Design Science

A scoping review on human-centered design approaches and considerations in the design of technologies for loneliness and social isolation in older adults

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Abstract

Loneliness and social isolation are prevalent concerns among older adults and can lead to negative health consequences and a reduced lifespan. New technologies are increasingly being developed to help address loneliness and social isolation in older adults, including monitoring systems, social networks, robots, companions, smart televisions, augmented reality (AR) and virtual reality (VR) applications. This systematic review maps human-centered design (HCD) and user-centered design (UCD) approaches, human needs, and contextual factors considered in current technological interventions designed to address the problems of loneliness and social isolation in older adults. We conducted a scoping review and in-depth examination of 98 papers through a qualitative content analysis. We found 12 studies applying either an HCD or UCD approach and observed strengths in continuous user involvement and implementation in field studies but limitations in participant inclusion criteria and methodological reporting. We also observed the consideration of important human needs and contextual factors. However, more research is needed on stakeholder perspectives, the functioning of applications in different housing environments, as well as studies that include diverse socio-economic groups.

Keywords: Loneliness, Social Isolation, Older Adults, Scoping Review, Human-Centered Design

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1. Introduction

Loneliness and social isolation negatively affect older adults' well-being and quality of life (Age UK 2018; Schrempft *et al.* 2019). Social isolation and loneliness have been shown to increase frailty and mortality risk (Luo *et al.* 2012; Holt-Lunstad; Davies *et al.* 2021). The healthcare system can also be affected because of the greater

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use of healthcare services by older adults who feel lonely (Gerst-Emerson & Jayawardhana 2015; Burns *et al.* 2022). Notably, the social isolation requirements implemented in response to COVID-19 have resulted in an additional increase in loneliness among older adults in recent years (Caruso Soares *et al.* 2022). Health, sociodemographic, and psychological factors have been indicated to affect loneliness in old age (Rees *et al.* 2023). Therefore, technologies have been increasingly designed and developed to address loneliness and social isolation among older adults. Commercial examples are “Elli Q” (Intuition Robotics, n.d.) and “PARO” (PARO Robots U.S., n.d.), which are desktop-based or soft toy robots that aim to provide “socialization” and “companionship” for older adults.

Several systematic reviews have contributed to a better overall understanding of the advances in technologies such as monitoring systems (Bouaziz *et al.* 2022; Qirtas *et al.* 2022) and information and communication technologies (Latikka *et al.* 2021). These reviews often focused on the effectiveness of interventions (Jarvis *et al.* 2020; Ambagtsheer *et al.* 2024; Döring *et al.* 2022). Some studies have provided insights into the ethical and personal considerations of and barriers to technology use (Corbett *et al.* 2021; Qirtas *et al.* 2022; Ambagtsheer *et al.* 2024), with the findings highlighting some important requirements for technology design. However, to the best of our knowledge, no in-depth review has been conducted on the current consideration of human-centered design (HCD) and user-centered design (UCD) approaches, human needs, and contextual influences in the development of loneliness- and isolation-related technologies for older adults.

The current review is informed by the concept of ‘human’ or ‘user centered design’. UCD emphasizes users’ perspectives and needs in design within the field of human-computer interaction (Norman & Draper 1986). HCD and UCD have been defined as an “*approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques*” (ISO 2010, p.VI). The overall approach consists of an analysis of requirements and needs, design, evaluation, and feedback (Gulliksen *et al.* 2003). UCD has been linked to characteristics such as a focus on the user, user involvement, iterative development, prototyping, evaluation in context, and multidisciplinary teams (Gulliksen *et al.* 2003). Previous HCD models also emphasized an understanding of the context, specifying user requirements, prototyping of design solutions and evaluation in iterative cycles until a solution is developed (ISO 2010). What sets HCD and UCD apart from participatory design is the participants’ views and involvement. Users are regarded as designers in participatory approaches, whereas in UCD and HCD approaches, researchers or designers often translate requirements into designs that users then test (Sanders 2002; Sanders & Stappers 2008).

Methods in the UCD and HCD process involve usability testing, field studies, user interviews or surveys, analysis of user requirements, participatory design methods, focus groups, task analysis, heuristic evaluations, card sorting activities, contextual inquiry, and ethnography (Vredenburg *et al.* 2002; Sanders & Stappers 2008). The purpose of the HCD process in healthcare applications is to improve patient satisfaction, usability, and effectiveness compared to more linear approaches (Altman *et al.* 2018). UCD and HCD are often understood to be synonymous (Steen 2011); however, HCD emphasizes “humanizing” the intended target users and human values (Steen 2011; Holeman & Kane 2020).

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HCD and UCD activities require an understanding of "the context of use" and "user requirements" (ISO 2010). Some examples of human needs, such as social, security, or physiological needs, are based on Maslow's hierarchy of needs (Desmet & Fokkinga 2020). Context could refer to institutional or cultural values that shape activities and goals or collaboration with other actors (Nardi 1996), a user's personal preferences and knowledge, technical network resources, and location or user tasks (Lieberman & Selker 2000). In this study, we focus on the UCD or HCD approach, user and stakeholder needs, contextual influences on the technology perception.

2. Aims

This study aims to summarize and discuss technologies designed to address loneliness and social isolation in older adults and the UCD and HCD approaches, human needs, and contextual influences that are considered. Accordingly, we focus on the following research questions:

1. How have UCD and HCD methods been applied in developing technologies to address loneliness and social isolation in older adults?
2. What stakeholder and user needs have the designers of these technologies identified as important?
3. What contextual influences have been identified that may affect the functioning of these technologies?

3. Significance

Technologies are increasingly being developed to address loneliness and isolation among older adults. In this review, we intend to inform designers of how UCD and HCD approaches are currently applied in this context to understand potential gaps and limitations. Designers and developers of such technologies will also benefit from an initial overview of previous insights into HCD and UCD considerations and what human needs or contextual influences to expect.

4. Method

We used a scoping review method, which is a structured approach similar to that of systematic reviews, but often involves e a more comprehensive literature search (Munn *et al.* 2018). This systematic approach to a literature search and synthesis aims to identify research gaps, define concepts, and map the current literature (Colquhoun *et al.* 2014; Munn *et al.* 2018). The approach is well-suited for our aim of providing an overview with a broader research question. We followed the updated PRISMA 2020 guidelines for reporting systematic reviews (Page *et al.* 2021) to ensure greater clarity and transparency in the review process. The research protocol is attached in Appendix A(Pyykkö *et al.* 2021).

We applied a qualitative content analysis suitable for systematic and scoping reviews to analyze the materials (Pasila *et al.* 2017; Manevska-Tasevska *et al.* 2023). Content analysis is defined as an objective, systematic approach that finds relevance by distinguishing the frequency at which a concept occurs in the analyzed material (Berelson 1952, p.18). Quantitative content analysis approaches a text with categories from existing theory and applies automatized analytical methods

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(Forman & Damschroder 2008); however, a qualitative approach involves reading and understanding of the meaning of the content and providing some context (Hsieh & Shannon 2005; Forman & Damschroder 2008).

4.1. Search strategy

The Scopus, Web of Science, and Association of Computing Machinery (ACM) digital library databases were searched between December 2022 and January 2023 and the search focused on papers with keywords indicating a focus on loneliness and social isolation (loneliness OR "social isolation"), older adults (elderly OR "old age" OR "older adults" OR "older people" OR geriatric OR senior), and technology (technolog* OR design OR system OR service OR innovat* OR wearable OR smart OR sensors OR monitoring OR internet) in the abstract. We focused on papers published after 2014, because members of the baby boom generation in the UK who were born between 1946 and1948 began to reach retirement age in 2014, resulting in a sharp increase in people aged 65 or above (Future Foundation 2014). A similar timeframe can be observed in other countries such as the US where the baby boom is considered to have begun in 1946 and peaked in 1947 (Colby & Ortman 2014).

4.2. Eligibility criteria

Publications that present newly designed technologies and applications to address loneliness and social isolation among older adults were included. Later life is characterized by physiological changes and higher risks for certain diseases (Amarya *et al.* 2018), which can lead to special technological design requirements (Huppert 2003). Moreover, parts of the older population have no access to the Internet or lack the technological skills to benefit from new applications (Age UK 2023; Government Office for Science 2016), requiring a design of more accessible technologies and systems. There are also unique social and cultural circumstances and reasons for loneliness linked to old age, such as the possibility of living in care facilities (Pinquart & Sörensen 2001), loss of a spouse (Savikko *et al.* 2005), or less participation in social activities (Arslantaş *et al.* 2015). The United Nations classify older people as those aged over 60 (United Nations 2017). One in six people worldwide will be aged 60 years or over by 2030 reaching 1.4 billion (World Health Organization 2022). It is predicted that this number will grow and that the populations of low-, middle- and high-income countries will shift "towards older ages" (World Health Organization 2022). In policy recommendations on how to address the demographic change, the UK Government Office for Science (2016) noted the importance of considering connectivity and social interaction of older adults. Since 2018, 'loneliness' is officially a consideration in policymaking (UK Government 2023). A systematic review of 29 countries revealed that one in four people over the age of 60 feel lonely (Chawla *et al.* 2021). In line with this, and to facilitate the breadth required from a scoping review, we chose an inclusion criteria age of 60.

In cases where age was not specified, articles were included if the stated focus was on groups such as "elderly," "older adults," or "residents in a care facility" (Fudge *et al.* 2007). We use the term "newly designed technologies" to refer to a specific application under development explicitly meant to help address loneliness and social isolation. These technologies are distinct from testing generic or existing

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applications and mainstream available technologies that are already out of development or have not been explicitly designed to help address loneliness (e.g., well-known social media platforms). Additionally, publications focusing on new social support initiatives and programs transmitted through digital means (e.g., a sports course delivered over a video communication platform and a social program carried out through telephone calls) were excluded as we were interested in technological design.

4.3. Selection process

Records were retrieved from the databases and imported to EndNote 20 (Gotschall 2021). Duplicate articles, review papers, and protocols were excluded. The titles and abstracts of the remaining articles were then screened. Where inclusion could not be deduced from titles and abstracts, full papers were retrieved and evaluated (Figure 1). The fourth author independently screened 10% of the papers randomly

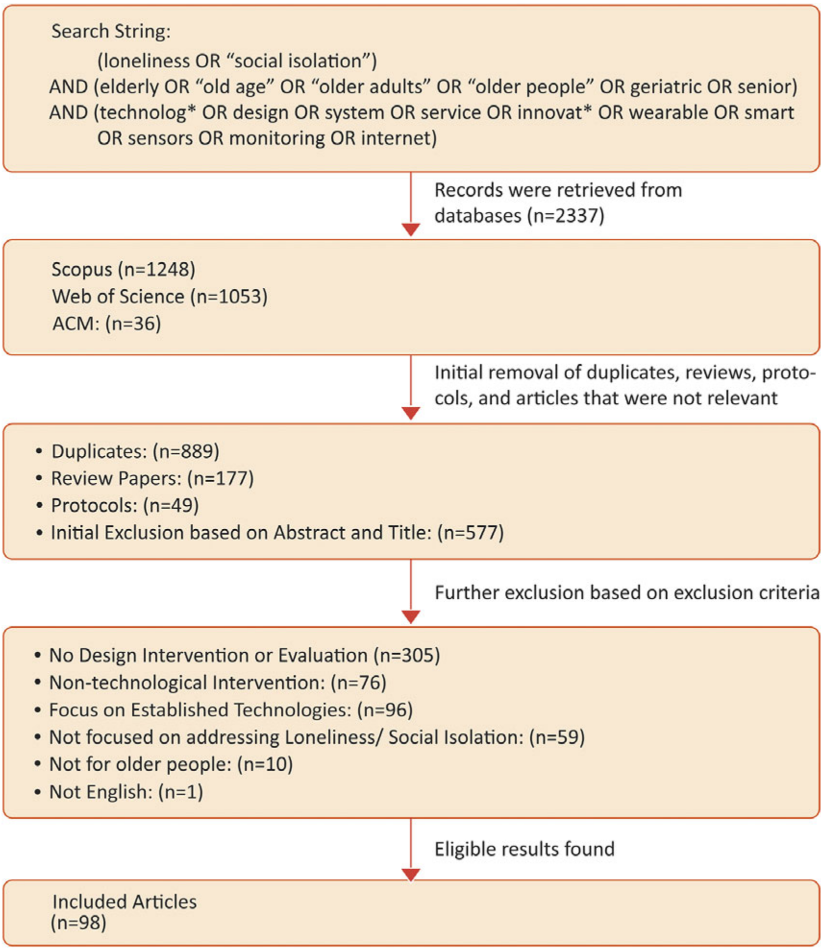

Figure 1. Flowchart of the review process showing the search terms, number of records retrieved, number of excluded papers, and the number of eligible results.

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selected from a closer selection (after removing duplicates, review papers, papers not written in English, and papers initially excluded as being beyond the scope of the review). Discrepancies were discussed until an agreement was reached.

4.4. Analysis

Analysis of the eligible results focused on UCD and HCD approaches, user and stakeholder needs, and influential contextual factors. Categories and descriptions were developed using inductive content analysis (Elo & Kyngäs 2008). This enabled the review to summarize key information relevant to the research questions from a large number of articles that did not always specifically focus on whether their technologies were user-centered. The questions for analysis were developed through discussions with the research team to determine the focus. Open coding was applied to part of the eligible papers. The initial codes were grouped and all the papers were categorized.

5. Results

The search initially yielded 2337 articles. After excluding duplicates, reviews, and protocols, 577 papers were excluded because they were outside the scope of the study, 306 because they did not present or discuss any designed intervention, and 77 because they did not present a technological intervention. Finally, some publications were removed because they did not focus on the correct demographic group, loneliness or social isolation, or because they were in a language other than English.

This review presents the results of an in-depth analysis of 98 papers (Appendix B). We constructed four main categories (Elo & Kyngäs 2008) to better understand and relay the data in the articles: UCD and HCD design approaches, user needs, stakeholder needs, and design context. To provide an overview of current UCD and HCD approaches we analyzed the applied process, methods, degrees of user and stakeholder involvement (Göttgens & Oertelt-Prigione 2021), demographic participant details, and experienced challenges. Codes were sorted into user needs if considerations were mentioned regarding improving the technology for the user. This could be a design consideration stated by the authors, the users themselves, or stakeholders. This category was further divided into the following subcategories: accessibility, enjoyment, privacy and safety, control and independence, and help maintaining relationships. We also analyzed stakeholder needs with "convenience" and "positive interactions" as subcategories. Moreover, the design context was divided into the following sub-categories: health conditions, technical infrastructure, social environment, cultural context, and housing environment.

5.1. Summary of UCD and HCD approaches

We found 12 papers that mentioned the application of a UCD or HCD approach (Table 1). Only one study mentioned HCD as the primary method (Goumopoulos *et al.* 2017). HCD and UCD are either used synonymously (Goumopoulos *et al.* 2017) or UCD is understood as a form of the HCD process that is more focused on users and tasks (Davis *et al.* 2017). In one case, a new method was developed based on UCD: the "Living Lab" approach was characterized by combining laboratory

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Table 1. UCD and HCD approach, process, and methods

	Approach	Process and Method Description
(Goumopoulos *et al.* 2017)	HCD/ UCD	Requirement and Design phase: - desk research, interviews, focus groups, stakeholder workshops, questionnaires. Evaluation: - deployment, questionnaires, interviews
(Broneder *et al.* 2022)	UCD	Workshops to iteratively test and improve prototypes, field study
(ter Voort *et al.* 2015)	UCD	Requirements: - Context inquiry, interviews, focus groups. Design: - Iterative design and brief testing phases Evaluation of prototype: - task-based usability testing in people's natural environment
(Meinert *et al.* 2020)	UCD	First iteration: - literature review, initial concepts, prototypes tested in focus groups. Second iteration: - more refined application, improvement through interviews Third iteration: - Deployed and published, testing through survey, interviews
(Louiesau *et al.* 2015)	UCD	Design and Requirements: - Literature review - Usability testing in focus groups
(Correia *et al.* 2016)	UCD	First iteration: - Lab testing Second iteration: - Field study
(Ghosh *et al.* 2022)	UCD	Iterative design with user feedback, field study evaluation
(Koceska & Koceski 2022)	UCD	Requirements: - Interviews, observation on site Evaluation: - Field testing, questionnaire
(Villaverde Naveira *et al.* 2022)	UCD	Design: - Co-Design Evaluation: - Usability testing
(Alaoui & Lewkowicz 2015)	UCD	Requirements: - Interviews, personas Design: - Iterative improvement of mockups in interaction with users

Continued

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Table 1. Continued

	Approach	Process and Method Description
		Evaluation: - Usability testing in the lab, expert-testing, heuristic evaluation - Field studies
(Doppler *et al.* 2018)	UCD	Requirements: - Focus groups, iterative design, testing Evaluation: - Field trial, questionnaire
(Davis *et al.* 2017)	UCD	Requirements: - Interviews, co-constructing stories, observations on site Evaluation: - Usability testing, field study

and field studies and a greater user engagement in the design process (Alaoui & Lewkowicz 2015). The studies reported on the use of HCD models (Goumopoulos *et al.* 2017), UCD principles (Ghosh *et al.* 2022; Villaverde Naveira *et al.* 2022), user-centered characteristics (Koceska & Koceski 2022; ter Voort *et al.* 2015), the researchers' own process model (Davis *et al.* 2017), or did not explicitly name a particular model or set of principles (Broneder *et al.* 2022; Meinert *et al.* 2020; Louiesau *et al.* 2015; Correia *et al.* 2016; Alaoui & Lewkowicz 2015; Doppler *et al.* 2018).

Most studies presented an iterative design and testing phase, followed by a more elaborate implementation and evaluation in the end (Broneder *et al.* 2022; ter Voort *et al.* 2015; Correia *et al.* 2016; Doppler *et al.* 2018). Some studies applied an approach without such iterations, consisting of three main phases: requirement gathering, design, and evaluation (Goumopoulos *et al.* 2017). Processes that combined an agile approach planned to deploy a working prototype early on and make iterative improvements (Meinert *et al.* 2020).

The methods used to develop the design requirements included interviews (ter Voort *et al.* 2015; Koceska & Koceski 2022; Alaoui & Lewkowicz 2015), focus groups (Doppler *et al.* 2018; ter Voort *et al.* 2015), questionnaires (Goumopoulos *et al.* 2017), contextual inquiry (ter Voort *et al.* 2015), on-site observations (Koceska & Koceski 2022), desk research (Goumopoulos *et al.* 2017), and literature reviews (Meinert *et al.* 2020). Focus groups and workshops often served to gather requirements and evaluations of initial prototypes from users and stakeholders (Louiesau *et al.* 2015; Broneder *et al.* 2022; Doppler *et al.* 2018). Other methods and tools included co-design(Villaverde Naveira *et al.* 2022), co-constructing stories (Davis *et al.* 2017), and personas: (Alaoui & Lewkowicz 2015).

Field testing was a commonly used method for prototype evaluation (Correia *et al.* 2016; Davis *et al.* 2017; Doppler *et al.* 2018; Broneder *et al.* 2022; Koceska & Koceski 2022). Some studies applied lab-based observations (Correia *et al.* 2016),

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heuristic evaluations, and expert testing before moving into participants' home environments (Alaoui & Lewkowicz 2015). Usability testing was another common evaluation method (Louiesau *et al.* 2015; ter Voort *et al.* 2015; Meinert *et al.* 2020). Usability, usefulness, user experience, privacy, the frequency of used features (Goumopoulos *et al.* 2017; Doppler *et al.* 2018; Broneder *et al.* 2022; Koceska & Koceski 2022), confidence, and comfort (Ghosh *et al.* 2022) were measured in the evaluation process. Moreover, the existing difficulties with these systems were explored (Correia *et al.* 2016). The effect measures focused on loneliness before and after system implementation, skills to live independently, relationship closeness with carers, and perceived social presence (having company or feeling belonging) (Davis *et al.* 2017; Goumopoulos *et al.* 2017).

Previous studies also attempted to achieve larger sample sizes using mixed quantitative and qualitative methods. For example, Goumopoulos *et al.* (2017) first developed requirements and initial system features based on qualitative focus groups and then sought validation using an online questionnaire with 69 older adults. Some field trials and usability evaluations involved larger sample sizes of 54 or 60 users (Correia *et al.* 2016; Broneder *et al.* 2022).

Users or stakeholders were regularly involved in developing requirements (Louiesau *et al.* 2015; ter Voort *et al.* 2015; Davis *et al.* 2017; Goumopoulos *et al.* 2017; Koceska & Koceski 2022) and providing feedback on prototype iterations (Louiesau *et al.* 2015; Broneder *et al.* 2022; Meinert *et al.* 2020; Ghosh *et al.* 2022), as well as participating in the evaluation phase (Correia *et al.* 2016; Goumopoulos *et al.* 2017; Broneder *et al.* 2022; Ghosh *et al.* 2022). The demographic details collected on older adults included their type of housing (ter Voort *et al.* 2015), level of education (Davis *et al.* 2017), cultural background (Davis *et al.* 2017), health concerns and marital status (Alaoui & Lewkowicz 2015).

Some studies reported challenges faced when using the UCD approach, such as the need for participants' continuous engagement and convincing them of the usefulness of a new technology (Alaoui & Lewkowicz 2015). Additionally, inviting stakeholders in the healthcare sector could be difficult because of time restrictions (Davis *et al.* 2017). If the implemented prototypes presented technical difficulties, participants could experience negative emotions or feel demotivated (Alaoui & Lewkowicz 2015). Working with older adults also requires an awareness of ethical considerations, such as reducing the time needed to participate in research studies (Davis *et al.* 2017).

5.2. User needs

5.2.1. Accessibility

Accessibility for older adults was a widely regarded concern found in 36 studies (Table 2). The representations of physical objects familiar to users, such as cards or flowers, were tested (Zhao *et al.* 2016; Peng 2018; Mueller *et al.* 2021). Mueller *et al.* (2021) developed NFC-coded cards to activate specific tablet applications, while Petersen *et al.* (2014) installed a monitoring system in traditional telephones rather than smartphones (Petersen *et al.* 2014). Owing its intuitive use, television was another platform widely employed for new systems (Limdumrongnukoon *et al.* 2015; Syeda & Kwon 2017; Isaacson *et al.* 2019; Garcia-Mendez *et al.* 2021; Noguchi *et al.* 2022; Yang & Chen 2022). Voice interaction was also proposed as a more accessible alternative to typing (Muñoz *et al.* 2015; Meinert *et al.* 2020).

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To overcome barriers to technology usage, such as the need for an Internet connection and volume settings, training sessions, step-by-step instructions, and ongoing guidance were recommended (Aaltonen *et al.* 2017; Alaoui & Lewkowicz 2015; ter Voort *et al.* 2015; Cook & Winkler 2016; Lundström *et al.* 2021; Broneder *et al.* 2022; Ghosh *et al.* 2022). Robotic interfaces were explored to assist older adults in using social networks and other applications (Marin Mejia 2014). Supportive attitudes from carers and family members promoted technological use and some applications enabled them to provide technical support remotely (Neves *et al.* 2018; Meinert *et al.* 2020). Technology adoption may entail different training needs for familiarization (Cook & Winkler 2016) as some users might be more open or familiar with the use of new technologies.

5.2.2. Enjoyment

The role of enjoyment in fostering the regular use of new systems was observed in 28 studies. Virtual reality (VR) was found to transform physiological rehabilitation exercises previously considered tedious into engaging activities (Høeg *et al.* 2023). Tailoring virtual pet companions to match user preferences, such as providing a more aggressive version for men, enhanced initial usage (Machesney *et al.* 2014). For robots and chatbots to be truly engaging, elements of natural conversation, emotional sensitivity, and gestural awareness were required (Correia *et al.* 2016; Garcia-Mendez *et al.* 2021). Virtual pets were found to serve as conduits for application use and learning support, enjoyment promotion, and sustained use (Hsieh 2015). A positive undertone in a website's language (Mahmud *et al.* 2022) and a social robot's friendly demeanor could enhance technology acceptance (Demaeght *et al.* 2022). Aesthetic and user-friendly designs helped avoid intimidation and increase appeal (Yamazaki *et al.* 2014). For robots, a child-like appearance and natural interactions increased technological acceptance among older adults (Chen *et al.* 2020). Social factors could also influence enjoyment and adherence as observed in online exercising groups (Nikitina *et al.* 2018).

Avoiding negative feelings and promoting emotional connections are vital for fostering enjoyment and engagement. For example, conversational agents were found to risk being hurtful towards users by touching on topics related to "family" (Bravo *et al.* 2020). Robotic systems were often designed for authentic expression and accurate detection of emotions (Onofrio *et al.* 2019; Khosla *et al.* 2021; Valtolina & Hu 2021; Demaeght *et al.* 2022) to provide a sense of companionship and understanding (Garcia-Mendez *et al.* 2021).

5.2.3. Safety and privacy

In 19 studies, privacy preservation was a paramount recommendation for fostering trust in and acceptance of technological systems (Morgavi 2015). Certain older adults expressed discomfort with anthropomorphic robot designs and felt they were constantly being observed in their daily lives (Wilson *et al.* 2022). Concerns over continuous monitoring, particularly through ubiquitous devices such as smartphones and associated microphones, deterred individuals from freely expressing themselves or sharing personal information (Davis *et al.* 2017).

To address privacy concerns, monitoring systems often eschewed cameras and instead used sensors for internal contact and motion sensing (Petersen *et al.* 2014;

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Goonawardene *et al.* 2017). Alternatively, systems could adopt low-resolution visual sensors (Eldib *et al.* 2015) or real-time picture deletion after feature extraction (Gaete *et al.* 2017). Textile stretch sensors were used as alternatives to audio recordings for speech detection, to avoid the risk of audio surveillance (Ejupi and Menon 2018). However, some studies acknowledged that using monitoring systems in domestic settings increases the risk of security breaches and hacking (Poulsen *et al.* 2020). In addition, integrated cameras would need to provide clear indications when turned on to ensure intentional recording.

Feeling and maintaining safety are key concerns for older adults as well as their relatives and carers. Although older adults want systems that enhance safety and provide reassurance (Huang *et al.* 2020), inherent risks are associated with new technologies. Concerns were expressed regarding meeting strangers online while using digital platforms (Gao *et al.* 2012), and some applications restricted the sharing of online-generated data to family members to enhance user safety (Ku 2018). Carers also considered safety risks, as evidenced by the potential for unintended emergency calls with telepresence robots (Aaltonen *et al.* 2017).

5.2.4. Control and independence

Some technologies can instill a sense of loss of control in older adults. The application of AI-driven robots raises concerns regarding non-consensual behavior and the loss of users' autonomy and dignity (Johnston 2022). For example, a robot could impose unwanted restrictions by preventing an older adult from climbing a chair (Johnston 2022). Older adults value retaining control over actions, such as initiating contact with their family members and carers, even if a robot assisted with monitoring and data transmission (Villaverde Naveira *et al.* 2022). When designing social robots to enhance older adults' social engagement, the potential fear of losing control is crucial to consider, as some may perceive robots as overriding personal decisions (Khosla *et al.* 2021).

Preserving independence is a key goal for older adults (Onofrio *et al.* 2019), who appreciate robotic support in completing tasks without relying on carers (Koceska & Koceski 2022). However, previous studies have shown that some systems may be perceived as patronizing by the elderly. For example, an application using conversational agents to address eating habits triggered such feelings (Kramer *et al.* 2022). Some participants expressed fear of losing independence if daily tasks were automatically managed by robots, especially if the robots were perceived as toys or age inappropriate (Coghlan *et al.* 2021). Designers have attempted to mitigate such concerns by ensuring interfaces are aesthetically appropriate and avoid 'infantilization and 'stigmatization' (Mueller *et al.* 2021).

5.2.5. Help maintaining relationships

Many older adults want technology that supports and facilitates their ability to maintain relationships with relatives and peers, which is often driven by a desire for independence (Onofrio *et al.* 2019). When interviewed, nursing home residents expressed challenges in forming meaningful connections with their fellow residents (Li *et al.* 2018). Initiatives such as public installations encourage interaction among older adults and other community members, addressing communication barriers that may otherwise hinder social engagement (Li *et al.* 2018; Mushiba 2018). Zhao *et al.* (2016) reported that older adults struggle to find

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conversation topics with younger family members and may feel uncertain about their availability for social contact such as phone calls (Zhao *et al.* 2016; Johansson-Pajala *et al.* 2023). Furthermore, networking applications were developed for older adults without relatives or family connections (Johansson-Pajala *et al.* 2023).

5.3. Stakeholder needs

5.3.1. Convenience and positive interactions

Effective operation of communication systems relies on accessibility and support from relatives or carers. Hence, application design should consider the accessibility requirements of both older adults and their communication partners. Integrating applications with commonly used messaging platforms such as WhatsApp and Facebook can facilitate engagement among younger users (Baecker *et al.* 2014; Alaoui & Lewkowicz 2015; Ruschin 2015; Ku 2018). Ku (2018) observed that older adults might perceive themselves as burdensome to their relatives and developed a gaming application with easy scheduling of playtime to address the issue (Ku 2018). Asynchronous communication was used to accommodate differences in time zones (Baecker *et al.* 2014).

Privacy considerations extend beyond older adults to carers and caregiving environments. For example, introducing telepresence robots in nursing homes, might result in relatives interfering in the care process. To mitigate this, systems should incorporate privacy features, such as buttons to enable temporary privacy for staff and carers (Aaltonen *et al.* 2017). Older adults' privacy should also be protected from a family member's perspective to avoid embarrassment when using telepresence robots (Niemelä *et al.* 2021).

Finally, carers may experience a sense of guilt if they lack the resources to make regular visits and calls. Implementing sensing systems can provide patients with a sense of the carer's social presence, easing such feelings of guilt (Davis *et al.* 2017).

5.4. Design context

5.4.1. Health conditions

Designing technologies for older adults requires careful consideration of their health conditions. For example, VR glasses are not suitable for people with visual impairments who wear glasses regularly (Graf *et al.* 2020; Lundström *et al.* 2021; Mackey *et al.* 2022). Mixed reality or VR applications must consider color blindness because items such as game figures might create confusion otherwise (Broneder *et al.* 2022). Speech by virtual pets may require subtitles to address hearing impairments, which could hinder fluent interactions (Machesney *et al.* 2014). Hearing difficulties could also result in telepresence robots being rejected (Aaltonen *et al.* 2017).

The use of smartphones as monitoring devices may be limited by the cognitive effort required to keep them nearby at all times (Martinez *et al.* 2017). Several studies have emphasized the importance of simplified, visible interfaces (Dos Santos *et al.* 2016; Goumopoulos *et al.* 2017; Ha & Hoang 2017; Isaacson *et al.* 2019; Sunghoon *et al.* 2019). Interfaces for smart television systems have been adapted to accommodate various perceptual, motor, and cognitive impairments, such as by featuring clear readability, higher volumes, larger controls, and intuitive

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navigation (Limdumrongnukoon *et al.* 2015; Pereira *et al.* 2015). Interaction with tablets has been simplified to include gestures such as swiping, waving, and tapping to cater to individuals with mobility restrictions, chronic pain, or arthritis (Baecker *et al.* 2014; Neves *et al.* 2018).

Inclusivity must be fostered beyond health conditions and disabilities. Robotic telecommunication was enabled through nonverbal communication for those with cognitive impairments (Yamazaki *et al.* 2014). Wearable devices and tablet-based input have been recommended for the intuitive interactions they provide for individuals with cognitive and physical restrictions (Marcelino *et al.* 2016). Social media applications were streamlined to reduce cognitive stress and memory burden by focusing solely on essential functions (Restyandito *et al.* 2020).

Technologies have been adapted to aid in memory retention and task recall among individuals with dementia and cognitive impairment. For instance, video recordings of activities in immersive environments helped patients with dementia remember their abilities and perform related tasks (Cunha *et al.* 2021). Carers and relatives recommended tailoring technological offers and implementation to different stages of dementia, recognizing that learning and understanding new technologies becomes more challenging as the condition progresses (Casey *et al.* 2020).

5.4.2. Technical infrastructure

Successful system implementation requires an understanding the existing technical infrastructure of housing conditions (Baecker *et al.* 2014). Inadequate infrastructure such as limited Internet and electricity access, can hinder system functionality (Machesney *et al.* 2014). For monitoring systems, power consumption optimization can reduce maintenance requirements (Goh *et al.* 2019). Large data transmission requirements for video calls can result in challenges when implementing online platforms for group conversations, potentially causing connectivity delays (Johansson-Pajala *et al.* 2023). Solutions to address Wi-Fi connectivity issues include wall-mounted devices or displays (Muñoz *et al.* 2015). Ensuring functionality without constant Internet connection was found to be essential for companion robotic systems operating both outside and indoors (Sansen and Torres 2016).

5.4.3. Social environment

The collective experience of technology in group settings can significantly influence user perceptions and motivations. The experience of a group exercise application was described as more enjoyable and motivating when participants were familiar with each other (Nikitina *et al.* 2018; Lundström *et al.* 2021). Conversely, relatives' reluctance or disinterest can discourage older adults from engaging with technology (Neves *et al.* 2018).

Technological interventions to combat loneliness and isolation may inadvertently trigger feelings of shame and embarrassment when used in the presence of others. For example, in a study on robots, participants expressed fear of being observed while interacting with such devices (Coghlan *et al.* 2021), likely because of the social stigma around loneliness. The presence of other residents in a long-term care home environment was also shown to hinder some people from engaging in video communication with relatives (Neves *et al.* 2018).

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5.4.4. *Cultural context*

Understanding cultural diversity is essential for designing inclusive systems. Using symbols instead of text can improve universal comprehension (Baecker *et al.* 2014). Interaction preferences differ across cultures, as observed in the varying levels of comfort with public posting on message boards among different cultural groups (Nikitina *et al.* 2018). Older adults who use ideograms (e.g., Chinese older adults) may encounter specific difficulties with technology owing to the complexity of inputting characters (Gao *et al.* 2012). The popularity of smartphones varies regionally and culturally among older populations (Goh *et al.* 2019). Cultural nuances can also affect usability, as evidenced by differences in the interpretation of gestures such as waving. For example, waving can be interpreted as a gesture to cancel rather than greet in some cultures, which affects feature use (Neves *et al.* 2018).

5.4.5. *Housing environment*

The adoption of a technology can be significantly influenced by an individual's housing environment, particularly with respect to whether older adults share rooms or technological devices are distributed by housing providers. For example, a communication device designed for asynchronous messaging with relatives through a picture frame highlighted the importance of introducing privacy settings, especially in shared spaces, with shared appliances, or when staff assistance is required to interact with the device (Baecker *et al.* 2014). In residential care settings, noise was shown to affect the functionality of voice recognition and interaction (Casey *et al.* 2020). Additionally, the feasibility of implementing a robotic system mounted on an electric wheelchair for mobility may be limited to specific housing environments, such as hospitals or retrofitted homes (Sansen & Torres 2016). The frequency of codes is enlisted in Table 2.

6. Discussion

This scoping review aimed to map current HCD and UCD approaches, considerations of user and stakeholder needs, and contextual influences when developing technologies to address loneliness and social isolation among older adults. Overall, we found that UCD was applied more frequently than HCD. Only three studies followed a specific process model or set of UCD principles. Most studies involved users when gathering requirements, performing iterative testing of designs, and evaluating systems. Previous studies have focused on usability, usefulness, and user experience. Only one UCD study examined loneliness-related measures and how they might be improved through an intervention. The UCD approach included challenges such as participant engagement, technical malfunctions in deployed prototypes, and awareness of ethical considerations.

Accessibility, enjoyment of the application, and privacy and safety were the most considered user needs. Fewer insights have been presented regarding stakeholder needs. Designers must consider how technologies are positioned and how they affect the stakeholders' interaction with others. Contextual factors shown to influence the technology use included health conditions that might impair people's ability to interact with or maintain technologies over

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Table 2. Sources and frequency of found codes

HCD/UCD Considerations	Sources	Frequency
User Needs		
Accessibility	(Gao *et al.* 2012; Marin Mejia 2014; Petersen *et al.* 2014; Alaoui & Lewkowicz 2015; Louiesau *et al.* 2015; Limdumrongnukoon *et al.* 2015; Muñoz *et al.* 2015; Pereira *et al.* 2015; ter Voort *et al.* 2015; Petersen *et al.* 2016; Cook & Winkler 2016; Dos Santos *et al.* 2016; Zhao *et al.* 2016; Aaltonen *et al.* 2017; Ha & Hoang 2017; Goumopoulos *et al.* 2017; Syeda & Kwon 2017; Neves *et al.* 2018; Peng 2018; Baez *et al.* 2019; Goh *et al.* 2019; Isaacson *et al.* 2019; Sunghoon *et al.* 2019; Bravo *et al.* 2020; Meinert *et al.* 2020; Restyandito *et al.* 2020; Lundström *et al.* 2021; Cunha *et al.* 2021; Garcia-Mendez *et al.* 2021; Lundström *et al.* 2021; Mueller *et al.* 2021; Broneder *et al.* 2022; Ghosh *et al.* 2022; Horie *et al.* 2022; Noguchi *et al.* 2022; Yang & Chen 2022)	36
Enjoyment	(Gao *et al.* 2012; Machesney *et al.* 2014; Yamazaki *et al.* 2014; Hsieh 2015; Muñoz *et al.* 2015; Marcelino *et al.* 2016; Davis *et al.* 2017; Nikitina *et al.* 2018; Alaoui & Lewkowicz 2015; Kramer *et al.* 2022; Correia *et al.* 2016; Doppler *et al.* 2016; Antunes *et al.* 2017; Peng 2018; Arlati *et al.* 2019; Onofrio *et al.* 2019; Bravo *et al.* 2020; Chen *et al.* 2020; Huang *et al.* 2020; Coghlan *et al.* 2021; Cunha *et al.* 2021; Garcia-Mendez *et al.* 2021; Lundström *et al.* 2021; Khosla *et al.* 2021; Valtolina & Hu 2021; Broneder *et al.* 2022; Mahmud *et al.* 2022; Demaeght *et al.* 2022; Høeg *et al.* 2023)	28
Privacy and Safety	(Gao *et al.* 2012; Petersen *et al.* 2014; Alaoui & Lewkowicz 2015; Eldib *et al.* 2015; Morgavi 2015; Sansen & Torres 2016; Davis *et al.* 2017; Gaete *et al.* 2017; Goonawardene *et al.* 2017; Aaltonen *et al.* 2017; Ejupi & Menon 2018; Ku 2018; Goh *et al.* 2019; Huang *et al.* 2020; Poulsen *et al.* 2020; Cunha *et al.* 2021; Johnston 2022; Kramer *et al.* 2022; Wilson *et al.* 2022)	19
Control and Independence	(Davis *et al.* 2017; Onofrio *et al.* 2019; Coghlan *et al.* 2021; Mueller *et al.* 2021; Khosla *et al.* 2021; Horie *et al.* 2022; Johnston 2022; Koceska & Koceski 2022; Kramer *et al.* 2022; Villaverde Naveira *et al.* 2022)	10
Help Maintaining Relationships	(Gao *et al.* 2012; Marcelino *et al.* 2016; Zhao *et al.* 2016; Ha & Hoang 2017; Li *et al.* 2018; Mushiba 2018; Onofrio *et al.* 2019; Huang *et al.* 2020; Johansson-Pajala *et al.* 2023)	8
Stakeholder Needs		
Convenience and Positive Interactions	(Baecker *et al.* 2014; Alaoui & Lewkowicz 2015; Ruschin 2015; Davis *et al.* 2017; Aaltonen *et al.* 2017; Neves *et al.* 2018; Ku 2018; Niemelä *et al.* 2021)	8
Design Context		
Health Conditions	(Baecker *et al.* 2014; Machesney *et al.* 2014; Yamazaki *et al.* 2014; Limdumrongnukoon *et al.* 2015; Pereira *et al.* 2015; ter Voort	22

Continued

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Table 2. Continued

HCD/UCD Considerations	Sources	Frequency
	et al. 2015; Marcelino *et al.* 2016; Santos *et al.* 2016; Aaltonen *et al.* 2017; Ha & Hoang 2017; Goumopoulos *et al.* 2017; Martinez *et al.* 2017; Neves *et al.* 2018; Graf *et al.* 2020; Isaacson *et al.* 2019; Sunghoon *et al.* 2019; Restyandito *et al.* 2020; Casey *et al.* 2020; Cunha *et al.* 2021; Lundström *et al.* 2021; Mackey *et al.* 2022; Broneder *et al.* 2022).	
Technical Infrastructure	(Baecker *et al.* 2014; Machesney *et al.* 2014; Muñoz *et al.* 2015; Cook & Winkler 2016; Sansen & Torres 2016; Goh *et al.* 2019; Johansson-Pajala *et al.* 2023)	7
Cultural Context	(Baecker *et al.* 2014; Nikitina *et al.* 2018; Gao *et al.* 2012; Goh *et al.* 2019; Neves *et al.* 2018)	5
Social Environment	(Neves *et al.* 2018; Nikitina *et al.* 2018; Coghlan *et al.* 2021; Lundström *et al.* 2021)	4
Housing Environment	(Baecker *et al.* 2014; Casey *et al.* 2020; Sansen & Torres 2016).	3

time and cultural differences in communicative preferences and interpretations. Moreover, the social environment can significantly impact older adults' motivation to use these technologies. If their housing environment provides shared devices or spaces, it could lead to special system requirements to maintain older adults' privacy. The Internet connectivity some technologies require could also represent a barrier.

Our findings align with previous insights indicating that UCD approaches are more common than HCD approaches in the healthcare context (Göttgens & Oertelt-Prigione 2021). While previous research found that those who applied UCD mainly involved users as "testers" and HCD approaches more frequently incorporated them as partners (Göttgens & Oertelt-Prigione 2021), we observed that many UCD studies involved users and stakeholders in the initial development of requirements obtained feedback from users throughout an iterative design process. Previous research also noted that deployment was rare in healthcare interventions (Altman *et al.* 2018). However, we observed that the applications developed were often implemented and tested in field studies. Previous studies also noted the limitations of more quantitative approaches and larger samples in applying HCD (Altman *et al.* 2018), and we found some evidence of studies that attempted to implement a mixed method approach or use larger sample sizes. Methods for UCD confirmed previous insights, including iterative design, field studies, usability evaluation, focus groups, interviews, questionnaires, expert testing, and heuristic evaluation, as well as requirement analysis, contextual inquiry, and participatory methods (Vredenburg *et al.* 2002; Sanders & Stappers 2008). Additional methods involved literature reviews and desk-based research such as designers gathering information from previous design studies.

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Only one study adopted an HCD approach. HCD also involves considering ethics and wider contextual circumstances. Questions remain related to health equity, social justice, and whether technologies are inclusive of people with different socioeconomical statuses (Holeman & Kane 2020). We found little consideration of participants' socioeconomic status in the retrieved UCD studies. Future systems to address loneliness and isolation in older adults should explore how their technologies suit people with different socioeconomic circumstances and their individual needs (Goumopoulos *et al.* 2017). For example, people in affordable housing programs can face problems with affordable Internet and telephone access (Ellison-Barnes *et al.* 2021). Training in technology use has become particularly important in this context (Ellison-Barnes *et al.* 2021). Approaches that extend or build on HCD also incorporate qualities beyond basic needs that have not been addressed, such as "self-actualization", "empowerment" and "purpose" (Seshadri *et al.* 2019; Desmet & Fokkinga 2020). Currently autonomy and control are considered important user needs in the retrieved papers. However, there is little active agency required by older adults in the development and use process of technologies. Thus, it is important to reflect on people's strengths and how technologies suit their purposes for self-growth.

Alternative design perspectives move beyond a user-centric focus. Universal design strives to achieve solutions that suit all people at any stage in their lives. The removal of barriers for diverse people provides inclusivity and usability to the majority (Herwig 2012, p.17–18; Coleman *et al.* 2003). This approach is less prone to stigmatization and presumptions (Herwig 2012, p.23), whereas the focus on specific user groups in HCD and UCD might lead to better acceptance and adoption among members of the intended group. Universal design can mean wheelchair accessibility in public spaces and transportation (Steinfeld 2001, p.19.1) or an increase in font sizes in mobile apps for better readability (Herwig 2012, p.16). Further research could explore similarities across demographic groups and outlier cases in technologies developed for loneliness among older adults. Life-centered design extends to a non-anthropocentric scope beyond direct users to society and other life forms, including design considerations for animals and the natural environment (Borthwick *et al.* 2022). Examples can range from considering more sustainable building materials (Van Der Ryn & Cowan 1996) to creating animal habitats in housing design (Keune 2021; Borthwick *et al.* 2022). Further research could reflect on long-term global, environmental, and societal effects of the technologies developed to address loneliness in older people. Practical case studies could show hoe these considerations become applicable in the technology design. Questions could also involve the material longevity, estimated maintenance costs, funding sources, and technical support requirements (Grey *et al.* 2024; Pradhan *et al.* 2021).

Regarding the observed design considerations, some of the factors aligned with ethical and user considerations emphasized in previous related systematic reviews. A commonly mentioned factor was privacy and control of information sharing (Liu *et al.* 2019; Corbett *et al.* 2021; Chan *et al.* 2022; Qirtas *et al.* 2022). Previous reviews also have also highlighted the need to provide technological training to older adults to improve accessibility (Balki *et al.* 2022). The aesthetics of social robotic systems was noted as important for their acceptance (Søraa *et al.* 2023). However, little discussion has taken place on why technologies can lead to negative feelings and the necessity for an engaging experience. The developed systems can

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serve as an unwanted reminder to users of their loneliness (Barbosa Neves *et al.* 2023). Being mentally occupied with more positive thoughts can be the key to not feeling lonely (Ratcliffe *et al.* 2023). Therefore, a regular reminder of one's loneliness may be particularly problematic. There were also risks of eliciting feelings of stigmatization and patronization (Yusif *et al.* 2016). People's ability to interact with a technology may affect their feelings of self-worth (Wilson 2022). Designers of such systems must be aware of how using these technologies could elicit negative emotional responses. "Enjoyment" was a commonly identified factor in successful interventions, which further underlines the need to develop systems that do not elicit negative feelings.

Few systematic reviews have reported on the contextual influences affecting technological functioning. Some studies addressed the need for cultural sensitivity in interactions with voice recognition systems to better understand non-native speakers (Corbett *et al.* 2021) as well as the need to adapt systems for different health conditions (Liu *et al.* 2019). One contextual factor that we would further emphasize is differences in forms of housing. For example, residential care facilities can be characterized as a combination of private and public areas, raising questions over who decides on the technologies positioned in shared spaces and how data are used (Courtney 2008). Additional contextual aspects to consider include the long-term implementation and development of technologies over time (Galvez-Hernandez *et al.* 2022) and critical attitudes toward technology (Jiang *et al.* 2022).

Only a few of the included studies reported on stakeholder considerations. To ensure the usefulness of communication technologies, family members must remain engaged. Thus, their needs should be considered in the application design. While the reviewed technologies were found to emphasize younger relatives, previous work also noted the consideration of older carer's wellbeing and their interaction with the technology (Garnett *et al.* 2022). In addition, more recent literature noted how technologies could risk create family tensions due to different communication preferences and issues could also arise in peer-to-peer networks if some people had a more difficult character (Barbosa Neves *et al.* 2023).

6.1. Future recommendations

We recommend future studies implementing UCD and HCD in technologies for tackling loneliness and isolation in older adults use statistical measures and qualitative lines of inquiry about loneliness in their prototype evaluations. Only one UCD study was found to measure perceived loneliness as a way to understand the intervention effectiveness (Davis *et al.* 2017). Whether participants have experienced loneliness and social isolation will affect what they might perceive as beneficial compared to people that have never experienced loneliness. Thus, it should be considered an inclusion criterion or relevant contextual information. More vulnerable user groups who might face socioeconomic restrictions are also important to involve when creating applications meant to serve more diverse populations and their needs. Further reporting on the needs of diverse stakeholders is also important to inform future studies on UCD and HCD.

We also identified potential improvements in reporting UCD and HCD studies on technologies developed to address loneliness and social isolation in older adults. Currently, nine out of twelve studies that applied UCD in this context did not explicitly mention the methodological basis of a process model or set of design

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principles to guide their design process. Reporting such models and how they influenced the design process could help provide a better understanding of the impact of the method on the process and outcome and allow for comparisons across different studies. More detailed reporting could also be provided on the complex methodological process, iterations, and challenges to inform future methodological advancements in design research. While researchers were aware of the principle of applying multidisciplinary teams in the UCD process (Goumopoulos *et al.* 2017), only one study explicitly mentioned an interdisciplinary team (Ghosh *et al.* 2022). Multidisciplinary teams are necessary to address the different aspects of a developed system (Gulliksen *et al.* 2003). We recommend that future studies report on team composition and how that becomes relevant to the UCD process.

Further emerging topics move beyond user and stakeholder needs or contextual influences. The rapid evolution of technologies requires adaptation of the legal framework for liability for mental health technologies (Keyur 2024). In addition, a high level of resource expenditure must be expected. For example, healthcare staff would need to gain knowledge on the implemented technological devices, enabling them to effectively explain systems to patients (Keyur 2024). To help providers select suitable services, the real impact of services and technologies require a formal evaluation (Grey *et al.* 2024). Individual user attitudes can play an important role in their willingness to adopt technology. A better understanding of users' individual concerns (such as privacy concerns, or a wish for greater usefulness) could inform the marketing of the technology and potentially lead to a more positive attitude of users towards new healthcare technologies (Zhang *et al.* 2014).

6.2. Limitations

A wide-reaching scoping review has been conducted, yet we mainly focused on technologies that aimed to address loneliness and social isolation. Technological developments focused on related topics, such as strengthening relationships and communities, but without explicitly stating loneliness or social isolation, could have been missed. This review only focused on the literature until the beginning of 2023, and new work has appeared since then. The use of a scoping review does not involve rating the quality of the included studies or evaluating the relative efficacy of the different systems identified. Nevertheless, employing this method allowed us to provide an extensive summary of design considerations vital to the production of technology meant to address loneliness among older adults.

7. Conclusion

We investigated the HCD and UCD approaches, human needs and contextual considerations found in technologies developed to address loneliness and social isolation in older adults. The strengths of current UCD research include the wide implementation of field studies, mixed-method approaches, and user involvement throughout the development and evaluation of the systems. However, current studies could improve the reporting of the methodological approach and measures related to loneliness. Common needs include accessibility, enjoyable interactions, and systems adapted for diverse health conditions. Our findings align with previous literature on the need for privacy, autonomy, and control. We add that

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technology can elicit negative memories and emotions or remind older adults of difficult relationships or health circumstances. We recommend that future research provide more insight into different stakeholder needs, as they play an important role in the acceptance and implementation of these systems. The understanding of how different housing environments can affect the feasibility of different technologies is also limited. Finally, we recommend that designers of future systems incorporate questions about greater health equity and older adults' strengths for self-realization.

Supplementary material

The supplementary material for this article can be found at http://doi.org/10.1017/dsj.2024.22.

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Competing interest

The authors declare none.

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