Assistance	Falls	Falls in general	Include Sensors in the Stairs; Fall detection using cameras; Fall alert activation to family members using voice; Emergency lighting has the whole house in case of power failure.
Health Care and Rehabilitation	Health Problems	Problems related to blood pressure (62.5% of the older users) and hearing (50%)	Bracelet for the analysis of danger symptoms; Fast response from the health plan in case of danger; Constant analysis of the health history.
Social and Comm.	None	Loneliness	None.

Table 15 Results of the affinity diagram regarding the main challenges in Home Care and AAL suggestion based on interviews conducted with health care professional

Category	Detail	Challenges	AAL
Safety and Security	Mistreatment	Caregivers are often not prepared to support the older users; they are many cases mistreated	Cameras and sensors in cellphone to monitoring by family members with danger alert.
Daily task facilitation	Forgetfulness	Memory failures and Alzheimer	Not identified.
Mobility Assistance	Night falls	Up on benches and chairs; sidewalks in front of the houses; stairs are not a very critical and observed problem	Lighting and voice sensors.
Health Care and Rehabilitation	Health Problems	Intestinal constipation, blood pressure, heart and respiratory	Voice controlled bracelet with health sensors and danger alerts to family and doctors.
Social and Comm.	None	None	None.

Table 16 Results of the affinity diagram regarding main challenges faced in Home Care and AAL suggestion based on interviews with relatives

Category	Detail	Challenges	AAL
Safety and Security	Theft	Theft and robbery	Interconnected system with emergency system and alerts; Sensors that identifies drop by sound and triggers SMS or WhatsApp alerts;
Daily task facilitation	Forgetfulness	Hyperactivity: the body does not follow the head; forgetfulness	Not identified.
Mobility Assistance	Night falls	Stairs; slippery floor	Device that notifies family members with mobile fall.
Health Care and Rehabilitation	Health problems	Joint problems; heart diseases; diabetes; spine problems	Bracelet with sensor to monitoring health, danger alerts, drones and intelligent cameras.
Social and Comm.	Solitude	Solitude	None.

Acknowledgements The authors thank the older users for their contributions to the activities and as family members and health professionals who made this case study feasible. We also thank the IrisSenior Serviços de Teleassistência for providing the Home Care devices and call center services used in our research. This study was financed in part by the Brazilian National Council for Scientific and Technological Development (CNPq) grant No.405352/2021-2.

Data availability The data that support the findings of this study are available on request from the corresponding author R.B. The data are not publicly available due to them containing information that could compromise research participant privacy/consent. Additional anonymous data are available in a technical report [49].

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

1. Aarts, E., Harwig, R., Schuurmans, M.: Ambient intelligence. McGraw-Hill Inc, USA (2001)
2. Ambe, A.H., Brereton, M., Soro, A., Chai, M.Z., Buys, L., Roe, P.: Older people inventing their personal internet of things with the iot un-kit experience, p. 1-15. association for computing machinery, New York, NY, USA (2019). https://doi.org/10.1145/3290605.3300552
3. Ashton, K.: Whither the five-cent tag. RFID J. **8**, 2017 (2011)
4. Askenäs, L., Aidemark, J.: Supporting elderly living longer at home: a framework for building a sustainable eco-system. in: iadis international conference internet technologies and society, São Paulo, Brazil, 5–7 February, 2020, pp. 3–11. IADIS Press (2020)
5. Atzori, L., Iera, A., Morabito, G.: The internet of things: a survey. Computer Netw. **54**(15), 2787–2805 (2010). https://doi.org/10.1016/j.comnet.2010.05.010
6. Bannon, L., Bardzell, J., Bødker, S.: Introduction: reimagining participatory design - emerging voices. ACM Trans. Comput. Hum. Interact **25**(1), 1–8 (2018). https://doi.org/10.1145/3177794
7. Becker, M., Werkman, E., Anastasopoulos, M., Kleinberger, T.: Approaching ambient intelligent home care systems. In: 2006 Pervasive Health Conference and Workshops, pp. 1–10 (2006)
8. Blythe, M., Wright, P., Monk, A.: Little brother: could and should wearable computing technologies be applied to reducing older people's fear of crime? Personal and Ubiquitous Comput. **8**(6), 402–415 (2004). https://doi.org/10.1007/s00779-004-0309-4
9. Bonacin, R., Dos Reis, J.C., Baranauskas, M.C.C.: Universal participatory design: achievements and challenges. J. Interactive Syst. **10**, 1 (2019)
10. Bradley, M.M., Lang, P.J.: Measuring emotion: the self-assessment manikin and the semantic differential. J. Behav. Ther. Exper. Psych. **25**(1), 49–59 (1994). https://doi.org/10.1016/0005-7916(94)90063-9
11. Brown, T., Katz, B.: Change by design: how design thinking transforms organizations and inspires innovation, vol. 20091. HarperBusiness (2019)
12. Camilli, M., Di Lucchio, L., Malakuczi, V., Salvetti, A.: A cross-disciplinary approach to design icts enabling active ageing and social inclusion. In: 7th Conference on Euro-Mediterranean Public Management Dialogue, pp. 08–10 (2014)
13. Charness, N., Best, R., Evans, J.: Supportive home health care technology for older adults: attitudes and implementation. Gerontechnology **15**(4), 233–242 (2016)
14. Chidzambwa, L., Michell, V., Liu, K.: Applying semiotics in configuration of home telecare devices in ambient assisted living environments, 8 p. university of reading (2017)
15. Cooper, A.: The inmates are running the asylum: why high-tech products drive us crazy and how to restore the sanity. Sams Publishing, USA (1999)
16. Davis, F.D.: Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly **13**(3), 319–340 (1989). http://www.jstor.org/stable/249008
17. Ferreira, B., Silva, W., Oliveira, E., Conte, T.: Designing personas with empathy map. In: SEKE, vol. 152 (2015)
18. Filho, G.P.R., Villas, L.A., Gonçalves, V.P., Pessin, G., Loureiro, A.A., Ueyama, J.: Energy-efficient smart home systems: infrastructure and decision-making process. Internet of Things **5**, 153–167 (2019). https://doi.org/10.1016/j.iot.2018.12.004
19. Fisk, A.D., Czaja, S.J., Rogers, W.A., Charness, N., Sharit, J.: Designing for older adults: principles and creative human factors approaches. CRC Press, Boca Raton (2020)
20. Gonçalves, V.P., de Almeida Neris, V.P., Seraphini, S., Dias, T.C., Pessin, G., Johnson, T., Ueyama, J.: Providing adaptive smartphone interfaces targeted at elderly people: an approach that takes into account diversity among the elderly. Univ. Access Inf. Soc. **16**(1), 129–149 (2017)
21. Gonçalves, V.P., Costa, E.P., Valejo, A., Geraldo Filho, P., Johnson, T.M., Pessin, G., Ueyama, J.: Enhancing intelligence in multimodal emotion assessments. Appl. Intell. **46**(2), 470–486 (2017)
22. Gonçalves, V.P., Geraldo Filho, P., Mano, L.Y., Bonacin, R.: Flexpersonas: Flexible design of iot-based home healthcare systems targeted at the older adults. AI Soc. **45**, 1–19 (2021)
23. Gonçalves, V.P., Giancristofaro, G.T., Geraldo Filho, P., Johnson, T., Carvalho, V., Pessin, G., de Almeida Neris, V.P., Ueyama, J.: Assessing users' emotion at interaction time: a multimodal approach with multiple sensors. Soft Comput. **21**(18), 5309–5323 (2017)
24. Grenier, C., Ibrahim, R., Duprat, L.: How to organize ephemeral third-place to foster the emergence of institutional innovations? the case of a cluster of homecare operators. Innovations **61**(1), 89–115 (2020). https://www.cairn-int.info/journal-innovations-2020-1-page-89.htm
25. Guan, A., Dannewitz, H.C., Stratton, L., Margrett, J., Boot, W.R., Charness, N.H., Narasimhan, B.: Perceptions, acceptability, expectations, and concerns of smart home technologies among older adults. Innov. Aging **3**(Suppl 1), S881 (2019)
26. Gubbi, J., Buyya, R., Marusic, S., Palaniswami, M.: Internet of things (iot): a vision, architectural elements, and future directions. Fut. Gener. Computer Syst. **29**(7), 1645–1660 (2013). https://doi.org/10.1016/j.future.2013.01.010
27. Haslwanter, J.D.H., Fitzpatrick, G.: Issues in the development of aal systems: what experts think. in: proceedings of the 10th international conference on pervasive technologies related to assistive environments, PETRA '17, p. 201-208. Association for computing machinery, New York, NY, USA (2017). https://doi.org/10.1145/3056540.3056554
28. Hernandez, J.M.C., Caldas, M.P.: Resistêcia a mudança: uma revisão critica. Revista de Administraçã de Empresas **41**, 31–45 (2001). https://doi.org/10.1590/S0034-75902001000200004
29. Hochwarter, S., Tangermann, P., Heinze, M., Schwarz, J.: Psychiatric home treatment for inpatient care - design, implementation and participation. CoRR (2020). https://arxiv.org/abs/2006.01523
30. Holzinger, A., Searle, G., Auinger, A., Ziefle, M.: Informatics as semiotics engineering: Lessons learned from design, development and evaluation of ambient assisted living applications for elderly

people. In: Stephanidis, C. (ed.) Universal access in human-computer interaction context diversity. Springer, Berlin Heidelberg (2011)
31. Kolkman, M.: Problem Articulation Methodology (PhD Thesis - University of Twente - Netherlands). University of Twente (1993)
32. Kolnick, H.A., Miller, J.E., Dupree, O., Gualtieri, L.: Design thinking to create a remote patient monitoring platform for older adults' homes. Online journal of public health informatics **13**(1), e9–e9 (2021) 10.5210/ojphi.v13i1.11582.
33. Konstantinidis, E.I., Petsani, D., Conti, G., Bamidis, P.D., Iliadou, P., Kladi, A., Frantzidis, C., Moraitou, D., Nday, C.M., Jackson, G., et al.: A new approach for ageing at home: the captain system. Stud. Health Technolo. Inf. **264**, 1704–1705 (2019)
34. Koreshoff, T.L., Leong, T.W., Robertson, T.: Approaching a human-centred internet of things. In: Proceedings of the 25th Australian computer-human interaction conference: augmentation, application, innovation, collaboration, ozchi '13, p. 363-366. association for computing machinery, New York, NY, USA (2013). https://doi.org/10.1145/2541016.2541093
35. Kuhn, S., Winograd, T.: Profile: participatory design' bringing design to software. ACM Press/Addison-Wesley, New York (1996)
36. Lane, B., Hanke, S.P., Giambra, B., Madsen, N.L., Staveski, S.L.: Development of a clinician-parent home care education intervention. Cardiol. Young **29**(10), 1230–1235 (2019). https://doi.org/10.1017/S1047951119001318
37. Leonardi, C., Mennecozzi, C., Not, E., Pianesi, F., Zancanaro, M., Gennai, F., Cristoforetti, A.: Knocking on elders' door: Investigating the functional and emotional geography of their domestic space. In: Proceedings of the SIGCHI conference on human factors in computing systems, CHI '09, p. 1703-1712. association for computing machinery, New York, NY, USA (2009). https://doi.org/10.1145/1518701.1518963
38. Leong, T.W., Robertson, T.: Voicing values: Laying foundations for ageing people to participate in design. In: Proceedings of the 14th Participatory Design Conference: Full Papers - Volume 1, PDC '16, p. 31-40. Association for Computing Machinery, New York, NY, USA (2016). https://doi.org/10.1145/2940299.2940301
39. Li, R., Lu, B., McDonald-Maier, K.D.: Cognitive assisted living ambient system: a survey. Digital Commun. Netw. **1**(4), 229–252 (2015)
40. Liu, K., Li, W.: Organisational semiotics for business informatics. Routledge, United Kingdom (2014)
41. Machado, S., Costa, L.V., Mealha, Ó.: Co-designing with senior citizens: a systematic literature review. In: Gao, Q., Zhou, J. (eds.) Human aspects of IT for the aged population technology design and acceptance. Springer International Publishing, Cham (2021)
42. Marti, P., Iacono, I.: Social and empathic behaviours: Novel interfaces and interaction modalities. In: 2015 24th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), pp. 217–222 (2015)
43. Mowafey, S., Gardner, S.: A novel adaptive approach for home care ambient intelligent environments with an emotion-aware system. In: Proceedings of 2012 UKACC International Conference on Control, pp. 771–777 (2012). 10.1109/CONTROL.2012.6334727
44. Ní Shé, E., Harrison, R.: Mitigating unintended consequences of co-design in health care. Health Expect. **24**(5), 1551–1556 (2021). https://doi.org/10.1111/hex.13308
45. Nora, C.R.D., Junges, J.R.: Humanization policy in primary health care: a systematic review. Revista de saude publica **47**(6), 1186–1200 (2013) 10.1590/s0034-8910.2013047004581.
46. Osterwalder, A., Pigneur, Y.: Business model generation: a handbook for visionaries, game changers, and challengers. Wiley, NY (2010)
47. Phull, R., Liscano, R., Mihailidis, A.: Comparative analysis of prominent middleware platforms in the domain of ambient assisted living (aal) for an older adults with dementia (oawd) scenario. Proc. Computer Sci. **83**, 537–544 (2016)
48. de Podestá Gaspar, R., Bonacin, R., Gonçalves, V.P.: Designing iot solutions for elderly home care: a systematic study of participatory design, personas and semiotics. In: Antona, M., Stephanidis, C. (eds.) Universal access in human-computer interaction. virtual, augmented, and intelligent environments. Springer International Publishing, Cham (2018)
49. de Podestá Gaspar, R., Bonacin, R., Gonçalves, V.: Um estudo sobre atividades participativas para soluções iot para o home care de pessoas idosas (2021). https://arxiv.org/abs/2103.01078
50. Pradhan, A., Jelen, B., Siek, K.A., Chan, J., Lazar, A.: Understanding older adults' participation in design workshops. In: Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems, CHI '20, p. 1-15. Association for Computing Machinery, New York, NY, USA (2020). https://doi.org/10.1145/3313831.3376299
51. dos Reis, J.C., dos Santos, A.C., Duarte, E.F., Gonçalves, F.M., de França, B.B.N., Bonacin, R., Baranauskas, M.C.C.: User stories and the socially-aware design towards the opendesign platform. In: Filipe, J., Śmiałek, M., Brodsky, A., Hammoudi, S. (eds.) Enterprise information systems. Springer International Publishing, Cham (2021)
52. Rowles, G.D., Chaudhury, H.: Home and identity in late life: International perspectives. Springer Publishing Company, Cham (2005)
53. Schulte, B.F., Marshall, P., Cox, A.L.: Homes for life: a design fiction probe. In: Proceedings of the 9th nordic conference on human-computer interaction, pp. 1–10 (2016)
54. Silva, K.L., Sena, R., Leite, J.C., Seixas, C.T., Gonçalves, A.M.C.: Home care in the Brazilian national health system (sus). Rev. Saude Publica **39**(3), 391–397 (2005)
55. Smeenk, W., Sturm, J., Eggen, B.: Empathic handover: how would you feel? handing over dementia experiences and feelings in empathic co-design. CoDesign **14**(4), 259–274 (2018). https://doi.org/10.1080/15710882.2017.1301960
56. Smeenk, W., Sturm, J., Eggen, B.: A comparison of existing frameworks leading to an empathic formation compass for co-design. Int. J. Des. **13**(3), 53–68 (2019)
57. Spinsante, S., Stara, V., Felici, E., Montanini, L., Raffaeli, L., Rossi, L., Gambi, E.: Chapter 4 - the human factor in the design of successful ambient assisted living technologies. In: C. Dobre, C. Mavromoustakis, N. Garcia, R. Goleva, G. Mastorakis (eds.) Ambient Assisted Living and Enhanced Living Environments, pp. 61 – 89. Butterworth-Heinemann (2017). https://doi.org/10.1016/B978-0-12-805195-5.00004-1
58. Steel, K., Tjassing, H.: Health care moves to the home. World Health **47**(4), 16–17 (1994)
59. Talamo, A., Camilli, M., Di Lucchio, L., Ventura, S.: Information from the past: how elderly people orchestrate presences, memories and technologies at home. Univ. Access Inf. Soc. **16**(3), 739–753 (2017)
60. Van Someren, M., Barnard, Y., Sandberg, J.: The think aloud method: a practical approach to modelling cognitive. AcademicPress, London (1994)
61. Vianna, M.: Design thinking: inovação em negócios. Des Think **2**, 65 (2012)
62. Wan, L., Müller, C., Randall, D., Wulf, V.: Design of a gps monitoring system for dementia care and its challenges in academia-industry project. ACM Trans Comput.-Hum. Interact. **23**, 5 (2016). https://doi.org/10.1145/2963095

63. Zallio, M., Berry, D., Leifer, L.J.: Meaningful age-friendly design. case studies on enabling assistive technology. In: Ahram, T., Falcão, C. (eds.) Advances in usability and user experience. Springer International Publishing, Cham (2020)