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The Deployment and Use of Social Robots for Home-Based Healthcare: a Systematic Review of Enablers and Barriers

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Abstract

Given the increasing challenges in today's healthcare landscape, the role of health promotion and care delivery in home settings is gaining importance. Social robots have emerged as promising tools to support this shift, offering assistance, motivation, and companionship to patients and caregivers. However, their integration into home-based healthcare remains limited. To understand the underlying reasons, this study systematically reviews the literature, identifying the enablers and barriers to the deployment and use of social robots in home environments. Seven electronic databases (Medline, Embase, Web of Science, CINAHL, PsycINFO, Scopus, and Google Scholar) were searched in June 2023 and July 2024. After screening and eligibility assessment, 39 studies, involving actual human-robot interaction and conducted in real home environments, were included and appraised using the Mixed Methods Appraisal Tool. Data extracted from these studies were synthesized thematically. The results show that all studies were conducted in high-income countries, with most focusing on older adults and employing high-cost, anthropomorphic robots that were rarely co-designed with users. The findings suggest that the deployment and use of social robots are shaped by an interplay of the characteristics of interaction, context, robot, and user. They also point to a lack of holistic consideration of these characteristics, limited attention to ethical and legal aspects, and insufficient stakeholder inclusion in current design and implementation practices. To address these limitations, future research may benefit from ecological, participatory, speculative, and performative design approaches that support the development of more inclusive, adaptive, and ethical social robots for home-based healthcare.

Keywords Social robots · Health promotion · Care delivery · Home · Enablers · Barriers

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1 Introduction

Demographic shifts and the rising prevalence of chronic conditions are placing significant strain on healthcare systems, affecting workforce capacity, infrastructure, and financial resources [1, 2]. In response, patients' daily living environments are increasingly seen as viable settings for health promotion and care delivery, a concept known as home-based healthcare [3]. This concept encompasses not only the provision of medical services and treatments, but also activities aimed at encouraging healthy behaviors and lifestyles, such as dietary guidance, physical activity promotion, assistance with activities of daily living (ADLs), and emotional support. As such, it offers multiple benefits, including reduced healthcare costs, expanded access to essential services, and improved quality of life [3–5]. However, realizing these benefits requires reconfiguring care practices, roles, and responsibilities, for example, by allowing patients to manage their own health, increasing informal caregiver involvement, and reducing the frequency of in-person visits by formal healthcare staff through remote sessions [6]. Such reconfigurations, therefore, point to the critical role of systems and tools in supporting home-based care.

One example of such systems and tools is social robots, which can provide assistance with ADLs, cognitive and physical stimulation, and companionship to patients, while reducing the burden on caregivers through remote monitoring and taking over tasks [7]. These robots are usually characterized by human- or animal-like (i.e., bio-inspired) appearances, behaviors, interaction styles, and/or social abilities, although some adopt functional or artifact-like designs [8, 9]. Consequently, technological sophistication and capabilities across social robots vary. For instance, The Greeting Machine by Anderson-Bashan et al. [10] features a minimalistic, non-bio-inspired appearance and relies on simple gestures to encourage social interaction, whereas Pepper by Softbank Robotics [11] can engage in conversations in natural language, recognize emotions, learn from users and their environment, provide entertainment, and perform tasks like object retrieval. These variations, in turn, affect the cost of these robots and how users perceive and interact with them [12–14], potentially enhancing or limiting their ability to support home-based healthcare.

Besides their design, their deployment process may also impact the capacity of social robots to contribute to home-based healthcare. Usually, even before a robot enters the home, users form expectations about it, which can influence their initial willingness to adopt and interact with it [15]. Subsequently, if deployment becomes successful, users can gradually learn about the robot through interaction, which may eventually lead to acceptance and adoption [16]. Over time, this adoption can result in the robot becoming incorporated into the user's daily life, characterized by functional dependency and the development of usage routines [16–18]. Thus, the point at which a robot becomes embedded in users' daily routines is where its potential to support home-based healthcare can be fully realized, as continuous usage is necessary to sustain behavior change, ensure adherence to care plans, and address users' evolving health needs linked to their chronic and complex health conditions [7].

However, achieving this level of dependency and routine use is challenging, as numerous factors throughout the deployment process can hinder sustained usage of social robots. The context in which a robot is deployed further compounds these challenges since homes are intimate, social, and dynamic settings [19]. Users in these environments prioritize privacy and safety, often expressing a strong desire to maintain control over their interactions with robots [20]. The presence of cohabitants, such as family members or visitors, can also inflict social influence on users, shaping their encounters with robots in unpredictable ways [20]. Moreover, the constantly changing conditions in homes, such as variations in furniture arrangements, noise, or the presence of others, can impact robots' consistent functioning and their incorporation into daily practices. An overview of all relevant factors is therefore necessary to facilitate the design and deployment of social robots that can effectively support home-based healthcare.

2 Related Work

The factors influencing the (continuous) use of a product, technology, or (social) robot have been explored across multiple domains, including user–product interaction [21, 22], technology acceptance [23, 24], care robot acceptance [12, 25, 26] and domestic robot acceptance [15, 18, 27–32]. Collectively, these studies offer valuable insights into how users perceive robots from both utilitarian and hedonistic perspectives, identifying how this perception is shaped by users' backgrounds, beliefs, skills, as well as the robots' design features such as appearance, and social norms [12, 15, 23–27, 29, 31, 32]. Beyond these factors, legal, ethical, and privacy concerns have been associated with users' intentions to adopt home healthcare robots [27]. Additionally, several studies have established the importance of the social, cultural, economic, and temporal context surrounding users and robots for robot use and adoption [18, 21, 22, 28, 30]. However, no single study provided an overview of the factors relevant to social robots supporting home-based healthcare.

Although prior reviews have investigated the determinants of robot implementation and use in healthcare, this

investigation has been mostly restricted to healthcare contexts other than home, specific robot subtypes, or certain populations. Notably, Huang et al. [33] summarized the antecedents and consequences of intelligent robot use in various healthcare settings, taking a broader perspective. Papadopoulos et al. [1] identified enablers and barriers to the implementation of humanoid social robots in health and social care, which encompassed not only home settings but also research and healthcare institutions. Similarly, Guemghar et al. [34], Koh et al. [35], and Felding et al. [36] focused on the barriers and facilitators of social robot applications and implementation within specific domains, such as mental health care and the care of older adults and people with dementia (PwD). Felding et al. [36] classified these barriers and facilitators according to the "Almere Model" [37], which was developed to predict the factors determining the acceptance of social agents by elderly users. Additionally, Ghafurian et al. [38], Kachouie et al. [39], and Pennisi et al. [40] conducted literature reviews on the effectiveness of social robots for specific populations, including older adults, PwD, and individuals with autism spectrum disorder (ASD). However, to our knowledge, no systematic review has investigated social robots that support home-based healthcare, focusing on the factors that facilitate or hinder their deployment and use across different populations and robot types.

To address this research gap, this study systematically reviews empirical research on social robots designed for health promotion and care delivery in home settings. It focuses specifically on studies that examine actual human–robot interaction (HRI) within real homes, excluding research conducted prior to robot design or in controlled laboratory environments. By analyzing evidence from real-world interactions, the review aims to describe the prevailing characteristics of deployed robots and the populations they serve, and to identify the key factors that facilitate or hinder their deployment and use in home-based healthcare. By considering the implications of these factors, the review attempts to offer insights that may support the design and development of social robots for health promotion and care delivery in domestic environments.

3 Methods

This systematic review was conducted and reported following the guidelines by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [41]. The completed PRISMA checklist is provided in Online Resource 1. A research protocol for this review was registered with the International Prospective Register of Systematic Reviews (PROSPERO, ID number: CRD42023432674).

3.1 Search Process

To retrieve empirical studies on healthcare-oriented HRI conducted in home settings, we performed an initial systematic search on June 1, 2023. This search was conducted across seven electronic databases that provide comprehensive collections of medically oriented research articles: Medline, Embase, Web of Science, CINAHL (Cumulative Index to Nursing and Allied Health Literature) via EBSCOhost, PsycINFO via Ovid, Scopus, and Google Scholar. For this search, we used keywords such as "robot," "health," "care," and "home." We deliberately omitted more specific terms such as "barriers," "enablers," "factors," "use," "deployment," or "implementation" to avoid overly narrowing the search results. However, we included terms that describe social robots, such as "personality," "interactive," and "social," to enhance the relevance of the search while excluding unrelated robotic technologies. The search terms and operators (e.g., AND, OR, asterisk (*)) used were tailored to meet the specific requirements of each database. We also applied built-in filters for each database to limit our search to English-language articles. No filters were applied regarding publication date to ensure comprehensive coverage. On 18 July 2024, we updated the database search using the same search strategy with a date filter of 2023 to present. This follow-up search aimed to ensure the inclusion of recently published studies. Details of the searches are provided in Online Resource 2.

3.2 Study Selection

The search results were imported into Rayyan software [42], which automatically removed duplicates. Using Rayyan's blind mode, two reviewers (EK and JMC) independently evaluated the titles and abstracts of the articles against the predefined inclusion and exclusion criteria. These criteria reflected our aim to identify empirical studies of any design that involved actual interactions with healthcare-oriented social robots in real home environments, while limiting the selection to peer-reviewed journal articles to ensure a baseline level of quality and academic rigor. For example, we would include studies involving a robot facilitating the communication between PwD and family or supporting children with attention deficit hyperactivity disorder (ADHD) in daily tasks. In contrast, studies with robots for entertainment (e.g., robot toys) or for educational purposes unrelated to clinical, wellbeing, functional independence or rehabilitation objectives (e.g., homework assistance robots for children) were excluded. The complete list of inclusion and exclusion criteria can be found in Online Resource 3.

After completing the independent assessments, the reviewers compared their decisions and reached a consensus

on which studies to include. Full texts of the included articles were then retrieved and uploaded into Zotero 6.0.19 for a second round of independent screening using the same criteria. Any disagreements at either stage were resolved through discussion.

3.3 Quality Assessment

The methodological quality of the included articles was assessed by one researcher (EK) and cross-checked by another (JMC), with disagreements being resolved through discussion. The Mixed Methods Appraisal Tool (MMAT, version 2018) [43] was chosen for this assessment due to its suitability across various study designs. Each study was evaluated against five criteria relevant to its design. For instance, randomized controlled trials (RCTs) were assessed for appropriate randomization, baseline group comparability, completeness of outcome data, blinding of outcome assessment, and adherence to the assigned intervention. For qualitative studies, the criteria were related to the appropriateness of the approach, adequacy of data collection and analysis methods, substantiation of results with data, and coherence between data sources, collection, analysis, and interpretation. Each criterion was rated as "yes," "no," or "can't tell," and the proportion of criteria rated as "yes" was calculated to quantify the methodological quality [43].

3.4 Data Extraction

One researcher (EK) extracted data from the final set of selected studies using a Microsoft® Excel® (Version 2409) table developed in advance for data extraction. The data extraction table template is provided in Online Resource 4. To ensure accuracy, a second researcher (JMC) randomly selected 20% of the studies and reviewed the data extracted from these studies. Data extraction focused on study findings and study, participant, and robot characteristics. Since not all studies explicitly reported enablers and barriers to the use and deployment of social robots, such data were extracted based on predefined criteria: enablers were identified as factors that facilitate or encourage the deployment or (continued) use of social robots at home, while barriers were defined as factors that hinder or prevent the deployment or (continued) use of social robots, or lead to dropouts in the studies.

Study characteristics collected included author(s), title, year of publication, country, aim, study design, data collection and analysis methods, outcome measures (e.g., acceptance, usability), duration of data collection, setting/context, and main findings regarding enablers and barriers reported in Results and Discussion sections. Participant characteristics encompassed sample size, age, gender, medical condition, ethnicity, level of education, technology literacy, socioeconomic status, and pet ownership, where relevant. Robot characteristics included the robot's name/model, manufacturer, dimensions and weight, embodiment, capabilities, mode of interaction, components, price, and whether it was co-designed with users.

3.5 Data Synthesis

Data extracted on study, participant, and robot characteristics were narratively summarized and organized into three separate tables. To synthesize data regarding enablers and barriers, we followed an inductive thematic approach inspired by [44] rather than a quantitative approach, given the inclusion of varying study designs. For each study, the main findings regarding enablers and barriers were transferred from the data extraction table to an individual Microsoft® Word® document. All documents were then imported into ATLAS.ti (version 23.2.3.27778).

In each document, one researcher (EK) went through each line of text, assigning codes that reflected the specific meaning or idea expressed in that line (i.e., open coding [45]). For example, the finding *"Subjects B and D's family members commented that they were less interested in Paro because they preferred to play with dogs at home than Paro."* [46] was given the code "Pet ownership". This initial round of coding generated 140 codes. These codes were subsequently reviewed with all co-authors, resulting in revisions and the merging of some codes. As a next step, the researcher reviewed the adjusted codes to identify overlaps, recurrent ideas, and conceptual connections. Individual codes that described similar phenomena were grouped together to form categories. For instance, the codes "energy usage" and "limited robustness" were combined to create the category "poor robot performance."

After further discussion with co-authors, categories were organized into 16 subdomains, which were then consolidated into four domains. For instance, the subdomain "perception of the robot" was created since a cluster of categories referred to the perceptual processes users experience while interacting with a robot (e.g., exploring and evaluating its attributes). Other subdomains highlighted related aspects of user-robot interaction, such as the cognitive and emotional processes users go through (e.g., making comparisons and reacting), as well as the temporal patterns of interaction. Consequently, these subdomains were categorized under the domain "Interaction", which encompassed all facets of a user's experience while interacting with a robot. The subdomains and domains were finalized following a last round of discussion. An example showcasing our coding process and the codebook is provided in Online Resource 5.

During the synthesis, we often encountered text segments that touched on several ideas at once. These instances often revealed potential interrelations, both within and across subdomains and domains. For example, the following excerpt illustrates this overlap: *"Eight participants appeared to be completely disconnected from their family members at the time of the interview. They reported that their social isolation was exacerbated by the COVID pandemic. All participants reported feeling less lonely and/or bored, because Hyodol made them talk, serving as 'tickets to talk.' […] Another participant stated that they treat it like a human being, and without it they would be depressed"* [47].

This excerpt pointed simultaneously to categories "COVID-19," "low level of social connectedness & independence," "perceived utility," "positive response," and "anthropomorphism." It also allowed us to infer possible links between these subdomains: for instance, situational factors such as the COVID-19 pandemic may influence a person's social positioning and self-concept, which in turn may shape how beneficial they perceive a robot to be and how positively they respond to it. Additionally, anthropomorphizing the robot may further amplify these effects. Noticing these connections allowed us to consider subdomains and domains in relation to one another rather than as separate categories. In the subsequent section, we introduce each domain and subdomain separately for clarity, while also summarizing the key relationships identified among them.

4 Results

A total of 7897 articles were retrieved from two searches conducted on 1 June 2023 and 18 July 2024. After removing duplicates, the title and abstract of 4244 articles were screened. Of those, 155 articles were deemed eligible for full-text screening. Following exclusions based on intervention, study, or reporting criteria, 39 articles were included in the final analysis (Fig. 1).

4.1 Quality Appraisal of the Included Studies

Among 39 included articles, 21 [46, 48–67] employed a mixed-methods design, eight [47, 68–73] were qualitative, five [74–78] were RCTs, two [79, 80] were quantitative non-randomized, and three [81–83] were quantitative descriptive studies. According to the methodological quality assessment, the majority of studies ($n=30$) [46–48, 50, 52, 54–56, 59, 60, 62, 63, 65–74, 76, 78–84] met three or more of the quality criteria relevant to their specific categories, indicating a generally satisfactory level of methodological rigor across the articles. However, there were still concerns regarding the risk of bias.

In the mixed-method and quantitative descriptive studies, concerns arose about the risk of non-response bias, as these studies did not report the number of nonrespondents or the reasons for non-response. Additionally, eight of the mixed-method studies [51, 53–55, 57, 58, 61, 64], the integration of the quantitative and qualitative results was insufficient, with some failing to address potential discrepancies. In the quantitative non-randomized studies, concerns were related to confounding bias, selection bias (e.g., recruitment of only tech-savvy older adults), and deviations in intervention administration. Among the RCTs, two [76, 77] lacked information on the randomization process, and nearly all ($n=4$) [74–77] exhibited ambiguity regarding whether the outcome assessors were blinded to the intervention. All studies with a qualitative design were of high quality, satisfying all the assessment criteria. Online Resource 6 provides a complete overview of the quality assessment.

4.2 Details of the Included Studies

The following subsections provide detailed information on the characteristics of the included studies, the participants of these studies, and the robots involved.

4.2.1 Study Characteristics

Almost all studies were conducted in high-income industrialized countries, with the exception of two that took place in China [56, 65].[1] Geographically, the majority of studies were carried out in Europe ($n=15$) [48–51, 58–60, 66, 69, 71–73, 79, 82, 83] and Eastern Asia ($n=14$) [46, 47, 53, 55, 56, 61, 62, 64, 65, 76–78, 80, 81]. Notably, four studies [48, 49, 79, 82] were conducted across multiple countries as part of European Union-funded research projects.

All studies were published between 2007 and 2024, with majority ($n=31$) being after 2019 [47, 49, 50, 52–56, 58–68, 70–73, 75, 77–82, 84]. Additionally, six studies reported a two-phase design, such as conducting experiments in different settings (e.g., lab and home) [61, 66], running a pilot study or focus group before or after the main study [55, 57, 62], or testing initial and updated versions of a prototype in consecutive studies [60]. Lastly, five studies [49, 56, 70, 72, 79] were conducted in settings other than or beside private homes, namely supported living units, where individuals reside in self-contained flats within a facility and receive professional care. For consistency, these settings are collectively referred to as *homes* throughout this article. Table 1 summarizes the main characteristics of the included studies,

[1] To report this information, we drew on the United Nations' country classification by stage of industrial development [135].

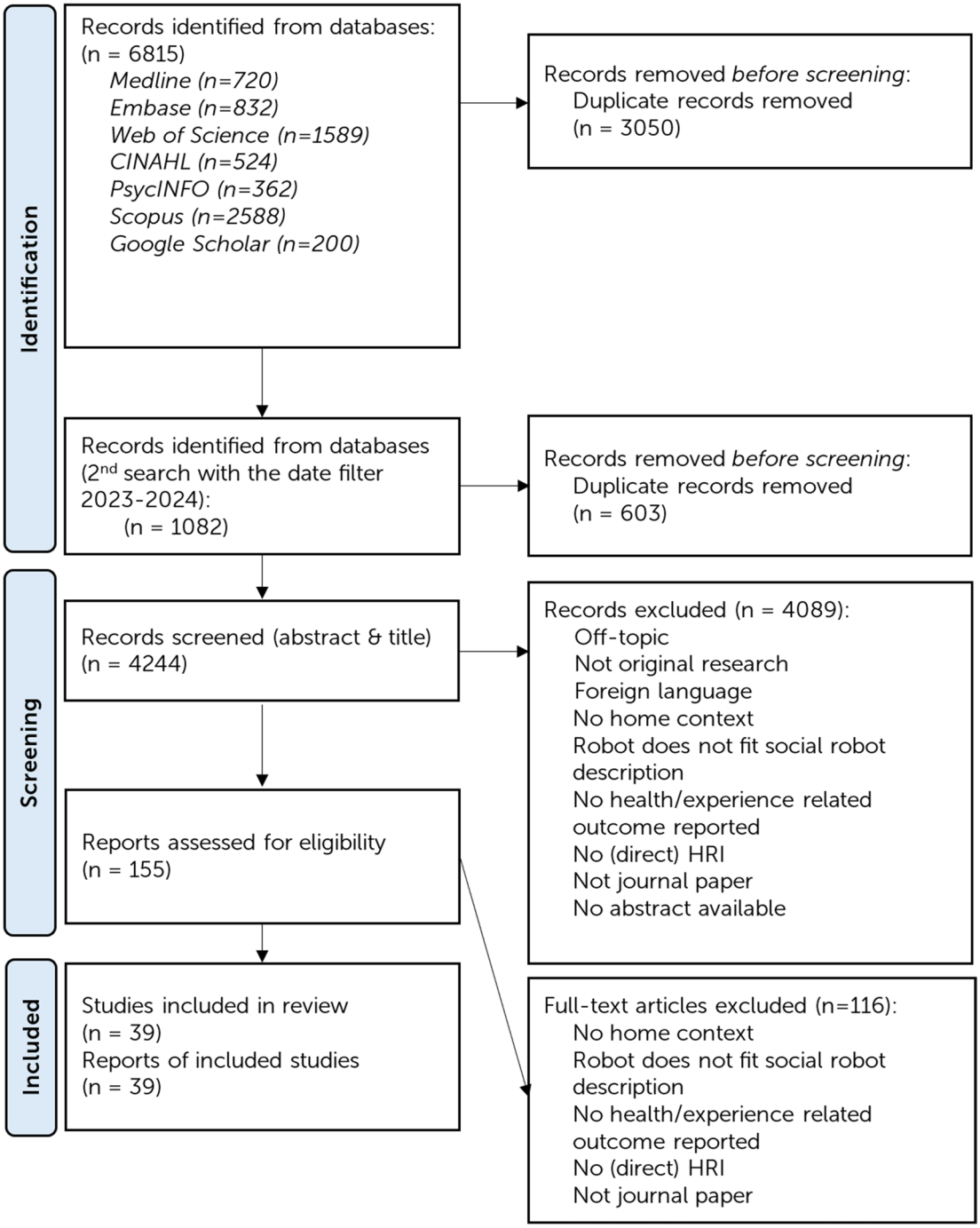

Fig. 1 PRISMA flowchart

while Online Resource 7 presents the complete details regarding these studies.

4.2.2 Participant Characteristics

The number of participants across studies varied widely, ranging from 1 to 220, due to the inclusion of both case studies and RCTs. Participant ages spanned from 18 to 98 years. On average, two-thirds of the participants across all studies were women; however, four studies [54, 72, 79, 82] did not report gender information. With the exception of one study that recruited university students living with family or roommates [68] and another that included younger individuals with executive dysfunction and their formal caregivers [59], all studies ($n=37$) [46–58, 60–67,

Table 1 Main characteristics of the included studies

Country	nr. of studies (n)
Japan	8
USA	5
South Korea	4
Italy	3
New Zealand	2
United Kingdom	2
Italy and Spain	2
China	2
The Netherlands	1
Poland, Greece, UK	1
Hungary	1
Germany	1
Israel	1
Norway	1
Australia	1
Belgium	1
Canada	1
Finland	1
Austria, Greece, Sweden	1

Year (range)	nr. of studies (n)
2020-2024	31
2015-2019	6
2010-2014	1
2005-2009	1

Setting	nr. of studies (n)
Private home	34
Supported living unit	5

69–84] focused on older adults aged 50 years or above. Five of these studies [48, 49, 53, 63, 74] also included informal caregivers, and two [60, 72] involved both informal and formal caregivers as secondary participants.

Among the studies involving older adults, 26 studies reported participant characteristics such as education, socioeconomic status, pet ownership and/or prior technology experience. 11 studies [58, 60–63, 66, 67, 69, 75, 78, 83] included participants from high-income countries with relatively high educational attainment (i.e., secondary education or above). Although four studies [55, 56, 65, 77] involved participants with lower levels of formal education, they were still from high- or upper-middle-income countries. Participants of three studies had a low socioeconomic status [47, 55, 57], and of two studies had previously owned pets [46, 84]. In six studies [48, 49, 58, 60, 61], participants had some technology experience through the use of smartphones, tablets, or computers. Participants in seven studies [50–52, 66, 72, 80, 83] had little or no prior technology experience.

Across 36 studies, further information regarding participants' living situation and/or health status was provided. In most studies ($n=16$) [47, 48, 52, 55, 56, 58, 62, 65, 69, 73, 76, 79, 80, 82–84], older adults were living alone. In eight studies [48, 53, 54, 63, 70, 71, 81, 84], participants lived with family, partners, roommates, and/or pets. 13 studies [46, 49, 50, 53, 58, 62, 63, 66, 71, 72, 74, 77, 78] included individuals with varying levels of cognitive impairment, nine [52, 60, 61, 64, 65, 67–69, 76, 80] involved healthy individuals, seven [47, 54, 55, 73, 75, 81, 83] involved those with multimorbidity, and three [51, 56, 70] involved mixed groups of healthy and multimorbid participants. Other conditions reported included frailty [79], loneliness [84], major depressive disorder [57], and physical impairments [48]. Table 2 provides an overview of the main participant characteristics, with full details available in Online Resource 7.

4.2.3 Robot & Intervention Characteristics

The robots included in this review highlight diverse characteristics and functionalities tailored to various assistive and therapeutic needs. The robots in the majority of the included studies ($n=35$) had a *bio-inspired* [8] appearance, 20 of which were human-inspired [47–50, 52, 54–56, 60–62, 65–67, 76–78, 80, 81, 83], 13 were animal-inspired [46, 51, 53, 57, 63, 64, 68–71, 74, 75, 84], and two had a mix of human- and object-like characteristics (i.e., flowerpot with a face) [59, 72]. The remaining four robots were mainly functional-looking, yet some incorporated human-inspired elements such as a virtual face [58, 73, 79, 82]. Figure 2 depicts the physical appearances of the robots featured in the studies included, except for those in [63, 65], and [73], as the exact models of the robots used in these studies could not be identified.

Table 2 Main characteristics of the participants across included studies

Sample size (range)	nr. of studies (n)
1-20	27
21-40	4
41-60	4
61-80	-
81-100	1
101-120	1
121-140	-
141-160	-
161-180	-
181-200	1
201-220	1

% of female participants (range)	nr. of studies (n)
10-20	1
21-30	-
31-40	2
41-50	5
51-60	5
61-70	6
71-80	5
81-90	4
91-100	6
Not reported	5

Education level	nr. of studies (n)
High (secondary education or above)	12
Low	4
Not reported	23

Prior technology experience	nr. of studies (n)
Prior technology experience	6
Little to no prior experience	7
Not reported	26

Mean age (range)	nr. of studies (n)
20-29	1
30-39	-
40-49	1
50-59	-
60-69	2
70-79	22
80-89	12
Not reported	1

Health status	nr. of studies (n)
Individuals with cognitive impairments	13
Healthy individuals	10
Multimorbid patients	7
Healthy & multimorbid patients	3
Frail older adults	1
Lonely older adults	1
Individuals with major depressive disorder	1
Individuals with physical impairments	1
Individuals with executive dysfunction	1
Not reported	1

Living situation	nr. of studies (n)
Living alone	16
Living with family, roommates, and/or pets	9
Not reported	14

Prior pet ownership (Y/N)	nr. of studies (n)
Yes	2
Not reported	37

Socioeconomic status	nr. of studies (n)
Low	3
Not reported	36

Human-inspired and functional robots were generally larger and multifunctional, designed to support ADLs, offer companionship and cognitive stimulation, and provide health coaching. These robots featured advanced functionalities, including autonomous navigation, speech recognition and generation, human and object detection, emergency handling, activity monitoring, and reminders. They interacted with users through speech, written messages, and facial expressions, supported by integrated components such as cameras, microphones, speakers, various sensors, touch screens, and, in some cases, robotic arms or manipulators. Their purchase price was typically high, averaging around $ 7,500. In contrast, animal-inspired robots were usually small, resembling stuffed toys, and responsive to touch, incorporating animal-like sounds and movements. With these qualities, they aimed to provide comfort and companionship. Their purchase price generally ranged between $ 100 and $ 150, except for PARO, which was significantly more expensive at around $ 6,000 [91]. Robots with a hybrid appearance were typically small and stationary, focusing on assisting with ADLs through vocal reminders and messages. Their price was around € 1,500. Notably, six robots with human-inspired or hybrid appearance were part of a system of ambient sensors, user and caregiver apps, and, in some cases, smart objects [49, 50, 60, 72, 79, 82].

The majority of these robots ($n=27$) were not co-designed with the target users in the studies. Instead, they were either off-the-shelf robots from companies that develop

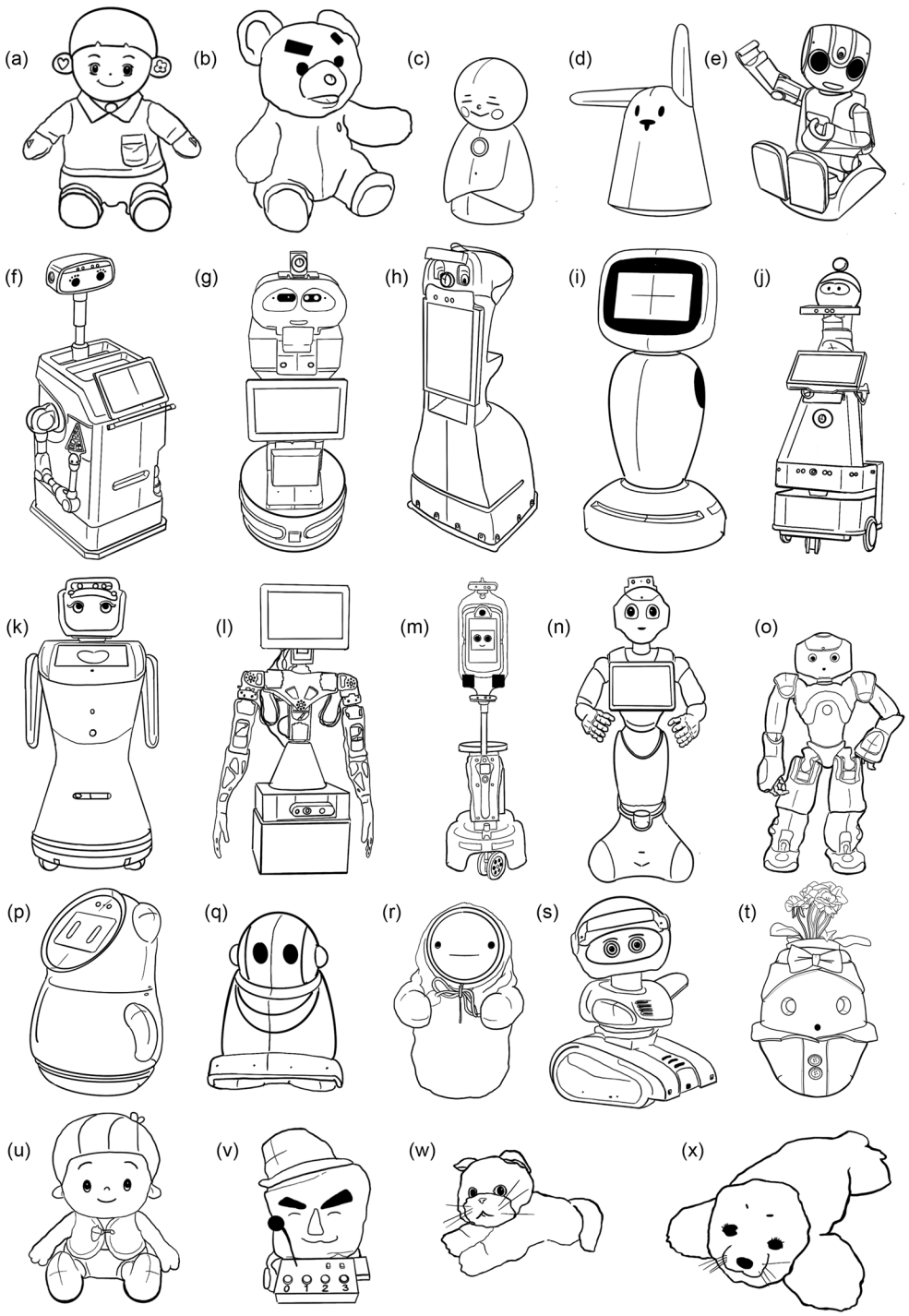

Fig. 2 Physical appearances of social robots used in home-based healthcare, identified from left to right as: (**a**) Hydodol (Hyodol Co., Ltd.) in [47, 55, 77], (**b**) Mysterious teddy bear (T.Arts Inc.) in [64], (**c**) Bono06 (Yukai Engineering) [78], (**d**) Nabaztag (Violet) [69], (**e**) RoBoHoN (Sharp) in [62], (**f**) Hobbit in [48], (**g**) TiaGo iron (PAL Robotics) [49], (**h**) Scitos G3 (MetraLabs) in [51], (**i**) James (Zorabots) in [58], (**j**) Kompaï (Robosoft) in [83], (**k**) Sanbot Elf (Qihan Technology) in [50, 66], (**l**) Gymmy in [67], (**m**) Giraff-X in [79, 82], (**n**) Pepper (Softbank) in [61], (**o**) NAO V6 (Aldebaran) in [52], (**p**) Bomy (Robocare & Ewha Womans University) in [70], (**q**) Matilda (RECCSI) in [54, 56], (**r**) Smibi (Togo Seisakusyo Corp.) in [81], (**s**) Misty (Misty Robotics) in [60], (**t**) Tessa (Tinybots) in [59, 72], (**u**) Kabochan (PIP Co., Ltd. & WiZ Co., Ltd.) in [76], (**v**) Communicaiton robot in [80], (**w**) Joy forAll robot kitten (Ageless Innovation LLC) in [68, 84], (**x**) PARO (PARO Robots) in [46, 53, 57, 74] (*drawings by the authors, adapted from publicly available images on manufacturer websites* [85–90] *and published articles* [47–49, 51, 56–58, 61, 62, 64, 67, 68, 70, 76, 78, 80–82])

research and development platforms without a specific user or application focus [51–53, 57, 58, 61, 62, 64–66, 68, 69, 71, 73–75, 84], or robots created with a *technology-push* approach [92], where development is steered by technological advancement rather than solving a specific problem or addressing a user need [46, 47, 54–56, 60, 67, 76–78]. In seven studies [49, 50, 70, 79, 80, 82, 83], the robots were partially co-designed, meaning researchers explored user preferences and attitudes regarding an existing robot concept before development. In four studies [59, 63, 72, 81], it was unclear whether the robots were co-designed with users. Only one study [48] fully co-designed the robot with target users before deploying and testing it at home. This co-design process entailed two workshops where target users engaged in *generative design research* activities [93], such as picture associations and prototyping [94].

Deployment of these robots in participants' homes ranged between two days [52] to four years [47], with two studies [51, 72] not reporting deployment duration. In most studies ($n=32$) [46–52, 54–58, 60, 62, 66–83], participants could use the robot at their discretion unsupervised after receiving instructions or training on robot functions and how to use it. However, in seven studies [53, 59, 61, 63–65, 84], participants were encouraged or instructed by caregivers or researchers to interact with the robots. Table 3 summarizes the key robot characteristics reported in the included studies, with further details provided in Online Resource 7.

4.3 Results of Syntheses: Enablers and Barriers

The thematic synthesis of enablers and barriers extracted from the studies resulted in categories, 16 subdomains composed of these categories, and four overarching domains: (1) interaction, (2) context, (3) robot, and (4) user. It also revealed that the subdomains and their categories can interact within and across subdomains, affecting one another. Table 4 and the following subsections present the identified domains, subdomains, and categories, with all elements ranked by their frequency of citation and categories further divided into enablers and barriers. The final subsection further describes how the categories and subdomains are interrelated.

4.3.1 Interaction

The enablers and barriers related to the emotional, cognitive, and perceptual experiences that unfold during user–robot interaction were classified under this domain. In nearly all of the studies ($n=38$) [46–77, 79–84], users evaluated the robots' utility, ease of use, novelty, safety, security, privacy, and/or the level of control they had over the robot during their interactions. The outcomes of these evaluations were influential in determining whether users interacted with robots at all, continued using the robots during the studies, or wished to continue using them afterwards.

Among these factors, perceived robot novelty was regarded as particularly important for sustaining long-term use [46–49, 51, 56, 57, 62, 64, 67–69, 71, 82]. Across studies, a general trend emerged: while robot features and behaviors were initially engaging, users often lost interest over time as they became familiar with the robot's capabilities, leading to reduced use. In some cases, users felt that robots lacked sufficient novelty compared to other technologies from the outset [57, 68]. To maintain engagement, users in three studies suggested diversifying robot behaviors or enabling robots to learn and adapt over time [55, 57, 67]. Unexpected, surprising, or accidentally triggered behaviors were also found effective in four studies [46, 51, 62, 68], while one study [68] highlighted the role of social networks in restoring perceived reduced novelty. Additionally, three studies [57, 64, 68] underscored the importance of balancing randomness with predictability to create an optimal user experience.

Besides how users perceived the robots, how they evaluated them *in comparison to* their expectations or to other entities, such as humans, animals, or technologies, was critical in 33 studies [46–72, 74, 75, 79, 82–84]. These comparisons often revealed the robots' advantages and limitations, influencing HRI in both positive and negative ways. Notably, users' tendency to liken the robot to humans or animals (i.e. anthropomorphization) generally helped users form emotional attachment with robots and enhanced robots' social presence [46–60, 62, 64, 67, 69–72, 74, 75, 79, 84], yet it also contributed to unmet expectations or the "uncanny valley" phenomenon [96] in some cases [49, 52, 54, 56, 58, 61, 65, 67, 69, 71, 72, 79, 82, 84].

Additionally, seven studies [49, 50, 61, 62, 69, 72, 77] highlighted the benefits of prolonged interaction with a

Table 3 Main characteristics of the robots across included studies

Robot appearance	nr. of studies (n)
Bio-inspired (human)	20
Bio-inspired (animal)	13
Functional	4
Mixed	2

Co-designed (Y/N)	nr. of studies (n)
Yes	1
Partially	7
No	27
Unknown	4

Interaction modality	nr. of studies (n)
Language-based (i.e., text or speech)	29
Sound & movement	7
Not reported	3

Price in dollars (range)	nr. of studies (n)
0-100	1
101-1000	11
1001-10000	12
10001-100000	6
Unknown	9

Duration of deployment in months (range)	nr. of studies (n)
<1 months	17
1-3 months	14
3-6 months	4
6-12 months	1
>12 months	1
Unknown	2

Table 4 Enablers and barriers identified from the included studies

Theme		Reference
1. Interaction (n=39)		
1.1. Perception of the robot (n=38)		
Enablers (n)	Perceived utility (n=36)	[46, 47, 49–64, 66–77, 79–84]
	Perceived ease of learning and use (n=17)	[48–52, 56, 58–61, 67, 73, 77–80, 84]
	Perceived novelty (n=14)	[46–49, 51, 56, 57, 62, 64, 67–69, 71, 82]
	Perceived safety & security (n=9)	[48, 49, 52, 54, 55, 67, 73, 79, 82]
	Perceived control over robot (n=6)	[52, 57, 58, 62, 64, 67]
	Reducing caregiver burden & stress (n=5)	[53, 59, 71–73]
Barriers (n)	Perceived low usability (n=16)	[49, 52, 55–57, 60–62, 65, 66, 72, 76, 79, 82, 83]
	Lack of utility (n=9)	[52, 57, 60, 67, 69, 71–73, 79]
	Privacy concerns (n=7)	[52, 57, 60, 61, 67, 69, 72]
	Lack of safety & security (n=5)	[51, 61, 65, 70, 82]
	Lack of robot novelty (n=5)	[56, 57, 66–68]
	Lack of control over robot (n=2)	[48, 79]
	Increasing caregiver burden (n=2)	[72, 73]
	Liability concerns (n=1)	[57]
1.2. Relative perception of the robot (n=33)		
Enablers (n)	Anthropomorphization (n=27)	[46–60, 62, 64, 67, 69–72, 74, 75, 79, 84]
	Perceived relative advantage (n=5)	[46, 47, 55, 67, 84]
	Match between expectations and robot features (n=4)	[49, 52, 68, 69]
Barriers (n)	Mismatch between expectations and robot features (n=20)	[47–50, 52–56, 58, 60, 61, 65–70, 72, 79]
	Anthropomorphization (n=14)	[49, 52, 54, 56, 58, 61, 65, 67, 69, 71, 72, 79, 82, 84]
	Lack of perceived relative advantage (n=3)	[57, 65, 68]
1.3. Emotional response (n=32)		
Enablers (n)	Positive response (e.g., Curiosity, enjoyment, satisfaction, comfort, and trust (n=29)	[46, 47, 49–59, 62–64, 66–75, 79, 81, 84]
Barriers (n)	Negative response (e.g., Anxiety, insecurity, distrust, annoyance, boredom, and fear) (n=19)	[48, 49, 51, 53–56, 59, 61, 63, 65–67, 69, 71–75]
1.4. Duration of interaction (n=9)		
Enablers (n)	Long-term interaction (n=7)	[49, 50, 61, 62, 69, 72, 77]
Barriers (n)	Long-term interaction (n=2)	[57, 68]
	Short-term interaction (n=1)	[69]
2. Context (n=35)		
2.1. Situational context (n=20)		
Enablers (n)	Daily schedule, events, time of the day (n=7)	[50, 52, 54, 57, 68, 69, 84]
	COVID-19 (n=5)	[47, 55, 58, 79, 82]
	Participation in a study (n=5)	[48, 56, 60, 65, 84]
Barriers (n)	Daily schedule, events, time of the day (n=11)	[50, 52–55, 59, 69, 70, 80, 82, 83]
2.2. Physical context (n=16)		
Enablers (n)	Robot location (n=2)	[69, 84]
Barriers (n)	Size and layout of the home (n=8)	[50–52, 59, 66, 70, 79, 83]
	Presence and placement of certain objects (n=5)	[48, 50, 51, 82, 83]
	Poor infrastructure (n=5)	[65, 66, 79, 82, 83]
	Lighting conditions (n=2)	[51, 61]
	Robot location (n=2)	[59, 72]
2.3. Social context (n=16)		
Enablers (n)	Interest, nudge, and guidance from social network (n=11)	[46, 48–50, 53, 63, 68, 70, 73, 74, 82]
Barriers (n)	Negative attitudes or opinions of social network (n=6)	[50, 66–68, 73, 84]

Table 4 (continued)

Theme		Reference
3. Robot (n=34)		
3.1. Physical attributes (n=28)		
Enablers (n)	Pleasant appearance (n=15)	[46–49, 52, 53, 58, 60, 62, 69, 71, 72, 74, 81, 84]
	Pleasant robot sound (n=4)	[46, 55, 56, 64]
	Pleasant tactile qualities (n=4)	[46, 64, 68, 74]
	Appropriate size (n=3)	[49, 52, 62]
Barriers (n)	Too big or small size (n=10)	[47, 48, 52, 53, 58, 61, 65, 70, 73, 79]
	Unpleasant robot sound (n=8)	[52, 56, 57, 65, 70–72, 74]
	Unpleasant appearance (n=7)	[57, 65, 69, 71, 74, 77, 84]
3.2. Capabilities (n=25)		
Enablers (n)	Human- or pet-like interactivity (n=15)	[46, 47, 51, 52, 55, 57, 58, 61, 62, 66, 68, 71, 72, 74, 84]
	Desired entertainment and functional capabilities (n=3)	[49, 54, 59]
	Predictable navigation (n=2)	[79, 82]
Barriers (n)	Lack of desired level of interactivity (n=5)	[56, 57, 69, 71, 79]
	Lack of desired entertainment and functional capabilities (n=2)	[65, 83]
3.3. Performance (n=23)		
Enablers (n)	Reliability & robustness (n=5)	[50, 60, 73, 79, 82]
Barriers (n)	Poor robot performance(n=23)	[48–53, 56, 57, 60–62, 64–67, 69, 70, 72, 73, 76, 79, 82, 83]
3.4. Adaptability & personalization (n=14)		
Enablers (n)	Ability to learn and adapt (n=7)	[49, 50, 57, 58, 66, 69, 82]
	Personalized content (n=5)	[50, 54, 66, 77, 83]
	Ability to recognize the user (n=2)	[48, 50]
	Culture-aware design (n=1)	[64]
Barriers (n)	Lack of customization (n=5)	[60, 61, 65, 72, 73]
3.5. Cost (n=4)		
Barriers (n)	Selling price and usage costs (n=4)	[57, 58, 60, 61]
4. User (n=33)		
4.1. Attitude towards technology and technology competence (n=23)		
Enablers (n)	Positive attitude towards technology (n=11)	[49, 52, 53, 58, 61, 67, 69, 70, 73, 79, 84]
	High technology competence (n=3)	[58, 69, 73]
	Low technology competence (n=1)	[67]
Barriers (n)	Low technology competence (n=14)	[47, 50, 55–57, 60, 65, 66, 69, 70, 72, 73, 78, 80]
	Negative attitude towards technology (n=10)	[53, 55, 57, 61, 65, 67, 71–73, 80]
	High technology competence (n=3)	[50, 66, 67]
4.2. Social positioning and self-concept (n=15)		
Enablers (n)	Low level of social connectedness & independence (n=8)	[47, 54, 56, 61, 62, 66, 72, 84]
Barriers (n)	Allo-enhancement effect [95] (n=11)	[46, 52, 57, 61, 66–68, 70–72, 84]
	High level of social connectedness & independence (n=5)	[54, 61, 66, 72, 84]
4.3. Demographic and lifestyle factors (n=15)		
Enablers (n)	Prior or current pet ownership (n=2)	[71, 84]
	Older age (n=1)	[60]
Barriers (n)	Prior or current pet ownership (n=7)	[46, 57, 63, 66, 71, 74, 84]
	Older age (n=4)	[65, 69, 79, 82]
	Gender: male (n=3)	[47, 75, 77]
	Younger age (n=2)	[67, 84]
	Higher education level (n=2)	[66, 67]
	Low literacy (n=1)	[66]
4.4. Physical, emotional, and cognitive capabilities (n=10)		
Enablers (n)	High cognitive functioning (n=2)	[74, 79]
Barriers (n)	Cognitive impairments (n=6)	[65, 66, 70, 72, 74, 79]
	Physical impairments (n=6)	[53, 55, 56, 60, 70, 72]
	High emotional intelligence (n=1)	[66]

robot. They noted that users become more familiar with robots' capabilities, gain confidence in using them, and develop greater comfort and emotional attachment as they spend more time with the robots. One study [50] emphasized that users who had longer exposure to the robot were the most enthusiastic, while another [69] included a participant's comment reflecting their need for longer interaction to form a bond with the robot. Conversely, two studies [57, 68] reported that long-term interaction could decrease robot novelty.

4.3.2 Context

A total of 35 studies [46–61, 63, 65–70, 72–74, 79, 80, 82–84] demonstrated the influence of physical, social, and situational contexts on robot deployment and use in home environments. Interestingly, COVID-19 was noted as an enabler in five studies [47, 55, 58, 79, 82], highlighting that robots were particularly valued during social isolation. However, other situational factors, such as going on vacation, having visitors, or being busy, sometimes disrupted robot use [50, 52–55, 59, 69, 70, 80, 82, 83]. Five studies [48, 56, 60, 65, 84] also noted that participation in a study itself could influence HRI, for example, by fostering a sense of obligation, encouraging caution to avoid damage, or increasing engagement at the start and end of the study period.

Physical and social context had mixed effects as well. Specifically, small or two-story houses and presence and placement of objects such as carpets, cables, and doorsteps hindered autonomous robot navigation or even led to participant exclusion before the study began [48, 50–52, 59, 66, 70, 79, 82, 83]. Similarly, limited or unreliable internet connectivity, a lack of charging outlets, and variable lighting conditions impaired object detection and localization functions, disrupted internet-based services (e.g., video calls and calendar applications), and contributed to participant dropout [51, 61, 65, 66, 79, 82, 83]. For non-mobile robots, placement in high-traffic areas within homes facilitated interactions [69, 84], whereas fixed positioning in larger homes often led to difficulties, such as users being unable to hear the robot [59, 72]. Additionally, 14 studies [46, 48–50, 53, 63, 66–68, 70, 73, 74, 82, 84] reported the significant role of social influence (e.g., judgment, stigmatization, interest, nudging, or guidance from family members and caregivers) in shaping users' willingness to use the robots.

4.3.3 Robot

The robot-related factors influencing the deployment and use of social robots in the included studies concerned capabilities, physical attributes, performance, adaptability and personalization, and cost. Physical attributes and capabilities of robots elicited mixed responses. For example, robots' appearance, size, tactile qualities, and sound were aesthetically and practically appealing to some users, yet impractical, annoying, or off-putting to others [46–49, 52–58, 60–62, 64, 65, 68–74, 77, 79, 81, 83, 84]. Overly life-like, toy-like, or unfamiliar appearances were particularly repelling in certain cases due to perceived social judgment, the uncanny valley phenomenon, or personal taste [57, 65, 69, 71, 74, 77, 84]. Human- or pet-like interactivity, entertainment features, and predictable navigation were generally appreciated [46, 47, 49, 51, 52, 54, 55, 57–59, 61, 62, 66, 68, 71, 72, 74, 79, 82, 84].

Poor robot performance, caused by hardware or software malfunctions, speech recognition errors, connectivity issues, or navigation challenges, was a significant barrier to deployment and acceptance, undermining trust, confidence, and perceptions of usefulness [48–53, 56, 57, 60–62, 64–67, 69, 70, 72, 73, 76, 79, 82, 83]. Adaptive and personalized capabilities, including learning users' habits, addressing them by name, or tailoring content, generally facilitated acceptance and positive experiences [48–50, 54, 57, 58, 61, 65, 66, 69, 72, 73, 79, 83]. Lastly, anticipated usage costs related to robots' energy consumption and their purchase price were perceived by older adults and caregivers as barriers to adoption [57, 58, 60, 61].

4.3.4 User

The factors under this domain concerned users' attitudes, capabilities, views, characteristics, and levels of social connectedness and independence. Attitude toward technology, a well-established determinant of technology acceptance, was highlighted in 16 studies [49, 52, 53, 55, 57, 58, 61, 65, 67, 69–73, 80, 84], with positive or curious attitudes facilitating engagement and negative or reluctant attitudes contributing to rejection or dropouts. This factor was particularly influential during the early stages of robot deployment in the home.

Evidence regarding the impact of technology competence, age, and pet ownership was mixed. High competence could enable use but also elevate expectations that robots failed to meet [49, 50, 66, 67, 69, 73]. Low competence generally impeded use [47, 50, 55–57, 60, 65, 66, 69, 70, 72, 73, 78, 80], though it paradoxically led users to overlook the robot's shortcomings in [67]. Similarly, older age was linked to lower technological interest, competence, and capabilities [65, 69, 79, 82] as well as to increased satisfaction with the robot [60]. In contrast, younger participants in [67] and [84] were more likely to perceive robots as irrelevant to their needs, associating them with older or marginalized populations, which reduced their willingness to engage

with them. Additionally, pet ownership often reduced interest in pet-like robots due to comparisons with real animals [46, 57, 63, 71, 74, 84] or posed a practical challenge to deploying mobile robots [66], though users also valued the "maintenance-free" companionship the robots provided in [71, 84].

The "allo-enhancement effect" [95] and gender were interesting barriers that emerged from the studies. The "allo-enhancement effect" refers to the tendency to view social robots as useful for others but not personally relevant to one's own needs or circumstances [95]. In 11 studies, this effect was reflected in participants' statements such as "they do not have any issues that require the use of robots" [57, 66, 67, 71, 72], "they are not of an age to play with a robot" [46], "they have friends, social activities, or real animals" [68], or "these robots are for older, lonely, and isolated people" [52, 61, 67, 68, 70, 84]. Similarly, some male participants in [47, 75, 77] perceived a mismatch between themselves and doll- or pet-like robots, leading to reduced engagement or dropouts.

4.3.5 Interactions Within and Across Subdomains

Across the included studies, enablers and barriers affecting robot deployment, willingness to use, or actual use were rarely reported in isolation. Instead, we found that multiple factors interact within and across subdomains, collectively shaping users' perceptions and behaviors. Based on the synthesis of the study reports, four recurrent interaction patterns were identified. However, these patterns represent qualitative conclusions from the synthesis and should not be interpreted as causal relationships.

First, users' attitude towards technology was often enhanced by interaction duration or social context, which in turn facilitated robot acceptance and use. This pattern was observed in eight studies [16, 49, 50, 61, 66, 68, 72, 73]. In these studies, interest, nudge, and guidance from participants' social networks or interacting with robots for longer periods shifted attitudes from initially negative or skeptical to more positive. As attitudes improved, participants reported perceiving the robots as easier to use, gradually integrating them into daily routines and, in some cases, developing relationships with them.

Second, the physical context of use, physical attributes of the robot, or a combination of the two, impaired robot performance in seven studies [48, 50, 61, 65, 72, 79, 82], causing users to perceive the robot as unreliable, underdeveloped, or useless. Particularly, in [48] and [50], the combination of large robots with small and cluttered homes hindered navigation and task execution, causing disappointment and reducing participants' willingness to adopt the robots.

Third, barriers associated with demographic and lifestyle factors and user capabilities were often amplified by robots' physical attributes and capabilities as well as physical context, resulting in more negative perceptions or responses. For example, across four studies [16, 65, 66, 79], older age or low literacy were associated with lower technology competence or impairments in cognitive capabilities. Four studies [55, 65, 70, 72] reported that hearing, vision, or cognitive impairments made it difficult for users to understand robot speech, know where the robot is, or remember how to interact with it, contributing to reduced technology competence. These difficulties were further amplified by robots' machine-like or low-volume speech, autonomous navigation capabilities, or interfaces requiring multiple input steps. In combination with robot characteristics, limited robot mobility in small houses or robot placement further away from users added another layer of complexity to the perceptions of safety, usability, and utility in two of these studies [70, 72].

Lastly, situational context negatively affected users' social positioning and self-concept, which, together with robot capabilities, led to positive responses and relative perceptions of the robots in four studies [47, 55, 58, 79]. These studies, conducted during the COVID-19 pandemic, reported that participants experienced lower levels of social connectedness due to lockdown measures. When this experience was combined with robots' life-like interactivity, participants were more likely to anthropomorphize the robots and derive companionship from them.

5 Discussion

This study aimed to provide a systematic synthesis of the empirical studies on social robots for health promotion and care delivery at home, focusing on the enablers and barriers to robot deployment and use. The review included 39 studies involving actual HRI in real home environments, with the majority being conducted in high-income industrialized countries and involving fewer than 20 participants. Moreover, more than two-thirds of these studies lacked data on participant diversity in terms of type (e.g., caregiver or patient), ethnicity, socioeconomic status, education level, and technology experience. The limited number of studies, the lack of attention to middle- and low-income contexts and participant diversity, and the scarcity of large-scale trials underscore the underdeveloped and fragmented state of this research field. In light of the global increase in aging populations [97] and the growing importance of home-based healthcare, large-scale studies, particularly in diverse socio-economic contexts, are critical for advancing research and practice in this area.

Regarding publication year, most studies were published after 2019, indicating the growing significance of social robots and home-based healthcare, particularly in response to the COVID-19 pandemic. Similarly, the high representation of older individuals as participants across the studies is not surprising, given that they were among the most severely affected by the pandemic [98] and considering the global increase in aging populations [97]. In contrast, the scarcity of studies targeting younger populations, particularly pediatric populations, is remarkable given the increasing prevalence of conditions such as obesity [99] and ASD [100]. Perhaps, this scarcity may be attributed to our focus on home-based healthcare, as settings for child healthcare with social robots often encompass hospitals or schools [101].

Regarding health status, most studies involved participants with cognitive impairments and/or other chronic or psychological conditions, such as hypertension and depression, with female participants outnumbering male participants. This difference in participant demographics may be attributed to the higher prevalence of these conditions among women compared to men [102, 103] as well as to generally more reserved attitudes among men toward social robots [26, 36], which was also reflected in this review. These findings suggest that gender differences should be carefully considered in the design and evaluation of social robots for home-based healthcare.

In terms of robots involved in the included studies, the majority were high-cost, bio-inspired devices designed to support the independent living of older adults. These robots typically featured advanced functionalities, numerous components, and language-based interaction, but lacked co-design with users. The predominance of such robots in the reviewed studies seems to be reflecting the current techno-centric approaches to social robot design, which often prioritize technical achievements—such as "creating the first humanoid robot in Europe" [104]—rather than addressing specific user and contextual needs [105–107]. Although these approaches can generate substantial advancements in the HRI field, they often lead to increased robot complexity, language- or text-based features that require users to read and understand a specific language, and the replication of life-like appearance and behavior without critical evaluation. In turn, these design choices can increase robot costs and reduce reliability, limiting scalability and accessibility, particularly for vulnerable user populations. Furthermore, they can trigger the uncanny valley phenomenon [25] and lead users to expect human-level intelligence or emotional understanding that the robots cannot fulfill [108]. Given these consequences, it is unsurprising that poor robot performance and mismatches between user expectations or preferences and robot characteristics emerged as the most frequently cited barriers in this review. These findings highlight the importance of participatory design approaches, which can help critically reflect on whether or to what extent bio-inspiredness or complexity is needed for home-based healthcare applications.

5.1 Enablers and Barriers

Although the evidence base was small, the included studies nonetheless provided rich insights into the enablers and barriers to robot deployment and use. Our bottom-up, inductive synthesis process of these factors led to 16 subdomains and four overarching domains: interaction, context, robot, and user. Moreover, we identified that these factors, and thus the subdomains and domains, often have compounded effects on the deployment and sustained use of social robots for home-based healthcare as they interact with each other.

In prior reviews [2, 34–36], the classifications of enablers and barriers differ, and these interactions seem to be lacking, perhaps due to the use of standardized frameworks such as CFIR [109] and CICI [110] for synthesizing findings. Notably, one review [33], which also used an inductive methodology to synthesize data, presents a similar classification, framing individual, robot, and contextual characteristics as antecedents, and positioning what we categorized as interaction as consequences of intelligent physical robot use in healthcare. While we acknowledge this view, our results suggest that interaction is both a consequence and an antecedent of robot use. The emotional, cognitive, and perceptual experiences that unfold during user-robot interaction not only result from prior robot use but also influence future willingness to use the robot, shaping sustained use over time.

Zooming in on the enablers and barriers, as well as their relative prominence based on citation frequency, our findings generally align with those from prior research [1, 2, 15, 20, 27, 29, 31, 34–36]. Consistent with [29] and [31], perceived utility—as being the most-cited enabler across the included studies—seems to have a central role in successful deployment and use. Also, factors such as positive emotional response, perceived ease of use, anthropomorphization, pleasant robot appearance, and life-like interactive capabilities of a robot were among the most repeatedly reported enablers across the included studies, further confirming that both hedonic and utilitarian factors influence social robot acceptance and use [16, 111]. The most frequently cited barriers (i.e., poor robot performance, a mismatch between user expectations and preferences and robot characteristics, negative emotional responses to robots, perceived low usability, and anthropomorphization) are also in line with those identified in prior research across different use contexts [1, 2, 15, 20, 29, 34–36]. This alignment

suggests that similar challenges persist in the deployment and use of social robots across various settings.

Additionally, in accordance with [28, 32], and [20], we found that prolonged use can foster familiarity and emotional attachment with the robot while also leading to decreased perceived novelty. However, it is important to note that what prolonged use entails and when exactly novelty diminishes remain unclear. Only a few studies we reviewed lasted more than three months. Perceived lack of novelty as a barrier was reported in studies lasting three months or less, whereas positive effects related to long-term interaction were reported in studies lasting both less and more than three months. Although more longitudinal research is needed, this dual effect still has important implications for home-based healthcare. On one hand, familiarity and attachment are desirable in home-based healthcare, as they can enhance trust, comfort, and willingness to engage with the robot over time. These qualities may support adherence to routines and improve health and wellbeing outcomes. On the other hand, the decline in perceived novelty can lead to habituation, reducing engagement and diminishing the motivational appeal that novelty initially provides. This tension suggests that sustained interaction requires strategies to maintain user interest without undermining the stability and predictability that foster attachment. For example, as suggested by the included studies [55, 57, 67], adaptive behaviors, personalized content, or occasional inclusion of social networks in the use process can help balance familiarity with ongoing stimulation.

In terms of the effects of high technological competence, pet ownership, and situational context, our findings diverge from previous studies. While prior research [2, 34–36] has highlighted how low technological competence can hinder robot use, it has overlooked that high technological competence may also pose a barrier by increasing sensitivity to a robot's limitations and technical flaws. Similarly, the potential negative impact of pet ownership on robot deployment and use has not been addressed, likely because previous studies focused on older adults, who often have lower technological competence, and/or on institutional settings where pets are uncommon. Finally, our review identified that certain circumstances, such as going on vacation or participating in a study, can alter how and how much a user interacts with a robot due to changes in daily routines or being observed (i.e., "Hawthorne effect" [112]). Previous research appears not to consider the influence of situational context on robot use. The emergence of these previously unexplored factors implies that the determinants of social robot use in home-based healthcare settings are context-dependent and may vary from those identified in other healthcare environments.

5.2 Implications for Practice and Future Research

Considering the frequently reported enablers and barriers and their interactions, the design of social robots can particularly benefit from balancing familiarity and novelty, integrating utilitarian and hedonic experiences, and calibrating the degree of life-like qualities embodied by the robot. Rather than striving for an all-around robot, which often increases complexity, designing for simplicity may be more effective in achieving reliable performance, sustained engagement, and broader accessibility in home-based healthcare settings. To apply these design principles, we advocate for a more ecological and participatory approach.

Before starting the development process, we recommend taking an ecological perspective, in which robots are considered as actors within socio-technical ecosystems consisting of humans, objects, and concepts such as societal norms, regulations, and politics [22, 113–116]. Adopting this perspective is particularly valuable for the development of social robots for home-based healthcare since both healthcare and home environments are inherently complex. Healthcare is a multi-layered context that requires consideration of diverse individuals with varying authorities and roles, established structures and organizations, and policies and regulations [117]. At the same time, home as a healthcare setting differs significantly from the clinical environment in terms of people, activities and relationships, and infrastructure due to its private, dynamic, and unstructured nature [19]. By viewing robots as part of these evolving and interdependent systems, designers can better account for the real-world conditions in which robots will be deployed and the broader range of human and nonhuman actors that shape their success.

As a second step, we suggest actively and continuously involving the human actors of the ecology (i.e., designers, engineers, researchers, patients, their social networks, healthcare professionals, organizational and management teams, and even representatives from regulatory and financial bodies) from the earliest phases of development through participatory design practices. Particularly, the inclusion of representatives from regulatory and financial bodies can help the development of safe and ethical robots by encouraging alignment with laws and policies, establishing governance frameworks, providing ethical oversight, and creating risk management protocols. Besides aligning with the growing person-centered healthcare movement [118], such collaboration fosters diversity, equity, and inclusion [119] and leads to appropriate, useful, and personalized solutions—qualities identified in this review as key facilitators of deployment and use. Furthermore, this approach supports the implementation of these solutions by identifying key elements, such as required resources, capacities, and maintenance needs,

early in the design process [120] and facilitates acceptance and adoption [121].

While applying the participatory approach, another point to consider is that HRI may play out differently depending on the specific moment, situation, or over time. In line with this, Forlizzi advises looking into "the ebbs and flows of time, and the phrasing of interactions with products, combined with particular hours, days, and seasons and the ages and lifestages of key people using a product" [22]. In considering these aspects, besides longitudinal studies, future work can benefit from speculative and performative methodologies within participatory practices. In the context of HRI, these methodologies can be defined as using prototypes, films, or improvisations to provoke people to experience, critique, and reflect on what it might be like to interact or live with a robot in the (near) future [122–124]. Consequently, they can help explore the effects of a robot on users' lives or society as well as the evolution of HRI over time, before the robot becomes a finalized product.

From a policy perspective, our findings highlight the importance of safety, security, and privacy, while pointing to a notable gap in the consideration of ethical issues. Existing regulations and standards, such as the EU 2016/679 General Data Protection Regulation [125], the EU 2023/1230 Machinery Regulation [126], and the forthcoming ISO 13482:2024 Safety Requirements for Service Robots Standard [127], address several relevant aspects, including cybersecurity, data protection, robot reliability, safe navigation, operation and charging, and ergonomic considerations. However, these frameworks do not encapsulate the ethical challenges that arise from the uniquely personal and dynamic context of home use, such as situations in which a robot may inadvertently harm a visitor or pet, or collect video data in intimate spaces for purposes such as fall-risk monitoring. Moreover, as also noted by [128], current regulations and standards predominantly focus on mechanical safety and the prevention of physical harm, are not tailored to social robots, and rarely account for the characteristics and vulnerabilities of typical users identified in HRI research. For example, although ISO 13482:2024 acknowledges that continuous robot use may cause mental stress [127], it offers little guidance on risks related to emotional attachment, dependency, or changes in user autonomy—issues that are particularly pronounced for vulnerable users in home-based healthcare settings. Addressing these gaps requires these frameworks to be more closely informed by empirical HRI research and to broaden their scope beyond physical safety.

Similarly, we observed limited in-depth ethical reflection across the reviewed studies, despite the fact that most involved older adults and human-inspired social robots. Ethical considerations were rarely examined beyond references to the uncanny valley phenomenon. As highlighted by [108, 129, 130], issues such as deception, stereotyping, and over-trust warrant greater attention, particularly in long-term, care-oriented interactions. Further investigation into these issues should be a priority for future research.

In this regard, the recent EU 2024/1689 Artificial Intelligence Act [131] introduces a broader risk-based regulatory framework governing the development and deployment of artificial intelligence (AI) systems, including AI-enabled technologies such as personal assistance and care robots. Among other provisions, it prohibits AI systems that exploit vulnerabilities related to age, disability, or socioeconomic circumstances and requires risk management, transparency regarding the system's machinic nature and trustworthiness, documentation, and human oversight for high-risk applications such as medical devices. Although social robots for home-based healthcare may not always fall under the category of medical devices, these requirements may nevertheless affect or complicate research trials and real-world deployments of such systems in Europe. In light of our findings indicating limited ethical consideration of user vulnerabilities and socio-technical risks in home environments, AI Act–aligned risk assessments and study designs should therefore explicitly consider several key aspects. These include (i) the inclusion and extent of potentially privacy-intrusive sensing components and algorithms (e.g., cameras or human recognition systems), (ii) the appropriate level of autonomy granted to the robot in functions such as navigation, decision-support, and information generation, (iii) the implementation of mechanisms that enable human oversight and intervention in situations where autonomous behavior may pose risks (e.g., generating offensive cmments), and (iv) how the robot's capabilities, limitations, and artificial nature are communicated transparently to users. In operationalizing (iv), *hybridity* can serve as a design strategy for balancing familiar social cues with visible markers of the robot's machinic nature [132, 133]. Boon et al. [134], for instance, demonstrate how a hybrid physical activity promotion robot that combines a ball shape with playful behaviours (e.g., wiggling to draw attention) can enhance engagement while reducing the likelihood that users overestimate the robot's cognitive or emotional capabilities.

5.3 Limitations

This review has several limitations. First, our search was limited to specific keywords, seven databases, and studies published in English, which may have resulted in the omission of relevant research. We also excluded conference proceedings, as these often present preliminary findings that may later change or even be contradicted by final results. Furthermore, the peer-review standards of conference publications can vary widely, which raises concerns

about consistency and reliability. Although we initially aimed to include additional databases, such as the Association for Computing Machinery (ACM) Digital Library and IEEE Xplore, technical constraints prevented systematic search and retrieval of results from these sources. Second, this review included studies regardless of their quality or sample size, necessitating a cautious interpretation of the findings. Third, the variability in research designs across the included studies made it difficult to draw direct comparisons and aggregate findings, with certain barriers and enablers being reported in only a single study. Further evidence is needed on the facilitating or hindering effect of such factors. Fourth, although we did not restrict our search to a specific population, most of the included studies focused on older individuals, potentially limiting the generalizability of our results. Finally, despite incorporating studies from various countries, certain cultural contexts and perspectives appear to be underrepresented, underscoring the need for future research to focus on these areas. Nevertheless, to our knowledge, this was the first review focusing on social robot deployment and use in home contexts for healthcare promotion and delivery.

6 Conclusion

This study reviewed empirical research on social robots designed for health promotion and care delivery in home settings, highlighting a wide range of enablers and barriers influencing their deployment and use. The inductive thematic synthesis of these factors led to the emergence of four domains, which often have compounded effects on deployment and use: interaction, context, robot, and user. Across the included studies, the most frequently cited enablers were perceived utility and positive emotional response, suggesting the importance of both functional and hedonic benefits. The most commonly reported barriers were poor robot performance and a mismatch between robot characteristics and user expectations and preferences. We also found that most studies involved high-cost anthropomorphic robots that were not co-designed with users, which may explain the high frequency of these barriers. Despite the high prevalence of such robots, ethical and legal considerations regarding their deployment and use within home-based healthcare were not explored in depth. Moreover, the analysis of the study, robot, and population characteristics pointed out that diverse cultural and economic contexts and perspectives of different groups within the population were underexplored, and potential alternative end-users of social robots, such as caregivers, were not adequately considered. To address these gaps, future work may benefit from adopting ecological, participatory, speculative, and performative methodologies and practices in the design and development of social robots. By shedding light on these factors and gaps, this review contributes to the development of social robots for health promotion and care delivery that are not only effective and ethical but also meaningfully embedded into the everyday lives of the users.

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Data Availability Online Resource 1 contains the completed PRISMA checklist. Online Resource 2 provides the search queries developed for each electronic database. Online Resource 3 outlines the inclusion and exclusion criteria. Online Resource 4 includes the template used for data extraction. Online Resource 5 presents an example of the data synthesis process and the complete codebook. Online Resource 6 reports the detailed results of the quality assessment for each included study. Online Resource 7 comprises three tables presenting the study characteristics, participant characteristics, and robot characteristics for each individual study. The registered protocol of the review can be found at https://www.crd.york.ac.uk/PROSPERO/view/CRD42023432674.

Materials Availability Not applicable.

Code Availability Not applicable.

Declarations

Ethics Approval and Consent to Participate Not applicable.

Consent for Publication Not applicable.

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