Facilitating the Emergence of Assistive Robots to Support Frailty: Psychosocial and Environmental Realities

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Abstract. While assistive robots have much potential to help older people with frailty-related needs, there are few in use. There is a gap between what is developed in research laboratories and what would be viable in real-world contexts. Through a series of co-design workshops with people with lived experience of frailty, carers, and healthcare professionals, we gained a deeper understanding of pragmatic everyday issues about how technology could fit into their lives and homes. A persona-based approach to facilitate conversations surfaced emotional, social and psychological issues. Any assistive solution must be developed in the context of this complex interplay of psychosocial and environmental factors. Our findings, presented as design requirements in direct relation to frailty, can help promote design thinking that addresses people's needs and concerns in a more pragmatic way to move closer to real-world use.

Keywords: older adults · assistive robots · co-design

1 Introduction

Frailty can be characterised as the loss of resilience due to the adverse effects of ageing. It has physical, emotional and cognitive dimensions, which can hinder effective functioning in daily life [1], with effects influenced by social, environmental and economic circumstances [2]. As populations worldwide age and countries experience care staff shortages, robots are often suggested as a means to support independent and healthy ageing. Designs which fail to take into account people's needs, wants, anxieties and circumstances are likely to result in unacceptable, impractical or ineffective robots. Currently, there are few deployable assistive robots on the market, and the research focus on using off-the-shelf robotic platforms has not been successful [3]. The primary aim of the Emergence Network [4] was to identify and address the barriers to moving assistive robots from laboratories into people's homes. Here we present our findings from workshops that gathered requirement to guide the assistive robotics community towards developments that directly address frailty.

2 Related Work

A previous related robotics co-design exercise was the ACCRA project, out of which were developed applications for the diagnosis of sarcopenia [5] and to support greater mobility [6]. However, these investigations were constrained by the use of pre-existing robots [5]. More recently, the City4Age project created a co-design toolkit to develop interventions for older people. In their critique of other projects, they note that co-design often begins only once the robot has already been developed or chosen, skipping the initial, scoping design work and thereby creating an immediate disconnect between under-defined problem and over-specified robot "solution" [7]. With this in mind, one exercise in co-design of robots to encourage physical activity ignored current robot capabilities and instead identified design guidelines from occupational therapists and older people themselves [8]. The resulting diversity of opinions highlighted the need for personalisation and adaptability, and for multimodal communication, ease of use, maintaining privacy, and behaving respectfully. The research described here takes a similar approach, seeking to identify interventions for frailty without using a pre-existing robotic platform, with a commitment to exploring ideas suggested by participants, regardless of their current feasibility. Another multidisciplinary exercise in the co-design of robots for frailty laid bare the extent of needs in this space, with over 70 distinct requirements initially identified [9]. Here we go a step further by viewing things through the prism of living with frailty more generally, described through a list of functional and non-functional requirements.

3 Methods

Inspired by the *Double Diamond* model of design thinking [10], Emergence held co-design workshops corresponding to the *"discover"* and *"define"* phases of the first diamond. (Subsequent activities, not covered here, would take the results into the *"develop"* and *"deliver"* phases of the second diamond.)

Workshops during the *"discover"* phase discussed issues surrounding activities of daily living (ADLs), self-management of frailty (SM), and the role of healthcare professionals (HCPs). Subsequent workshops were held to further *"define"* the constraints on assistive robots. Research approval was obtained from the University of Nottingham research ethics committee, ref no. CS-2021-R40.

The workshops, each lasting 3-4 hours, were held during 2022 around the UK, at times and places convenient for attendees. Recruitment took place through sector partners, professional networks, and word of mouth. Table 1 gives an overview of workshop participants. There were paired *"define"* and *"discover"* workshops at each location, with participants invited to attend both; however, some were able to attend only one. The second workshop took place around a fortnight after the first. All workshops were audio recorded, with additional manual notes taken. A graphic facilitator helped capture the content of several of the workshops [11].

Table 1: Workshop Information

Stage	**Participants**
Discover: ADL1	8 older people, 1 housing support officer
Discover: SM1	8 older people, 2 OTs, 1 telecare rep, 1 carer
Define: ADL2	5 older people, 2 housing support officers
Define: SM2	8 older people, 3 HCPs
Discover: HCP1	4 HCPs
Discover: HCP2	10 HCPs
Discover+Define: ADL3	4 older people, 4 carers

Discover The ADL, SM, and HCP discover workshops used personas to prompt discussion of the challenges and opportunities faced by people living with frailty. ADL workshops asked participants to identify and prioritise difficulties and opportunities during common daily activities. The SM workshop explored diet, exercise, mental health, sleep, and personal security. The HCP workshops reflected on key challenges faced by individuals during the patient journey and opportunities for robotic support.

Interim data analysis Workshop analysis resulted in a total of 6 potential applications of assistive robots. These *"speculative"* robots were suggested by the needs of workshop participants and not constrained by technical feasibility. Each such robot was summarised in terms of the need/want it meets, its functioning, and its application or operation. These summaries, now incorporating an illustration from the graphic facilitator, were used in the *"define"* workshops.

Define Workshops were held for both the ADL workshop groups and the SM group, and in each case the format was the same. Participants were presented with each speculative robot design and asked what they did or did not like about it, or what else they would need to know about it. The group was then asked for their opinions about various aspects of the robot and how they imagined it would behave. Specifically, they were asked to consider the robot's appearance, control, performance, practicalities, and concerns.

Data Analysis Data collected during the workshops were subjected to a thematic analysis by two of the research team independently and then compared, with discrepancies resolved through discussion. A combined inductive and deductive approach was used, with deductive codes based on workshop topics and inductive codes developed from workshop discussions. These were sorted into functional and non-functional requirements as described in the Volere specification template [12].

4 Results and Discussion

4.1 Discover

ADL1 Workshop Participants indicated that lack of motivation had a negative impact on many important ADLs. They acknowledged that this can lead to further deterioration in mental and physical health, which leads to a vicious circle of decline, which can be difficult to break once initiated. Some attributed problems with motivation to isolation, stating that well-being derived from *"being cared about and car[ing] about yourself"*. Pets were considered a potential source of both motivation and companionship, but could be but impractical due to housing restrictions or care demands. Fear of falling was identified as a barrier to performing ADLs, it was acknowledged that this was also cyclical process, with anxiety leading to reduced activity, and to increased fear of falls. Another issue was the difficulty of remembering to take medication at the correct time.

Practical and cost concerns were frequently raised, particularly the amount of electricity consumed by a robot. Older adults had often downsized their homes and were wary of the amount of space that would be taken up by multiple robots.

SM1 Workshop Participants discussed already using technology to set reminders and for home security. However, they were apprehensive about technology leaving them open to scammers or the loss of the human touch. Frustration was expressed at the general lack of support for maintaining their health, particularly mental health care. Personalisation of a robot to the user and their needs was seen as a necessity, with control in the hands of the service user.

As in the ADL workshops participants were receptive to the idea of robotic pets, and concerned about the practicalities of robot ownership. Communal robots were viewed as a possible solution, particularly for cleaning robots.

HCP1 and HCP2 Workshops Both HCP workshops repeatedly returned to the theme of motivation and a need for self-efficacy. Due to typical multimorbidity and the link between physical and emotional health, a holistic approach was emphasised. HCPs expressed frustration with current electronic healthcare records, and lack of communication and data sharing, leaving them with information about their patients. They stated that they only ever saw a "snapshot" of a patient, often at their worst after an adverse health event, therefore monitoring and assessment after a hospital stay may be enhanced by technology.

Suggested areas for robotic support included fall prevention, medication management, incontinence, and especially preventive interventions for pre-frailty. In general, technology that supports pre-frail individuals could benefit the wider care system. This was combined with acknowledgement of care workers whose job is often demanding and poorly paid. Technologies which would make care workers' jobs easier would help alleviate this burden (as would higher wages).

ADL3 Workshop The ADL3 workshop consisted of both "discover" and "define" sessions and did not inform the speculative robot concepts. Themes from earlier workshops were echoed, including space constraints, fall anxiety, medication management, and interest in robotic pets. Participants expressed the need for both physical and emotional support after a fall or other medical incident, but expressed that equipment was often over-medicalised.

Technology usability was raised, with participants stating that they particularly struggled with initial set up. This particular group expressed a desire to learn technological skills, noting the need for instructions to be tailored to people's accessibility issues.

Table 2: Descriptions of speculative robot scenarios

Robot	Description
Motibot	Detects low mood/lack of activity & suggests activities
Foodee	Suggests recipes & helps users follow them step-by-step
EasyUp	Offers a reassuring arm as you climb up and down stairs
AutoReach	Hoovers, dusts and washes difficult-to-reach places
RoPet	Robot pet companion, available in different models
Toilittle	Toileting robot with options according to user's situation

4.2 Define

All speculative robot scenarios that were discussed and evaluated in "define" are available online [13], with short descriptions shown in Table 2.

Personalisation The need for robots to adapt to users' physical, emotional, or practical context was considered essential for all scenarios. For example, Motibot should tailor its motivational approach, EasyUp must match mobility needs, and Foodee should reflect personal taste and dietary requirements.

Appearance Robotic aesthetics would need to be adjusted depending on both the function and user of the robot. For example, RoPet should be soft and cuddly, Foodee should appear functional, and Toilittle should be discreet. However, participants felt that all robots should look unintimidating, trustworthy, and unobtrusive but easy to spot to avoid collisions.

Interaction Voice interaction was preferred by older people, sometimes supplemented with screens, but robots would need to understand regional speech and terminology. However, it was highlighted that this would be unsuitable for people with speech or hearing impairments.

Maintenance Participants wanted low-maintenance robots, with repair services readily available. This is clear in the case of AutoReach; a cleaning robot that would require regular cleaning would be self-defeating. However, some, like RoPet, could require to light upkeep, treating it more like a pet.

Monitoring and Autonomy Robotic monitoring was acceptable if tailored to the user's needs and frailty. Likewise, levels of robot autonomy might need to change depending on the user's day-to-day needs: for example, Foodee taking more initiative in food preparation if the user was unwell. Robots would also need to understand multiple steps within a process, such as not only reminding a user to take their medication but also confirming this had been done.

Safety and Security Participants accepted that failures would occur with any technology, but highlighted that they should *"fail safely"*, giving the example that EasyUp could call for help in case of failure. Trip hazards were also frequently mentioned as a potential hazard presented by domestic robots, so they should be highly visible and able to navigate to safe locations. Data privacy and protection from scams were also strongly emphasised.

The Human Touch Robots for domestic tasks were considered potentially useful and could even outperform humans in certain tasks. Robots like Toilittle were seen as beneficial for tasks that cause discomfort for both carers and service users. However, many indicated that they would still prefer the "human touch".

Table 3: Functional Requirements in Relation to Frailty

Requirement	In Relation to Frailty
Support a holistic model of healthy ageing	Influenced by biological, psychological, social, and environmental factors
Address multiple facets of frailty	People living with frailty often have multiple long-term conditions
Reduce isolation	Isolation can impact health, so a robot companion should also encourage human-to-human interaction
Not replace or undermine human care	Enable the care of frail older people to be done with dignity and improve jobs within the care sector
Be affordable	Older adults often have less disposable income, so robots should provide good value for money
Be part of a service ecosystem	The whole service delivery model should be considered, including who buys and distributes the robots
Have adjustable levels of autonomy	Over-reliance may increase frailty, but when users need extra support, the robot should be able to provide it
Have adjustable levels of monitoring	This may not be needed for all, but this may change if their condition progresses or after a health incident

Operating Environment Robots must work in small, cluttered, real-world spaces, and not require home modifications. Those living in a residential setting also noted that a robot like EasyUp could be usefully shared between people.

Multipurpose Participants doubted the viability of a single robot to do everything, while space considerations limit the desirability of single-task robots. There were suggestions on how each robot in the scenarios could be for both emotional and physical support, such as EasyUp also providing motivation.

Speculative robots Overall, Motibot, Foodee, EasyUp, and AutoReach were well received. Opinions on RoPet varied, and while Toilittle was a sensitive topic, most agreed it could be useful for those with greater health needs.

4.3 Requirements

The problems, opportunities and ideas from our stakeholder participants are organised into functional (Table 3) and non-functional (Table 4). These have been related to specific needs for people living with frailty.

5 Conclusion

Findings suggest that older people and healthcare professionals are willing to use robotic interventions to support independence and manage frailty. However, despite an abundance of research into assistive robots, few interventions have made the leap into the real world. As others have noted, researchers often start with a specific robotic platform in mind (and preconceived notions of the needs and abilities of older people), rather than seeking basic requirements. With this research, we hope to redress the balance and guide the development of assistive robots that are useful, usable, acceptable and feasible.

Table 4: Non-Functional Requirements in Relation to Frailty

Category	Requirement	In Relation to Frailty
Look and Feel	Highly visible	Avoid creating trip hazards
	Unobtrusive appearance	No distress for those with cognitive impairments
	Non-medical	Avoid medicalisation in daily life
Usability & Humanity	Easy for older people to use	Support users when they are alone
	Easy for carers, HCPs and others to use	Allow people in the user's wider support circle to use it
	Reduce cognitive load	To enhance memory & concentration
	Personalisation	Suit the user's changing needs
	Multimodal control	Interact with users with multiple, intersecting accessibility needs
Performance	Fail safely	Prevent injury or stranding users
	Awareness of home hazards	Does not create more hazards
Operational & Environment	Suitable for small homes	Older adults often downsize
	Consider shared environments	More older people live in shared or sheltered accommodation
	Fit to the environment	People do not want to change their homes for robots
Maintenance & Support	Full maintenance services	Older people are unlikely to be able to maintain a robot
	Encourage caring for the robot	Build a sense of responsibility for day-to-day maintenance
Security	Controlled by primary user	Protection from bad actors
Cultural	Understand regional difference	Users do not have to alter their language for the robot
	Different language options	To negate language barriers

Older people, their carers, and healthcare professionals shared their experiences of living with frailty, and opportunities to develop technological interventions. Cognitive, emotional and physical challenges were identified related to daily life and self-management, and all groups emphasised the need for a holistic approach to managing frailty. Technology needs to be personalised, as older people are not a homogeneous group. Safety and trust and user-friendliness are issues, and people are concerned about the cost and logistics of robotic provision and support, so developers should consider the design and cost-effectiveness of the widerservice model. Finally, we have also created a set of "empathy cards" using the illustrations made during the workshops [13]. To aid dissemination, we use these as prompts and provocations in workshops with developers and other stakeholders to help promote more holistic design concepts for assistive robots.

6 Limitations

The study involved a limited, self-selecting sample, so findings may not generalise to the wider population. Moreover, the findings are specific to a particular cohort, time, and place. At this stage, we excluded participants with technical backgrounds to allow future phases of the project to engage developers, incorporating insights from older adults and HCPs into robotic design.

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