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Assistive Robotics Needs for Older Care: Using Authentic Citations to Bridge the Gap between Understanding Older Persons' Needs and Defining Solutions

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Abstract
Developing an authentic understanding of potential users' needs and translating these into usable categories as an input to research and development is an open problem. It is generally accepted that genuine knowledge of user needs is essential for the creation of any new technology. For assistive robots, however, this knowledge is even more important for two key reasons. First, because the form and function of these technologies is still in the process of negotiation, and second, because assistive robots are ultimately intended for a vulnerable population. In this paper, we describe a number of existing strategies to address this challenge and discuss some of their shortcomings, including a loss of data richness and context, the stereotyping of users and a lack of transparency and traceability. The primary contribution of this paper is a novel Authentic Citations process for capturing needs which aims to address these shortcomings. This process involves a thematic analysis of complex qualitative data to derive robotics needs for older people, which emphasises the retention of the original situated description, or 'authentic citation', for ongoing sensitising and grounding at all stages of the research and development cycle, and by various stakeholders. The Authentic Citations process adds additional rigour to a process that can be tacit and opaque and can be used by robotics researchers to analyse and translate qualitative research into usable categories. An additional contribution of this paper is an initial outline of a taxonomy of assistive robotics needs for older people, which contributes to improving the understanding of the user as a situated and complex person and can be used as an input to design.

Keywords Human–robot interaction (HRI) · Human-centred design · Assistive robotics · Social robots · Assistive technology · Older care · User needs

1 Introduction

Across the world, people are living longer. By 2050, the world's population aged over 60 years is expected to reach 2.1 billion, representing 22% of the world's total population and an increase from 12% in 2015 [1]. In Europe, the situation is even more dramatic, with the OECD predicting that the share of older people will rise to one third (29.3%) by 2060 [2]. These changing demographics represent a challenge to global health and social systems: there will be an increasing number of people in need of care, with a corresponding decrease in people available to provide it. Although there is no causal relationship between ageing and disability, ageing is nonetheless a key risk factor in an increase in various health problems and frailty. These include both loss of physical and functional abilities, cognitive decline, as well as an increase in chronic health conditions, and multiple health conditions, or multimorbidity. These factors impact a person's independence and quality of life, and contribute to greater requirements for assistance, hospitalisation, and dependence on others [3–5]. Among the solutions proposed to address these challenges is the increased use of assistive technologies, which includes the use of assistive and social robots.

The World Health Organization (WHO) defines assistive technologies as products, systems and services that help to maintain or improve functioning and promote well-being [6]. Assistive robots are thus devices that use the capabilities of robot systems, such as sensing, processing, and mobility, to support this aim. Stanford's David Jaffe has defined an

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assistive robot as, 'a device that can sense, process sensory information, and perform actions that benefit people with disabilities and older adults in the course of their daily living' [7]. According to this definition, many social robots are also assistive robots. The field of assistive robots includes mobility aids, such as Hitachi's walking support system [8] and Kompaï-3 mobility assistance [9], as well as smart walkers, smart canes, and exoskeletons. It also includes lifting and transferring robots such as ROBEAR [10] and Autobed [11], service robots such as Toyota Human Support Robot (HSR) [12], Nursebot [13] and Care-o-Bot [14], companion robots, such as AIBO [15] and the seal robot PARO [16], as well as socially interactive robots, such as Pepper [17] and CompanionAble [18]. However, social and care robotic technologies are still largely in their infancy, with few being deployed in practice [19–21]. The form and function of these technologies is therefore still in negotiation.

Global digital health strategies, such as the WHO global strategy on digital health, recognise the need to develop solutions that are not only affordable, accessible, and scalable, but also appropriate and person-centred [22]. However, true person-centredness is often lacking in the design of assistive technologies due to a lack of coherent assessments of people's needs [23–25]. This is particularly acute in research related to older people, which is often based on stereotypical representations [26] and a 'deficit' model of ageing [27]. Additionally, wider contextual issues, such as the environment and the role of care providers, are often not considered [25].

There is thus a clear need to develop an authentic and nuanced understanding of older people's real lives and lived experiences, rather than the stereotypical and generalised view that is often prevalent in human–computer interaction (HCI) and human–robot interaction (HRI) research. However, developing this deep understanding and then translating it into actionable requirements is not a straightforward task. These issues are exacerbated in the case of robots, due to the fact that there are only limited examples of commercially and long-term successful robotic deployments to draw on, and people's experience of them. Additionally, the cost and complexity of developing robot capabilities can make an iterative and person-centred design approach more challenging.

In this paper we propose a novel Authentic Citations process, which can be used to translate complex, qualitative data into distinct, actionable ideas for robotics research. We describe the process of analysing qualitative data in order to identify user needs and look at existing approaches for translating the knowledge between the experiential and design domains. We articulate some of the shortcomings of these approaches, including how the situated qualitative nuance may be lost in translation and how this may lead to a misunderstanding of the problem context and stereotyping of users. Unlike other methods, when using the Authentic Citations process, the resulting categories retain the situated and nuanced qualitative data that produced them. As we will show, this adds additional rigour to the act of interpretation and translation by making it explicit and transparent and addresses quality criteria pertaining to both scientific and design practice [28]. The second contribution of this paper is the output of this process: an outline taxonomy of needs for older people, including high-level themes and sub-themes representing distinct needs, based on deep ethnographic investigation into their lives [29] and an initial proposal for a database of Authentic Citations and usable interface for robotics researchers that can be used in isolation or linked to other design artefacts. This second contribution is further developed in a subsequent paper.

2 Understanding User Needs

Early approaches to considering the human in the engineering process drew on fields such as human factors engineering and ergonomics, which considered the human solely as user of a machine. As such, the focus was primarily on the performance of the machine [30]. These approaches were 'model-driven', in that the human 'user' was considered, in a sense, an extension of the machine and a subject to be studied through formal methods and systematic testing [30, 31]. Designing for a user often involved optimising the design of an existing system based on preconceived assumptions and schema [32]. However, driven in part by the spread of technologies from controlled factory settings into homes and everyday lives [31] new fields such as HCI and user experience (UX) emerged, with scholars emphasising the importance of context of use and situated action [33]. The focus became less about fitting the human around the technology, and moved to developing an understanding of the human, and their needs, in order to develop technology around them.

In the context of assistive robotics technologies, however, scholars have raised concerns about the tendency to ascribe general needs to older people, based on societal factors such as ageing demographics, rather than the specific and situated needs of real people [26, 34]. This approach tends towards a 'deficit' model of ageing and decline, focused on physical decline and social isolation rather than people's abilities [27]. Thus, assumed needs are often based on stereotypical conceptions of older people, such as that they are lonely, frail, and in need of assistance [26]. This leads to the design and development of technologies that carry a stigma and thereby decreases adoption [27].

A similar problem is evident in the HCI field, where, in a discourse analysis of 30 years of HCI research, [35] identifies the ways in which older people are considered: as

having health concerns, as experiencing physical and cognitive decline, as socially isolated and increasingly dependent, and as technological laggards. The authors draw on [36] to argue that this act of 'framing' the potential user (depicting them as frail, isolated and in decline) also 'configures' them (contributing to how they are perceived in society, both opening up and closing down possibilities). To counter this trend, the authors propose to problematise the concept of 'old', a concept which, the authors argue, is entangled in specific cultural assumptions and anxieties. Instead, older users should be 'reconfigured' as active and diverse, rich in experience, who can contribute actively to the field.

However, as scholars have increasingly focused on user needs, the complexity of this concept has moved into the foreground. Asking people to explicitly enumerate their technology needs is not necessarily a straightforward task [37–39]. Most users do not understand technology as the goal of the activity, rather it is 'an intrinsic mediating influence' in the context of their wider, continuous, and holistic experience and actions on the world [37, p. 31]. Thus, as [39] explore in their study of unmet needs, older people do not necessarily identify the difficulties they experience in everyday life as representing a need for technological solution, or even for assistance [41]. Instead, they may simply interpret them as a natural part of the ageing process for which no intervention is necessary, or available.

To address this, rather than asking users directly to articulate their needs, in the design and HCI fields, there has been a trend towards approaches that aim to capture some of the context and richness of the user's worlds [28]. One approach to bridge the gap between the user's world and that of the designer/developer is to bring the potential user into the design process using co-design or participatory methods [40]. Participatory design originated in the Scandinavian participatory design movement of the 1990s and sought to allow workers to influence the design of computer applications in the workplace [41]. Co-design techniques attempt to bring the users into the design process through collaborative conceptualisation, evaluation, and prototyping of solutions. The benefits of including older users in the design process include increased learning, new and adjusted designs, and a sense of participation for the older user [42]. However, including older people in the design process can be both demanding and challenging, and power may not be distributed equally among older people and technical experts [42, 43].

Another approach is using qualitative research methods, which are exploratory, and can be used to capture wider contextual and long-term data about the user's world [44]. These methods, drawn from social science and design fields, include contextual inquiry, interviews, focus groups, surveys, as well as ethnographic and observational field studies. These approaches are also slowly being adopted to understand robots in social settings [45]. Qualitative research has been used to conduct investigations into the wider contexts, attitudes, and opinions of older adults towards robots in general, or to gain feedback on specific robotics solutions. This may vary from short focus groups, e.g., [38, 46], observations and interviews, e.g., [47–49], to longer-term ethnographic studies, e.g., [50–54]. While these studies make a valuable contribution to our understanding of human attitudes and relations to robots, the data gathered is generally constrained by the study's orientation around feedback on a single robot, or a few specific robots. While this makes it easier to narrow the amount of information gathered and to analyse findings, it also means that considerations outside of the scope of the existing robot, such as wider user needs and contexts, as well as alternative designs, may go uncaptured or unrecognised.

To offset this tendency in HRI, the authors of [55] call for the foregrounding of exploratory design methods. As they argue, exploratory design allows developers to reconsider underlying assumptions and thereby query what is the right thing to design, rather than simply how to make the (existing) thing right. They introduce a method of Research through Design (RtD) for HRI, which includes using unstructured generative and speculative design methods with users. Similarly, [27] combine collaborative design probes with exploratory methods both to elicit participants' experience of ageing and to facilitate a critical analysis of technical artifacts. An alternative (although complementary) approach is to start with a deep qualitative investigation into the lives of older people using methods such as ethnographic fieldwork or interviews. This allows for an investigation of the problem space without prior assumptions regarding available technological solutions or societal factors. Thus, a nuanced, empathetic, and empirical understanding of older people's lives is acquired, without the need for them to attempt to represent themselves in an artificial laboratory setting [43].

3 Translating Empirical Data into Actionable Ideas

Qualitative research allows for gaining deep insights into the users' worlds and perspectives. However, as the data gathered becomes increasingly dense, open, and exploratory, translating these extended, complex, and nuanced empirical details of users' lives into actionable requirements remains a challenge [28, 56, 57]. There are two ways in which this is generally approached [28]. The first is affinity diagramming, drawn from design research, in which a group collaboratively identifies key themes and organises them into higher thematic areas. This method is highly effective for identifying themes quickly and collaboratively. However, it lacks the thoroughness and rigour of other methods and is not generally feasible with large amounts of complex data [58].

Thematic analysis is an alternative method, drawn from social science, and involves a systematic review of data and identifying key themes. The output of this method is generally a lengthy descriptive text articulating findings and themes and supported in places by illustrative quotes. As an input to technology design, the research is often required to further articulate 'Implications for Design'. As is reported in [28], generating design implications is a complex process in which researchers have employed a wide variety of approaches. In their study with HCI designers, the authors find that implications may be presented as short descriptions, prescriptions, abstractions or meta-abstractions, sensitising concepts and instantiations. In particular, they find that there is a strong interest for 'short descriptions' of fieldwork data, in contrast with either traditional ethnographic 'thick description',[1] or personas and scenarios. They thus propose short descriptions that are summaries and abstractions from the rich interview or ethnographic data.

Another approach to bridging the gap between empirical research and design knowledge is the construction of an intermediary fictional model, aiming to capture some of the qualitative nuance of the user's perspective as a reference point throughout development. These include use cases and scenarios, in which developers describe how the user might interact with a future system to aid understanding, clarify user requirements, and provide a basis for later usability testing [59]. It also includes the creation of 'personas', or fictional user representatives or archetypes, depicting what is essentially a caricature of a user, their goals, and usually accompanied by a picture. Personas were originally created to represent a specific individual in the mind of the developer or designer, rather than an abstract 'user' [60]. For this reason, [60] recommend that they are made as specific and detailed as possible, in order that they might become a 'real' person in the mind of the developers. Personas are particularly useful as communication tools between various stakeholders [61]. In particular, they are seen as useful where project constraints make large user studies and more participatory methods challenging [62].

Despite aiming to emphasise a situated, rather than generalised, user, and thus increase understanding and empathy for designers and developers [28], personas nonetheless may introduce a layer of abstraction into a process which can prevent designers and developers from understanding real users. Indeed, personas can introduce a 'false sense of knowing' into the design and development process [63, pp. 2–3]. Moreover, personas are often not used by designers [62] or developers [64]. Where they do use them, they will often develop personas based on their own impressions and intuitions, rather than on empirical, 'real world' data [64–66]. Although this may be effective in certain circumstances, it can also lead to the creation of stereotypes or misrepresentations of users [63, 67]. For example, [66] observes a tendency for cross-cultural personas to reinforce existing biases by not being grounded in real people and their lives. This, they argue, brings with it the risk of stereotypical enactments and designing for deficits leading the authors to emphasise the non-triviality of representing real people in a fictitious summary. In interviews with user-centred design (UCD) practitioners, [62] finds that personas are perceived as too abstract, with the abstraction process from user data to persona considered opaque. Additionally, the authors find them impersonal, rather than empathic, as well as misleading and distracting. Instead, the user-centred design practitioners they interviewed wanted either 'first-hand experience with users, or personal access to user study data', which they viewed this as necessary to gain a full understanding of the user to aid design [62, p. 1123].

In practice, then, we find there is little consensus and much confusion about how to translate from empirical research to design knowledge including in the Assistive Technology and Assistive Robotics literature. In [68], a qualitative study to investigate the barriers to creating a unified electronic communicable disease reporting system resulted in abstract representations which, the authors acknowledge, failed to illustrate the values and contexts of users. The creation of personas, scenarios and user stories then necessitated a separate, parallel process of interpretation. Similarly, in an ethnographic study of workflows at a hospital, [69, p. 202] reflects on the author's concerns that the 'richness and context-sensitivity of the data obtained in the ethnographic observation' may not easily be translated into use cases. They therefore suggest further participatory user-centred design to ensure that the technological solutions developed really meet user needs. In a qualitative study, [49] aims to elicit robotics needs from older people and their caregivers to define requirements. First, they conduct thematic content analysis to translate the data into usable categories and second, a bi-located, multidisciplinary team of experts collaboratively translates these into categories of needs and corresponding services. A third step involves then translating these needs and services into 29 technical and functional requirements. While the process succeeds in grounding requirements in genuine user research, by expressing the needs in technical and medical terms, the qualitative nuance of the original input is severed.

In the literature on personas, a number of scholars have sought to overcome the challenge of retaining a link to the original qualitative data in the final artefact. In [61], a 'foundation document' for each persona is used as a 'storehouse' for information about the persona, which includes explicit

[1] 'Thick description', popularised by anthropologist Clifford Geertz [76] refers to the 'thick' quality of ethnographic descriptions: rich, detailed, and concrete descriptions of people and their contexts from which the reader can draw their own interpretations.

links between persona characteristics and supporting data. Alternatively, [62] propose to make the original user data available along with personas in a 'three layer' approach, in which persona, user role, and user study data are made available for continuous access and immersion. 'Persona cases' are proposed in [70] to ground personas in empirical data and ensure they remain traceable to their source. The authors use a combination of Grounded Theory and the Toulmin model of argumentation to analyse the data and develop 'propositions' from the original quotes on the basis that quotes are 'factoids' rather than established facts. The propositions are then linked to the personas through a tool called CAIRIS, which allows for backwards traceability and provides an empirical rationale for the elements of the persona.

All of these approaches aim to overcome the same challenges, and there are commonalities. All seek to ground their results in authentic user data and preserve the richness and qualitative nuance of the data throughout the abstraction process. However, while design implications, personas and use cases may provide designers and developers with a more qualitatively nuanced account of the users' landscape, their success is dependent on the presence, quality, authenticity and accessibility of the underlying data. In many cases, however, these design artefacts may not be based on real data at all, as it is not mandated in their development. Where it is present, it is typically presented as an abstraction, and it is rarely possible, or prohibitively difficult, to trace back from the artefact to the original data, either to validate them or to access additional contextual and situated nuance. Attempts to make this connection more transparent have resulted in a proliferation of documents which can make the process more complex and less accessible. Further, the approaches often presume a great deal of analytical expertise and specific domain knowledge. Finally, despite being grounded in genuine user research, the output is often expressed in technical or medical terminology, rather than in the language of the user. This not only risks losing some of the qualitative nuance of the original data, but also precludes transparency for the user and other non-technical stakeholders.

4 The Authentic Citations Process

In this paper, we describe a process which aims to resolve some of the difficulties described above. In particular, we build on the research indicating that designers and developers prefer both short descriptions [28] and personal access to study data [62]. 'Authentic Citations' are direct quotations from interviews and other qualitative data sources, such as ethnographic description.[2] The Authentic Citations process that we propose in this paper is a method for capturing user needs that involves translating complex, qualitative data into distinct, actionable ideas for robotics research. Unlike other methods, however, the resulting categories retain the situated and nuanced qualitative data, or 'authentic citations' that produced them. It thus allows for the generation of short descriptions without the need for creating summaries or abstractions from the original qualitative data. Instead, using the Authentic Citations process, the original grounded and situated statement remains the basis for, and is linked to, subsequently generated categories. Thus, this method is used to distil in-depth, qualitative research into usable categories without losing the original situated context through the abstraction process.

As [28] identifies, design knowledge must address quality criteria pertaining to both scientific and design practice, which are seldom met satisfactorily. From a scientific perspective, this includes empirical, theoretical and external validity (or generaliseability), as well as originality, and from a design perspective, generativity, inspirability and actionability. As we will show in the following sections, the Authentic Citations process contributes on both of these counts. Specifically, it contributes empirical validity by providing an explicit and transparent account of how the knowledge is grounded in fieldwork [28]. Further, basing needs in open, exploratory, and qualitative research can uncover novel insights which can lead to both theoretical and practical novelty, the latter of which can prompt design generativity, inspirability, and actionability. Although 'needs' are commonly thought of as universal, internalised states that motivate behaviour and thus as 'discoverable', as is argued in [71], needs are in fact geographically and historically specific, often constructed through dominant discourses such as marketing and advertising. The act of identifying needs is thus a process of co-construction rather than discovery, based on an understanding of the user group and an awareness of the technological possibilities, articulated within a specific conceptual framework. In the process that we describe in this paper, the overarching conceptual framework for defining needs is human-centred, thus while [28] defines actionability as describing design implications in technological terms, our method stops short of this and instead preserves the language of the user.

4.1 The Source Data

The process starts with extensive, qualitative data that can be interrogated for needs. In this paper, we present an example of

[2] [77] uses the term 'authentic citations' to refer to quotations from interviews and other data sources. In this paper, we expand the use of the term to include both quotations and ethnographic description.

its implementation as part of the Smart and Healthy Ageing through People Engaging in Supportive Systems (SHAPES) project. SHAPES is an EU Horizon 2020 Action Research project that is developing a digital platform and ecosystem to support older adults ageing-in-place. As part of the project, a 20-month ethnographic study was conducted with 94 older adults living independently in eight countries across Europe [29]. The ethnography does not specifically focus on technology use, rather it describes older people's lives, including their social, working, and financial worlds, how they navigate at home and in the outside world, the practices of caregiving and receiving care, as well as their thoughts about the future. All participants in the study gave informed consent and the data captured was fully anonymised. Participants are presented in the ethnography, and in this paper, using pseudonyms chosen either by the researchers or the participants themselves.

The ethnography is a descriptive text written by a team of anthropologists and ethnographers and thus has already been through a process of interpretation. The ethnographic study itself falls outside the scope of the Authentic Citations process. The process focuses instead on how to make the source information accessible throughout design and development, responding to an emergent need of the project. Our analysis of the data thus involved interrogating it further for potential robotics needs. Although the study that we use to illustrate the Authentic Citations process is an ethnography, the process can be used with any qualitative data, such as that gathered from observations, in the form of field notes and researcher description, from interviews, focus groups and open-ended survey responses in the form of direct quotations. Essentially, any qualitative data that allows the reader to enter into the situation presented [72].

4.2 Identifying the Problem Context

The first step in the Authentic Citations process is for the researchers to identify the question to be asked of the data. In our case it was: 'What needs do older people have that might be solved by current or future robotics solutions?'. This provides an overarching orientation for the review and analysis process. For the purpose of our review, 'needs' were defined as expressed desires, needs and aspirations; existing or past activities and hobbies; as well as frustrations, challenges and changing requirements. Further, our review was guided both by a search for needs, as well as familiarity with robotics and other assistive technologies.

The next step is a full reading of the original qualitative data to get a holistic sense of the problem space, overarching themes, and personal narratives that are represented. It is useful for the reviewer to have some distance from the text, see also [28, pp. 1976–1977], either by not having participated in the original data collection, or by having some temporal distance between the gathering and analysis of data. In this way, the reviewer(s) will get a sense of the overall problem context, rather than focusing on specific details. It is important at this point not to look for solutions but to aim at developing an understanding of, and feeling for, the context and perspectives represented in the source. Although not yet coding the data on this preliminary reading, it may be useful to highlight or use notes to mark emerging themes or insights.

4.3 Conducting a Thematic Analysis

The preliminary reading is followed by a thematic analysis of the data. In a thematic analysis, the analyst searches for patterns in the data related to the defined problem context. This may be done deductively, according to a pre-defined schema or model, or through an inductive analysis, in which the analyst identifies emergent patterns in the data using open, grounded methods. A search for user needs necessarily involves looking for new and unidentified needs and therefore we adopt an open, grounded approach. A number of scholars, e.g., [73, 74] have described the use of 'grounded theory' to analyse qualitative data in HRI research. Grounded theory emphasises an open and emergent approach to data analysis in which codes and categories iteratively emerge during the gathering and analysis of data, rather than from a pre-existing theory or hypothesis [78]. Additionally, one of the key principles of 'grounded theory' studies is that they seek to develop novel social theories, rather than simply identify patterns of meaning in the text [75]. A search for needs is thus not using grounded theory in a strict sense, as it results in a discrete list of categories, rather than a novel social theory. Nonetheless, the review should remain 'grounded', or 'open', eschewing a priori assumptions and existing or identified solutions and remaining open to new or previously unidentified needs.

In this closer, second reading, statements that reveal potential needs are extracted from the data and stored for subsequent analysis. It is important to ensure at this point that sufficient context is retained from the original text, even if some of it may seem superfluous to the core need. In particular, pay attention to any situational information, such as details related to spatial, historical and psycho-social (e.g. habits, preferences) aspects which might add valuable nuance related to the identified need. For example, instead of the simply capturing the statement: 'the garden steps became too much for him', the wider situational context adds additional useful insights, such as:

> Evelin's husband used to like to walk into town but over time the climb back up the mountain, followed by the garden steps became too much for him. At first, he would take a rest every few minutes and pretend to

look at the scenery as he was embarrassed about what people would think.

The wider context reveals that it is not just climbing the steps that present a problem but climbing the steps in the context of the wider landscape. Through the additional situated description, we also get a sense of the feelings of stigma related to reduced autonomy and physical abilities that may provide valuable insights for subsequent technology design. Once coding is complete and themes have been refined, any additional text deemed superfluous to grounding the need may be removed to ensure the final citation is focused and to minimise overlap.

The focus of the analysis is primarily on needs and not solutions. Therefore, the process will also identify needs that require non-technical solutions or needs that cannot wholly be met by a particular technological solution. In our review, non-technical needs captured included challenges related to the physical environment and to health systems, as well as the effects of negative perceptions of older people. Figure 1 below shows a section of ethnographic description with statements of needs highlighted.

The captured data may be stored in a simple spreadsheet or in a dedicated software analysis support tool, such as NVivo. Our review resulted in the identification of 136 separate 'statements of needs', which were a combination of direct quotes and ethnographic descriptions and were stored in a spreadsheet. In general, once a specific need has been captured from a participant, there is no need to capture it again if it is repeated later in the text. Nonetheless, duplicates will occur and can be removed later on in the analysis process.

The next phase involves coding the captured statements and looking for recurrent regularities [72]. A code is a descriptive label that is assigned to a piece of data. Sometimes codes may be found 'in vivo', that is, taken directly from quotations in the source data, at other times the code is chosen by the researcher to describe the phenomenon identified. Statements that suggest more than one need should be replicated and assigned more than one code. This process continues iteratively until all the statements have been coded and codes with similar qualities have been merged. Figure 2 below shows an example of statements of needs coded as 'Domestic Cleaning' and 'Lifting person'. This is necessarily an iterative process, which involves going back and forward between the source data and resulting the codes throughout the process. The final list of codes is determined using two criteria: internal homogeneity (the extent to which the data in a category hold together in a meaningful way and external heterogeneity (the extent to which the differences in the categories are clear) [72].

In our case, the initial set of 136 statements was expanded to 208, as many statements were assigned more than one code. For example, the statement: 'She provides him assistance with tasks bathing, feeding, and dressing, or his daily personal hygiene needs' clearly calls out a need for 'Personal care', but it also suggests a specific technological capability, prompting a need for 'Lifting person'. The statement would therefore generate, and/or be mapped to, both relevant needs. Similarly, an expressed interest in dancing could reveal a need for exercise, or social activity, or for companionship, or all three. This process of assigning codes ultimately resulted in 59 separate codes, each representing a distinct 'need', see Fig. 3 below. Although in our example we included the full data set in our analysis and results, the process of 'saturation' [78, 79] may be used for scalability when dealing with larger data sets. Saturation is reached when no additional insights emerge from the data and the same themes are repeatedly identified. This approach would suggest an iterative process of data selection, coding and thematic analysis, incrementally increasing the size of the data set until saturation is reached. Another approach to achieve scalability is to use multiple analysts, although approaches would need to be taken to ensure standardised protocols across them, as elaborated in Sect. 5 below.

Table 1 High-level themes

	Main categories
1	Community
2	Physical assistance
3	Healthcare services & supports
4	Household & care organisation
5	Teaching & Learning
6	Personal contact
7	Monitoring & alerts
8	Navigating local environment
9	Exercise & rehabilitation coaching
10	Culture, media, entertainment
11	Curating

4.4 Developing Themes for Robotics Research

The next stage of the process involves organising the codes into coherent higher-level themes, a process that will have started while developing the initial codes. Although at this point the focus is still primarily on the problem space, it continues to involve ongoing conceptualisation of the possible solutions space. Once again, this process will require multiple iterations, checking and rechecking codes and categories. The 11 high-level themes that resulted from our analysis are presented in Table 1 below.

Fig. 1 Section of ethnographic description with statements of needs captured

"adopted" him to the family. Having become an honorary grandfather of ten children, he enjoys regular visits, eating and cooking with the "lady of the house", and the monthly whisky tasting that he and the older boys established. Furthermore, Paul tells us,

> "The most important thing is that they keep an eye on me. If the shutters don't go up in the morning, their alarm bells go off. That's important, right? because otherwise you could lie here for days."

Like Paul many older adults have created some kind of safety net. In Northern Ireland, 71-year-old Ted lives within a neighbourly sociality.

> "The guy across the street has Alzheimer's, he's 91. I would join him occasionally and just have a chat and I am in touch with his family because I keep an eye over him. If the blinds are down for any length during the day, I would ring one of the daughters and ask her to make sure he is okay. (…) The neighbours around here, we all have each other's telephone numbers so if

Need identified	Page	Name	Perspective	Category 1 (sub-
Gisella has always enjoyed cooking "but now I begin to be a little fed up with it, but I obviously continue doing it, because my husband would not". Tasks she has always intensely disliked include dusting and ironing. Ironing clothes now gives her backache	57	Gisella	Older person (65+)	Domestic cleaning & mea
Susanne also receives support from the Diakonie, a social welfare organisation of Germany's Protestant churches offering a wide range of care support, including practical aid and legal representation... She is grateful that the group helps her keep track of and regulate the dizzying array of medications she takes. The group also provide essential non-medical supports like general housekeeping and maintenance: They come to me every 14 days for two hours and help me make my bed and they wipe the floors and clean the windows, which is difficult.	68	Susanne	Older person (65+)	Domestic cleaning & mea
Eleftheria is the one to exclusively undertake all the care and support for Thanos. She provides him assistance with tasks bathing, feeding, and dressing, or his daily personal hygiene needs.	77	Eleftheria	Informal care giver	Lifting person
He had left his mobile phone charging upstairs out of reach and to that point had resisted wearing an alarm pendant because of the stigma associated with it. His left leg gave way and Bert didn't have the bodily strength to pull himself up. He managed to pull a blanket off the sofa and wrapped himself in that and recalls how nobody called or came around. "I lost count of how many times I wet myself." After three days, he knew he was close to death and vaguely recalls slowly inching his way into his hallway acquiring severe carpet burns on the way to his landline telephone where he managed to call 999.	46	Bert	Older person (65+)	Lifting person
When I returned, I found him under the bed. It was impossible to pick him up, so I had to call a neighbour to help me. After that, I put a railing on his bed."	77	Eleftheria	Informal care giver	Lifting person

Fig. 2 Example of coded statements in spreadsheet

Codes such as 'Paid/voluntary work', 'Interest groups', 'Community groups', 'Caregiver support networks, 'Community spaces (non-tech)' and 'Shared spaces (non-tech)' revealed an overarching need for engagement with a community of likeminded people, which can in some cases be met or supported by robotics solutions. For example, a robot could mediate between people, or allow for telepresence, or even, in a sufficiently advanced state, itself comprise a member of a community. However, it also revealed needs that cannot be solved by technological solutions alone, such as that of being in the same physical space as other people, as well as, for example, accessible public spaces and care communities that encourage participation. These codes were gathered into an overarching theme of 'Community'.

Other coded statements, while ostensibly also 'social', revealed quite a different overarching theme, that of 'Personal contact'. These were the codes 'Personal interaction', 'Companionship' and 'Tactile & multimodal communication', which relate to a distinct need for more intimate and personal social need, such as a companion to call when unwell, or romantic needs. 'Paid/voluntary work' features in the 'Community' theme but also overlaps closely with

Accessibility maps	Financial constraints	Online events
Accessible built environment	Fitness & exercise	Online task support
Accessible design	Fitness & health tracking	Opening doors
Anomaly detection & alert	Future planning	Paid/voluntary work
Attending events	Health & care system design	Patient empowerment
Autonomous movement/navigation	Healthcare system information	Personal care
Books	Interacting with the healthcare system	Personal care reminders
Caregiver support network	Interest groups	Personal interaction
Caregiver training	Lifting person	Personal records
Community groups	Local information	Physical rehabilitation & care
Community spaces	Locating/Fetching/passing	Public records
Companionship	Location monitoring & alert	Reliable medical information
Daily care plan	Medicine tracking/reminders	Remote medical/healthcare
Daily household coordination	Memory training	Safety & security
Digital training	Mobility assistance	Shared space
Domestic cleaning & meal preparation	Motivation/prompts	Supporting/guiding
Education & training	Music	Tactile & multimodal communication
Emergency alert system	Navigating healthcare system	Treatment plan adherence
Events information	Navigating steps	Wisdom & knowledge sharing
Fall detection & alert	Night surveillance	

Fig. 3 59 codes representing needs derived from statements

'Wisdom & knowledge sharing' in the 'Teaching & learning' theme. This highlights the social aspect of both, but also the need to contribute to the community and to feel a sense of purpose.

The theme of 'Physical assistance' deals with needs such as 'Opening doors', 'Navigating steps', 'Mobility', 'Supporting/guiding' and 'Domestic cleaning & meal preparation'. Needs such as 'Daily household coordination', 'Daily care plan' and 'Medicine tracking/reminders' are gathered under the theme of 'Household and Care Organisation', while needs such as 'Navigating healthcare system', 'Reliable medical information' and 'Remote medical/healthcare' are categorised together as 'Healthcare services & supports'. In this paper, the themes are ordered according to the number of coded statements in each, thus giving an indication as to its importance to the participant community. The themes and sub-themes will be further elaborated in a subsequent paper.

4.5 Developing a Linked Database of Authentic Citations

Key to the process elaborated in this paper is to ensure that each of the themes remains connected to the original statements that produced them, by creating a linked database of authentic citations. To facilitate this, once the themes, codes and associated statements have been finalised, it is useful to assign a unique identifier for traceability throughout the project and solution building process. This is done in a hierarchical way, working in reverse order to the way that the codes and themes were generated. Thus, each of the top-level themes is given a number, its associated codes (or sub-themes) are assigned a second-level number and the authentic citations are assigned a third-level number. The results of this analysis reveal a taxonomy of needs, including a set of meaningful themes (listed in Table 1) and subthemes, each representing distinct needs (listed in Fig. 3), grounded in authentic and situated empirical data which can be used as a basis for product ideation, conceptualisation, requirements planning, and evaluation in the area of robotics and assistive technologies. In our project, we initially used a spreadsheet to link themes to Authentic Citations. However, in order to make it more usable and more widely accessible, we propose a web-enabled version of the numbered and linked database which facilitates direct linking to citations from other documents and has a mock-up user interface as shown in Fig. 4 below.

5 Guidelines for Reliability and Rigour in the Authentic Citations Process

The Authentic Citations process is intended for use with a body of qualitative data, for example, field notes, ethnographic description and direct quotes from interviews, focus groups and open-ended survey responses. As we have documented in this paper, there are a number of defined steps to be taken in the process of identifying, selecting, coding and thematically analysing data in order to present it for use as authentic citations. The first step is to identify the research question that will guide the reading and analysis of the data and determine the criteria for inclusion and exclusion. This is followed by an initial reading of the source data to ensure a holistic understanding of the problem space, overarching themes, and personal narratives that are represented. Next, guided by the research question, relevant statements are identified, extracted and stored. The captured statements

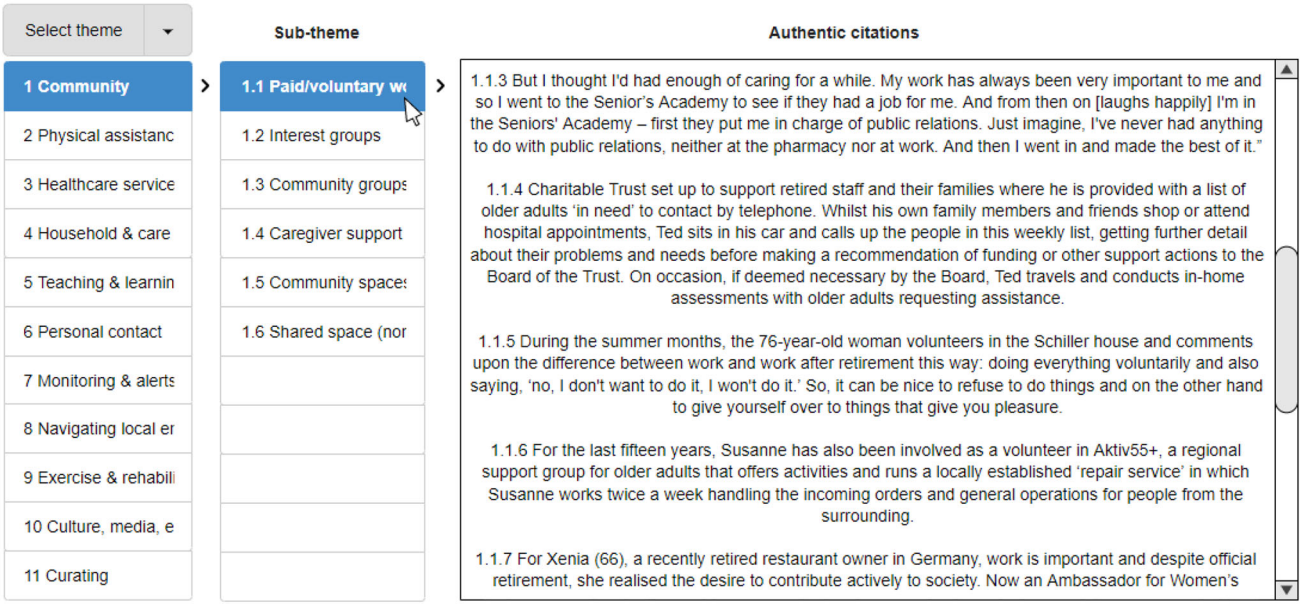

Fig. 4 Mock-up UI for linked database

are then iteratively coded based on recurrent regularities. Following this, the coded statements are organised into coherent higher-level themes. Finally, a linked database is created to connect higher-level themes, codes and their associated authentic citations.

It is important to recognise that qualitative analysis necessarily involves a level of interpretation by the researcher. A number of strategies can be used to further enhance the credibility, rigour and reliability of this process. Triangulation involves checking results, either against other studies and methods, or the use of multiple analysts [80]. The former might include checking categories against previous studies with a similar focus, and/or checking against other data-collection methods that may have been used in the same study, e.g. a parallel quantitative study. There are a number of ways to increase reliability using multiple analysts. If resources allow, and depending on the aims of the project, two or more analysts may carry out the review, comparing results and resolving differences through discussion and refined coding. In design research, it is common to conduct a collaborative thematic analysis, using techniques such as card sorting or affinity diagramming.

It is useful to test for 'substantive significance' [81] of the resulting themes and associated citations with others, such as study participants and users, or with research peers. Substantive significance checks for the credibility, understandability and coherence of the results, asking, for example, whether they demonstrate a credible account and deepen the understanding of the problem context. In our process, we presented, discussed and evaluated our emerging themes with the researchers involved in the data collection.

An additional technique is an 'audit trail', which involves a review of the inquiry process to allow for validation [82]. By linking the themes to their original source statement, a method such as Authentic Citations aims to render the analysis process transparent, allowing for the ongoing evaluation of the research conclusions. It is also useful for analysts to document their decisions and rationale during the analysis to allow for subsequent review.

Finally, because the analyst's judgement is central to the process, attention should be paid to the practice of analysis. In our case, defining needs involved gaining a deep understanding of the user's world through engaging with the ethnography, an existing awareness of robotics and technological capabilities, as well as a familiarity with health and care discourses, while maintaining an overarching commitment to the users' perspectives. It is recommended that the analyst practice 'reflexivity' [72], specifically acknowledging and becoming aware of one's own positionality in relation to the research. This includes a consideration of power imbalances that may exist, such as those between the researcher and the study participants.

6 Using Authentic Citations

Resulting from this process is a list of Authentic Citations by relevant theme and sub-theme. Authentic Citations do not represent solutions, rather they are a means to interrogate the problem space fully and translate it into usable categories to inspire, guide and ground subsequent ideation, conceptualisation, evaluation and development work. Additionally,

they add rigour and transparency to a process that can be opaque. In our research, the Authentic Citations process and the resulting taxonomy has been used to select, evaluate, and identify gaps in technologies for specific projects, to refine existing technologies, to provide inspiration for new technologies and to identify novel research directions. For example, although anomaly detection is a known solution in Assistive Robotics, the multiple and specific references to curtains and blinds remaining closed in the morning revealed a specific and actionable sensing device for older people. Further, Authentic Citations have been used to validate and prioritise existing use cases and personas and to communicate across disciplinary boundaries and between various stakeholders.

The Authentic Citations database and user interface proposed in this paper can be used by robotics researchers to access empirical data directly, see Fig. 4, or can be linked to other artefacts. Authentic Citations can be used to directly inspire user stories. For example, the poignant statement:

> He had left his mobile phone charging upstairs out of reach and to that point had resisted wearing an alarm pendant because of the stigma associated with it. His left leg gave way and Bert didn't have the bodily strength to pull himself up. He managed to pull a blanket off the sofa and wrapped himself in that and recalls how nobody called or came around. "I lost count of how many times I wet myself." After three days, he knew he was close to death and vaguely recalls slowly inching his way into his hallway acquiring severe carpet burns on the way to his landline telephone where he managed to call 999.

may inspire several user stories, for example:

As a user, I want the robot to check on me regularly, so that when I am lying immobile on the floor, it will alert a caregiver

As a user, I want the robot to bring me my phone, so that I can ring an ambulance, even when I am lying injured and immobile on the floor

As a user, I want a robot to lift me up, so that I can reach my phone to call an ambulance

As a user, I want the robot to call for help when I am lying injured and immobile on the floor, so that I can alert others

The presence of the original Authentic Citations means it can continue to inspire new and future ideas and conceptualisations. Thus:

As a user, I want my robotic exoskeleton to sense when I am weaker and adapt, so that I can avoid falling over.

Authentic Citations may also be used in the development of personas. As we have seen, creating fictional representations of users runs the risk of misrepresenting users and reinforcing existing biases. To avoid this, several scholars have proposed and discussed the challenges of linking the supporting data to persona characteristics [61, 62, 70]. Authentic Citations that illustrate specific themes can be used instead to ensure that personas, although fictitious, are nonetheless based around an authentic, descriptive, and situated need. The example in Fig. 5 below shows an original persona developed for the SHAPES project which has been modified to explicitly include authentic citations based on the SHAPES ethnography. Personas can also be built around multiple Authentic Citations representing a composite character. In Fig. 5, we show how multiple Authentic Citations may be represented in a persona, with direct links to other relevant Authentic Citations. As well as facilitating a composite and multi-layered persona, this also allows for ongoing and further interrogation of the data later in the process by developers and other stakeholders. This could also involve searching for other Authentic Citations in the same theme, or by filtering for Authentic Citations from the same participant.

As well as providing pivotal quotes for the persona, the wider context captured can be used to develop additional features, such as goals, motivations, frustrations, and so on.

Authentic Citations have a similar aim to co-design processes: to ensure that the user remains 'present' throughout the design cycle and continues to ensure that development is driven by authentic needs. Although direct interaction between developers and users is an advantage at key stages of the design and development process, it is not possible, or indeed necessarily desirable, at every step of the process. The process described in this paper allows the designer/developer, and indeed, other stakeholders, to asynchronously gain insights into, and communicate, a rich, considered, and authentic account of the users' situation at all stages of the design and development process. Ongoing evaluation and verification with intended users can only enhance this process.

7 Discussion

In this paper, we have proposed the Authentic Citations process as a solution to the problem of retaining the context and nuance of qualitative and exploratory data for solutions conceptualisation, development, and evaluation. Existing strategies and techniques that aim to address this challenge include use cases, scenarios, and personas, in which stories or other descriptions are used to try to imbue the development process with a qualitative sense of the user [28, 60]. However, they are essentially works of fiction and retain no

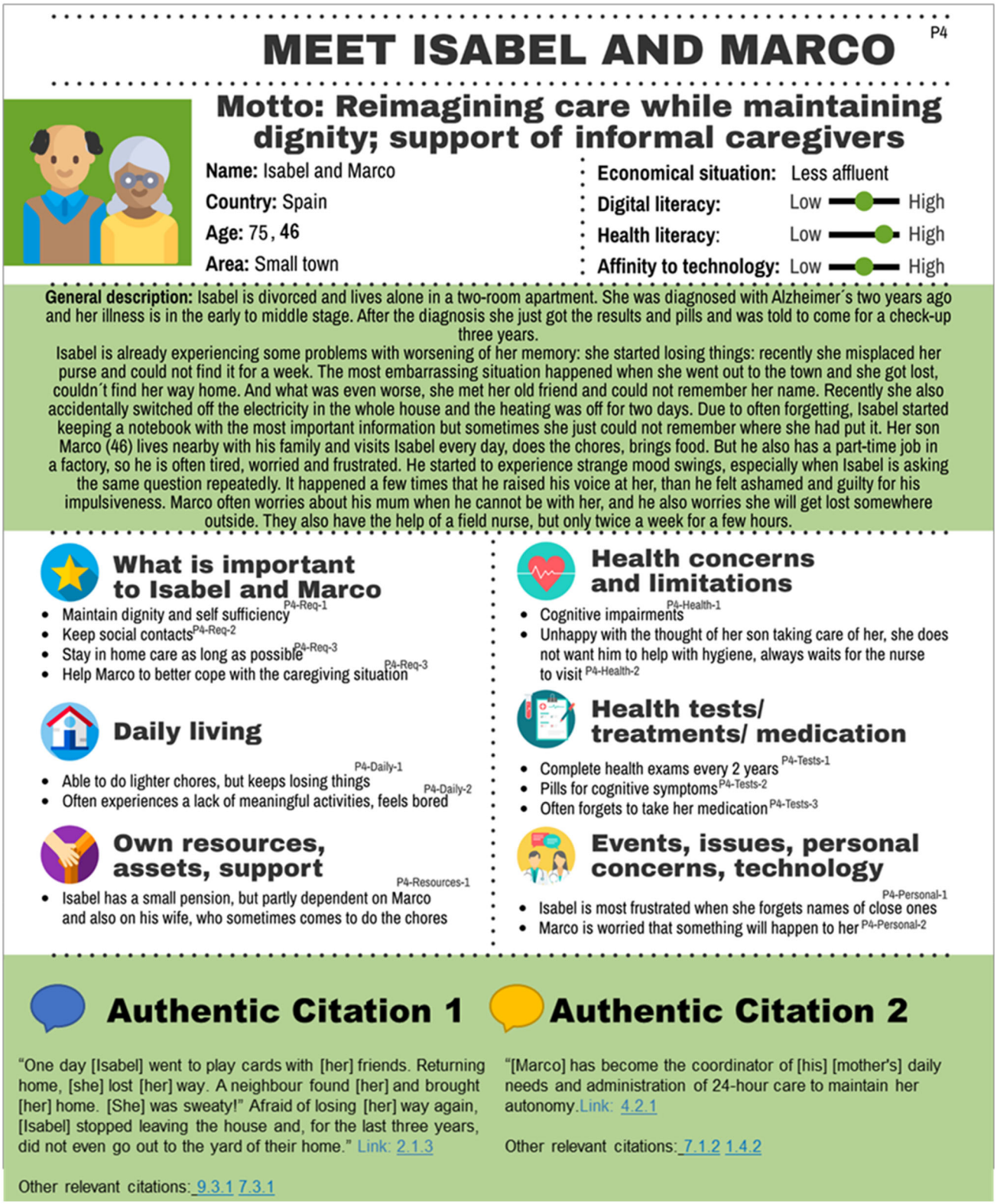

Fig. 5 Persona for the SHAPES project modified to include Authentic Citations

traceable link to the data that produced them [62]. Indeed, in many cases they are not based in empirical research at all [64–66]. Thus, they may result in misrepresenting users and reproducing stereotypes rather than providing genuine situated and the qualitative nuance [63, 66, 67].

Other challenges are experienced by those who use thematic analysis to interrogate qualitative data for user needs and design implications, in particular retaining the richness of the original data in the resulting abstract representations [49, 68, 69]. In the literature on personas, a number of scholars have sought to overcome this challenge, e.g., [61, 62, 70]. However, the methods proposed often add a substantial amount of complexity and a proliferation of data and documents to a process that is already often prohibitively convoluted.

The Authentic Citations process aims to resolve a number of these issues by (1) adding additional rigour to the act of interpretation and translation by making it explicit and transparent, (2) improving the accessibility, use and intelligibility of qualitative data for design and development, (3) eliminating the need for building an interim fictional model by directly connecting situated qualitative descriptions to resulting representations, and 4) reducing the complexity of the process. More fundamentally, however, the Authentic Citations process aims to improve the understanding of the situated user, leading to better and more appropriate solutions.

The Authentic Citations process aims to help roboticists, developers, and designers to gain a deeper understanding of user needs and contexts, and to translate them into actionable outputs. While it is important to bring multiple disciplinary perspectives into a project, this process can be carried out without necessitating outside expertise on the project, as long as it is carried out with the intent of genuinely listening to, and understanding, the users' perspective, and by following protocols for reliability and rigour, as described in Sect. 5 above. It should, however, be noted, that it also relies heavily on the quality of the source data. In our case, it is rooted in an in-depth ethnographic description of the lives of older people across Europe carried out by a team of anthropologists [29]. Additionally, although we have already seen benefits from this process, as described in Sect. 6 above, as it is a novel technique, its efficacy and contribution to robotics research and development will need to be further evaluated in future studies.

The problem discussed in this paper thus is essentially how to translate between two different types of knowledge: the free-flowing, experiential, contextual and qualitative knowledge of the user's world and the abstract, formal, and technical knowledge required for solutions evaluation, design, and development. The Authentic Citations process aims to navigate the contradictions inherent in the two different epistemologies by integrating the richness, nuance, and intuitiveness of the former with the bounded practicality of the latter. We argue that overcoming this challenge is particularly important in Assistive Robotics, where the form and function of the technologies is still in the process of negotiation. This need is compounded by the fact that these technologies are being designed for potentially vulnerable populations, such as older people, who have previously been subject to stereotypical representations. Instead, the Authentic Citations process can help to ensure that user needs are founded on, and remain faithful to, authentic and rigorous research into older people, in all their richness and complexity.

The goal of all human-centred approaches is to bring the potential user and the designer/developer into closer alignment throughout the development lifecycle. The user is an expert in their own lives, but not in all the technological possibilities that might be brought to bear on it. People cannot imagine that which they do not know. Therefore, the design process should be an ongoing (but not necessarily synchronous) dialogue between the designer/developer and those that they are designing for. Technology researchers, designers and developers therefore must bring their knowledge of technological limitations and future possibilities into dialogue with users' needs, exploring and imagining new possibilities. User needs are a powerful and vital sensitising tool which can provide an overarching vision for the project, as well as orienting various stakeholders and perspectives. By maintaining a commitment to the perspective captured by the qualitative research throughout the abstraction process, user worlds are not reduced solely to technical outcomes. Technical solutions are envisaged in the wider context within which they necessarily exist, including political, economic, and social relations.

8 Conclusion

In this paper, we have described a novel Authentic Citations process as a solution to the problem of translating in-depth, qualitative research into actionable categories for use in robotics research and design. A central assumption of the method outlined in the paper is that the process of translation should not sever the link to qualitative nuance of the original data. Therefore, although the creation of categories is necessarily an abstraction, each category retains a connection to the original qualitative statements that produced them. This ensures that the subtle, nuanced, and qualitative understanding of the potential technology user is retained and accessible by all stakeholders, including users, throughout the development cycle. This is particularly beneficial in the case of assistive robotics, which are intended for older and vulnerable people.

The process articulated in this paper is useful for robotics and HRI researchers who are not necessarily trained in empirical research but who are interested in conducting rigorous research into the design space and the needs of their potential users. The process makes a valuable contribution by adding additional rigour and validity to the act of translating empirical findings into actionable ideas by making it explicit and transparent. A second contribution of the paper is the creation of a taxonomy of needs for older people including a set of meaningful themes and subthemes that represent distinct needs that are grounded in authentic and situated empirical data and a proposal for an authentic citations database and interface. This provides stakeholders with an accessible and genuine insight into older people's lives and their needs in relation to assistive robots and contributes to understanding of the older user as engaged, situated, and complex. This method can be used as a standalone technique or in combination with existing human-centred methods, such as the creation of personas, to inform the ideation, conceptualisation, design, evaluation and development of assistive robotics technologies. Ultimately, this supports the wider goal of ensuring a greater understanding of the complex and rich lives of older users, as well as their needs, which contributes to improved solutions that increase people's well-being and quality of life in ways that are sustainable and affordable.

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Data availability The datasets analysed during the current study are available in the SHAPES repository, https://shapes2020.eu/deliverables/.

Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

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