Empathy-Driven Assistive Technologies for Older Adults: A Narrative Review and Practical Implementation Framework

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Abstract

Empathetic technologies transform elderly care by enhancing emotional well-being, autonomy, and social engagement. This study combines a narrative review of 42 relevant publications with practical implementation frameworks derived from seven case studies. We examine integrating assistive technologies (ATs) with empathy-driven principles to support older adults. We conduct a structured narrative literature review, categorizing existing studies based on key themes such as emotional recognition, adaptive interaction, and user-centered design. The findings highlight the potential benefits of Artificial Intelligence (AI)-driven virtual agents, wearable health monitoring devices, and accessible user interfaces in mitigating age-related challenges. However, barriers such as usability, digital literacy, ethical concerns, and privacy risks must be addressed for broader adoption. Human-Computer Interaction (HCI) insight provides valuable guidance in designing effective ATs, incorporating user-centered approaches, co-design methodologies, and affective computing techniques. This study integrates practical implementation strategies derived from real-world deployments, offering an evaluation matrix, a deployment checklist, and forward-looking perspectives for public integration. These additions provide actionable insights for researchers, designers, and policy-makers. This paper also identifies critical research gaps, including the need for experimental validation, improved emotion recognition models, and strategies to ensure ethical implementation. Future research should focus on refining AI frameworks, enhancing accessibility, and promoting transparency in data usage to foster greater acceptance and effectiveness of empathetic assistive technologies. By combining conceptual exploration with implementation guidance, this study aims to bridge the gap between innovation and adoption, ensuring that ATs better support aging populations by improving their quality of life and social inclusion.

Keywords: Empathetic Technologies, Assistive Technology, Human-Computer Interaction, Older Adults, Implementation Strategies, Public Health Integration, Evaluation Matrix

1 Introduction

Population aging is inevitable due to increased life expectancy and declining birth rates worldwide. According to the World Health Organization (WHO), most people today can expect to reach their 60s or beyond, a particularly evident trend in both developed and developing nations [1]. While this demographic transition marks a significant public health achievement, it also raises concerns about the sustainability of healthcare

systems, social security, and the well-being of older adults [2]. Key challenges associated with aging include functional decline, cognitive impairments, and emotional vulnerabilities, all of which can compromise independence and quality of life. Functional limitations, often linked to chronic diseases and reduced mobility, increase the demand for long-term care services [1]. Moreover, mental health conditions such as depression, anxiety, and dementia are becoming increasingly prevalent among older populations, necessitating innovative intervention approaches [2].

In this context, Assistive Technology (AT) has been recognized as an effective tool for mitigating aging-related challenges and enhancing the quality of life. The WHO's global strategy for aging and health highlights the potential of technology to maintain functionality, improve autonomy, and support the emotional well-being of older individuals [2].

These technologies encompass mobility aids, digital interfaces tailored for older users, Artificial Intelligence (AI)-based virtual assistants, and remote health monitoring solutions. While assistive technologies offer viable solutions to address the physical, cognitive, and emotional challenges of aging, their adoption requires strategies to ensure accessibility, usability, and acceptance among older users and caregivers.

In this sense, empathetic technologies, which integrate principles of emotional recognition and adaptive interaction, present promising avenues for enhancing elderly care. Empathetic technologies are digital tools and systems designed to recognize, respond to, and simulate human emotions to foster meaningful and affective interactions between users and technological systems. These technologies rely on AI, affective computing, and human-centered design to create emotionally intelligent systems.

In this work, we present a narrative literature review that aims to provide actionable insights for researchers and designers in the Human-Computer Interaction (HCI) field, particularly those working on AI and aging. By aligning theoretical findings with practical frameworks, the main contribution lies in the promotion of human-centered and ethically aware technological innovations. Furthermore, the study incorporates real-world implementation strategies derived from recent pilot projects and experimental deployments. These include a practical assessment matrix and a deployment checklist designed to support decision-making in healthcare and policy environments.

Thus, this paper explores how HCI can influence the design of technologies, ensuring they are practical and culturally sensitive. The main objective is to provide a comprehensive understanding of the role empathetic technologies can play in enhancing elderly care and how insights from HCI can guide the development of these technologies. By examining the challenges the aging population faces and presenting innovative solutions, we highlight the potential for empathetic technologies to significantly improve the quality of life for older adults while ensuring cultural sensitivity and usability.

Ultimately, by addressing both conceptual and operational dimensions, this work contributes toward the responsible deployment of empathetic systems in public health strategies and community-based care.

2 Empathetic Technology Foundations and Applications

Empathetic technologies are digital tools and techniques designed to foster empathetic encounters and understanding between users and systems. These technologies are characterized by their ability to create relational and emergent experiences where digital and material elements interact dynamically. This concept emphasizes a processual view of digital materiality, suggesting that empathetic understanding emerges from user interaction and technology [3].

These technologies leverage AI, machine learning, and affective computing advancements to recognize and respond to users' emotional states. For example, robotic companions can use AI to engage older adults in cognitive activities and social interactions, thereby reducing feelings of loneliness [4]. Similarly, wearable devices with biosensors can monitor physiological signals, such as heart rate variability, to detect stress and suggest interventions, such as guided breathing exercises [5].

Empathetic technologies address older adults' functional needs and emotional and social well-being. They can significantly enhance the quality of life for seniors by providing personalized support and companionship. These systems can adapt to users' unique preferences and behaviors, offering a more tailored and practical experience.

Pilot implementations demonstrate that empathetic technologies can be scaled into real-world environments. Studies show a 73% user retention rate when virtual agents use collaborative dialogue and expressive avatars [6]. Similarly, smart wearable textiles offer cost-effective solutions for health monitoring, with units priced significantly below commercial alternatives and preferred by older users due to their discreet design [7]. Key principles of empathetic design include:

- Emotional Recognition – use of AI to analyze facial expressions, voice tones and behavioral patterns. This allows the system to detect and interpret the emotional states of users, enabling more responsive and sensitive interactions.

- Adaptive Interaction – alter responses based on individual preferences and cultural contexts. This principle involves recognizing and respecting cultural differences and providing care that is not only effective but also culturally sensitive.

The integration of empathetic technologies in elderly care has the additional potential advantage to alleviate the burden on caregivers. By providing consistent and reliable support, these technologies can assist caregivers in managing the daily needs of older adults, reducing stress and allowing for better focus on more complex care tasks.

This work presents a practical assessment matrix and deployment checklist to support further implementation, derived from findings across multiple case studies [6, 7, 8, 9, 10]. These tools aim to guide designers and healthcare managers in evaluating empathy-driven systems based on real-world constraints and ethical considerations. Empathetic technologies represent a promising frontier in enhancing care for the ageing population. By combining advanced AI capabilities with a deep understanding of human emotions and cultural nuances, these technologies offer a comprehensive approach to addressing the multifaceted needs of older adults.

3 Methodology

The present study adopted a narrative literature review aimed to synthesize significant findings on applying empathetic technologies in elderly care. It provides a comprehensive topic overview, incorporating relevant studies and theories, and helps to contextualize the existing research, highlighting gaps and proposing future research directions.

Various academic databases were consulted to identify publications related to the subject:

- IEEE Xplore
- ACM Digital Library
- Springer Link
- Web of Science
- AI-based literature discovery tools, such as Consensus and Semantic Scholar

The review adopted the following keywords:

"empathic technology", "empathetic technology", "empathy", "elderly", "older adults", "elderly care", and "assistive technology".

To ensure the relevance and quality of the selected studies, inclusion and exclusion criteria were applied. Inclusion criteria were:

IC1. Peer-reviewed articles.

IC2. Publications in English.

IC3. Studies focusing on assistive technologies and empathy in the context of elderly care.

IC4. Articles published in the last five years.

Exclusion criteria:

EC1. Non-peer-reviewed works (e.g., non-reviewed conference papers, white papers).

EC2. Studies not directly related to the intersection of assistive technology and empathy.

The analysis was conducted by reviewing the abstracts and conclusions of the selected articles to extract key findings. Then, researchers performed a more in-depth reading to understand the studies better. In total, 157 articles were identified. After applying the exclusion criteria, 42 articles were retained for detailed analysis.

The 42 articles were analyzed through thematic coding, identifying recurring patterns in empathetic technology design. Key themes included: emotional recognition accuracy, adaptive interaction methods, user-centered design approaches), co-design methodologies, and ethical considerations. This analysis revealed that successful implementations consistently addressed usability barriers while maintaining emotional

authenticity. The findings from these articles directly informed the development of our practical tools, with particular emphasis on usability requirements and ethical guidelines.

A complete list of the analyzed articles is available upon request to the corresponding author. These articles were primarily sourced from HCI and gerontechnology articles published between 2019–2024, with the majority focusing on empirical studies of empathetic technologies in real-world settings.

In addition to theoretical categorization, this study also incorporates a structured analysis of seven illustrative case studies: COMODAL, MATUROLIFE, Wheelchair Stability Assessment System, Ommetje App, CollectiveEyes and CollectiveEars, EMPATHIC-VC, and PERGAMEX. These projects were selected due to their practical relevance, diversity in technological approaches, and focus on older populations.

Each case was analyzed qualitatively through thematic coding. The analysis focused on extracting design challenges, implementation strategies, usability factors, emotional responses, and economic feasibility indicators. Insights were coded into categories such as usability, emotional engagement, stigma reduction, adaptability, and cultural sensitivity. These themes were then synthesized to identify patterns and generate practical guidance.

The case studies served as an empirical foundation to complement the conceptual findings from the literature review. They directly informed the development of two practical tools: (1) an **evaluation matrix** mapping strengths, challenges, and recommendations for empathetic technologies, and (2) a **deployment checklist** intended to assist designers, researchers, and health professionals in replicating successful implementations.

Additionally, data points on cost-benefit indicators and socio-economic scalability were extracted to inform the Economic Viability dimension of the evaluation matrix. Each item in the matrix and checklist was linked to one or more case studies to ensure traceability and applicability.

This methodological step ensures that the literature review not only addresses conceptual frameworks but also generates actionable models that support the responsible integration of empathy-aware systems into public care infrastructures.

3.1 Barriers to Integrating Empathy into Assistive Technologies

Adopting empathy in ATs for older adults faces significant ethical and technological issues. Ethical barriers include privacy and autonomy, stigmatization and exclusion, risks of social isolation, and the need to extend rather than replace human needs for social contact.

Using technologies to monitor and respond to seniors' emotions raises questions about **Privacy and autonomy**. Collecting data on emotional states and behavior can be seen as intrusive, especially if there is no adequate informed consent and clear understanding of how this data will be used and protected. There is also the concern that these technologies may limit the freedom of movement and independence of the aging population [1].

Stigmatization and exclusion refers to the possibility of discrimination and exclusion of certain groups of people due to the classification and organization of assistive technologies [11]. If technologies are organized according to their ability to improve physical, intellectual, or social abilities, those who cannot afford such technologies may be marginalized. Assistive technology may symbolize vulnerability and stigma, affecting users' self-esteem and mental well-being [12].

Although technology can reduce physical and emotional distance, there are also risks of **social isolation**, especially when seniors attempt to replace real human contact with virtual interactions [1]. Assistive technologies must be very clear in communicating that they are designed to **complement, not substitute**, basic human needs for social connection.

From a technological perspective, barriers hinder the effective implementation of empathetic assistive technologies, including limitations in emotion detection accuracy, lack of intuitive interfaces, low digital literacy, and challenges in maintaining personalization over time. Design approaches often neglect users' aesthetic, emotional, and cognitive preferences [12], reinforcing the need for co-design and participatory models [13].

Many of these challenges are addressed in the practical tools proposed in this study. The evaluation matrix highlights common risks such as dependency and usability gaps, while the deployment checklist ensures a minimum standard of accessibility and user testing prior to implementation.

Ultimately, HCI frameworks provide valuable guidance to overcome these barriers, ensuring that technologies not only meet functional needs but also foster trust, emotional connection, and sustained use among older adults.

Furthermore, it is crucial to analyze how empathetic systems might inadvertently evoke negative emotional responses. Technologies that misinterpret emotional cues or provide inappropriate responses could lead to frustration, anxiety, or emotional dependency [1, 11]. Ethical implementation must therefore include

safeguards against emotional manipulation and ensure these technologies augment rather than replace human connection. Regular emotional impact assessments and user feedback mechanisms should be integrated into the development lifecycle.

4 Insights from Human-Computer Interaction

HCI offers various perspectives on developing empathetic technologies for older adults, focusing on enhancing their emotional and social well-being. A fundamental principle is the user-centered approach, which recommends actively involving seniors in the design process, considering their needs, abilities, preferences, and emotional states when developing technologies tailored to their specific requirements [6]. This is achieved through engaging aged individuals in continuous testing, allowing them to interact with simulated systems or prototypes to gather valuable insights for future improvements [6].

Designing interfaces for the aging population must balance functionality and usability, ensuring that sophisticated systems are both effective and accessible [14]. Interfaces should also accommodate a wide range of older users, considering different levels of technological literacy, needs, and abilities [6].

Likewise, empathetic technologies play a crucial role in addressing social isolation and loneliness, which significantly impacts the mental and physical health of older adults [1, 6]. A key component of these systems is emotion analysis, a subfield of computer science that focuses on recognizing, analyzing, and interpreting human emotions through various inputs such as text, speech, facial expressions, and physiological signals.

Regarding design preferences, studies indicate that older adults prefer virtual agents with female voices and visual representations [15, 16]. Additionally, agents with expressive voices and distinct personalities are generally well received [16]. While the system's response speed and potential errors in text or speech can be issues, users tend to be more tolerant of technical problems when they know they are interacting with an artificial agent [6].

These insights, derived from HCI research, inspired the development of the evaluation matrix and implementation checklist presented later in this article. Both tools aim to operationalize HCI principles in designing empathetic assistive technologies that are culturally sensitive, emotionally intelligent, and practically feasible.

4.1 HCI Frameworks Applicable to the Design of ATs

Various HCI frameworks have been developed to translate theoretical insights into practical design principles for empathetic assistive technologies. User-Centered Design (UCD) [17, 18], Co-Design [12, 19], and Affective Computing [6, 20] are examples of models that enable ATs to integrate adaptive emotional responses and promote greater acceptance among older adults. By connecting theoretical insights with concrete methodological approaches, these frameworks help develop technologies that not only meet functional needs but also respect the social and emotional dimensions of the user experience. The studies referenced in this section were drawn both from the narrative literature review and from complementary sources considered highly relevant to illustrate practical applications of the discussed frameworks.

These frameworks provided the conceptual foundation for the practical tools proposed in this study (Section 6). The evaluation matrix synthesizes recurring themes in user acceptance, emotional support, and cost-benefit, while the checklist translates inclusive design and co-design requirements into implementable actions.

4.1.1 User-Centered Design

User-Centered Design is a philosophy and a design process that places the user at the center of the development process. The main objective of UCD is to create products and services that are easy to use, effective, and satisfying for end users [17, 18].

UCD involves deeply understanding users' needs, desires, and limitations and using this information to guide design decisions. This includes analyzing the context of use, users' cognitive and physical abilities, and their emotional needs [17].

Applying UCD principles in developing assistive technologies for seniors is essential to ensure the usability and acceptance of devices [17]. For example, considering the location of controls, text size, color contrast, and clarity of instructions are important for effective technology use [8].

UCD also emphasizes the importance of iterative evaluation, where designers test prototypes with users and adjust based on the feedback received. This framework requires empathetic qualitative approaches to inform and inspire designers to understand the user's personal experience and private context [17].

4.1.2 Co-Design with Seniors

Co-Design is a participatory approach that involves users in the design process. Rather than designing "for" seniors, Co-Design seeks to design "with" them, recognizing them as experts in their own needs and experiences [12].

This collaboration technique allows mature adults to contribute creatively to the solution and problem formulation, which can lead to more relevant and effective solutions. This approach can be crucial when the needs of older adults are not evident at the beginning of the design process [12].

Co-Design also creates opportunities for users to interact with each other, share ideas, and test new concepts, promoting a sense of belonging and empowerment. For example, co-design has been successfully applied in developing touchscreen applications for people with dementia [12]. Using storyboards, sketches, prototyping, and participatory workshops may help engage older adults in the design process [19].

4.1.3 Affective Computing

Affective Computing is an HCI field aimed at equipping systems with the ability to recognize, interpret, and respond to human emotions. The ability to recognize emotions can enable assistive technologies to become more personalized and adaptable to the needs of older adults [20].

In affective computing, emotion recognition can be performed by analyzing facial expressions, voice, and other physiological signals. For example, cameras capture facial images, and voice processing can recognize the user's emotional state [6]. This information can be used to adapt technology's behavior, providing emotional support when needed and making the interaction more natural and intuitive [6].

Emotion detection is fundamental in offering personalized and practical support. Affective computing is being used to develop empathetic virtual agents that can respond to the emotions of older adults, increasing their engagement and well-being [14].

4.1.4 Other Important Concepts

Inclusive Design, which considers the diversity of needs and capabilities, ensuring that products are accessible and usable by the broadest possible range of people, including older adults [12].

Usability, a critical feature in developing assistive technologies, is especially important for older adults, due to potential physical and cognitive changes that may hinder interaction with devices. Usability includes various factors such as ease of learning, efficiency, ease of memorization, and user satisfaction [13, 17, 18].

Empathy-Driven Design, an approach that seeks to create products that not only meet functional needs but also evoke positive emotions in users, considering the social and cultural context [8]. This approach is operationalized in the deployment checklist through hobby-based personalization requirements derived from case studies like Ommetje.

Materiality, the study of the relationship between people and objects, can influence the perception and acceptance of assistive technologies, emphasizing that technology should be naturally integrated into the daily lives of older adults [12].

It is important to consider the context of use, including where and how the product will be used, as well as potential distractions and other variables that may affect device performance [17].

In summary, designing effective assistive technologies for older adults requires a holistic approach that combines HCI knowledge with the inclusion of UCD principles, co-design, affective computing, inclusive design, and an understanding of the importance of usability, empathy, and materiality. By applying these frameworks and principles, it is possible to create technologies that enhance the quality of life and promote the autonomy and well-being of older adults.

5 Case Studies and Practical Applications

This section presents projects and approaches in designing AT for seniors, focusing on HCI and empathy.

5.1 COMODAL Project

The COMODAL Project explored the consumer market for assistive technology products (ATP) for individuals with ages varying from 50 to 70 years [8]. Using mixed methods such as literature reviews, market analyses, interviews, and co-creation workshops, it developed a characteristics matrix to assist designers and companies. High rates of non-use and abandonment of ATPs were found due to factors such as aesthetic appeal and stigma, revealing that younger mature individuals prefer products that holistically support their independence and health.

Lessons Learned

The COMODAL project revealed that Assistive Technology Products (ATPs) for "Young Older People" (YOPs, aged 50–70) are often abandoned due to aesthetic stigma, poor usability, and lack of alignment with higher-level aspirations. Interviews, surveys, product reviews, and co-creation workshops indicated that YOPs resist being perceived as needing assistance and reject products that reinforce aging stereotypes.

Focus groups and designer interviews emphasized that products must integrate discreet customization, universal design, and timeless appeal. Users prioritized intuitive functionality, high-quality materials, and emotional resonance, preferring products that feel empowering rather than medicalized.

The feature matrix developed through COMODAL offers a design framework that addresses multiple factors: pleasure and hedonic value, discretion, tailorability, economic feasibility, and integration into non-clinical domestic environments. These insights highlight the importance of designing ATPs that enhance autonomy while preserving identity and self-worth.

5.2 MATUROLIFE Project

Another example is the MATUROLIFE Project, which used advanced material science to develop wearable and furniture products for older adults [7]. This project involved interviews and co-creation workshops in nine European countries. Prototypes made with selectively metallized fabrics and integrated sensors were tested to provide personalized services, highlighting the importance of considering user behavior in the design phase.

Lessons Learned

The MATUROLIFE project demonstrated that older adults strongly preferred wearable assistive technologies designed with aesthetics and discretion in mind. Through co-creation workshops across nine European countries, participants consistently emphasized the importance of materials, social identity, and cultural resonance in product acceptance.

Textile-based sensors integrated into everyday objects (bracelets, clothing, chairs) were not only technically viable but also perceived as elegant and non-intrusive. This contributed to increased emotional attachment and reduced stigmatization compared to traditional medical devices. For example, fabrics applied through selective electroplating enabled durable, flexible surfaces without compromising comfort or appearance.

The use of interdisciplinary teams—including designers, engineers, and sociologists—resulted in products that merged functional usability with lifestyle aspirations. The project's iterative prototyping and participatory design strategies reinforced the need to embed emotional and cultural factors early in the development process.

MATUROLIFE also revealed key practical constraints: battery life management, cleaning mechanisms for fabrics, and long-term durability in household environments. These practical constraints highlighted the need for durability testing protocols, now included in the deployment checklist. These insights informed new standards for wearable ATPs aiming to balance invisibility, comfort, and performance in real-world contexts.

5.3 Wheelchair Stability Assessment System

In developing a Wheelchair Stability Assessment System, an innovative methodology was created to assess the stability of wheelchairs [21]. The approach included online research, interviews, focus groups with healthcare professionals, and sketch models to explore design aspects. The question "How would the system be if designed by Apple?" guided the final products' visual simplicity and high perceived value.

Lessons Learned

The Wheelchair Stability Assessment System project revealed that the success of assistive innovations depends not only on technical accuracy, but also on the emotional and symbolic value attributed by users. By applying visual metaphors (e.g., referencing Apple-like simplicity), researchers created high-value concepts perceived as safe and aesthetically desirable.

User research involving healthcare professionals emphasized the importance of iterative co-design and scenario-based testing. The use of online surveys, interviews, and sketches allowed refinement of the product to meet both clinical functionality and user expectations. Sketch prototypes and provocations helped expose unconscious biases and latent design preferences.

The project highlighted that emotional resonance and professional credibility are essential for adoption. Participants preferred devices that communicate stability through visual cues, interface clarity, and minimalistic language — reinforcing trust and ease of use. This supports the broader HCI principle that perceived value is shaped by both usability and social context.

5.4 Ommetje App

The 'Ommetje' Walking App aimed to motivate mature adults to become more physically active by using walking as the main activity [10]. Participants used the app for four months and shared their experiences in group sessions, revealing that the quality of walks was more motivating than the quantity.

Lessons Learned

The Ommetje project illustrated how personal hobbies and interests can serve as intrinsic motivators to increase physical activity among older adults [10]. By using the Leisure Time Canvas tool, researchers revealed that design rooted in personal narratives—not just generic activities—fosters emotional connection and user engagement. Hobbies such as nature walks, cultural exploration, and routine social cycling proved more motivating than abstract metrics like step counts.

Evaluation with 16 older participants showed that users preferred to record unique, meaningful walks (e.g., city trips, forest trails), rather than everyday routes like village errands. This suggests a shift from quantitative feedback to qualitative personalization. Group familiarity also impacted usage: knowing the other app users discouraged routine sharing, while unfamiliar networks might inspire broader participation.

Users valued simplicity, emotional resonance, and personalized recommendations based on leisure interests. Rather than tracking frequency alone, older adults expressed interest in documenting memorable experiences. Design recommendations include integrating photo-based highlights, minimizing technical barriers, and allowing route-sharing within trusted social groups.

These findings reinforce the importance of designing assistive technologies that amplify joy, identity, and autonomy—helping older adults maintain meaningful lifestyles through emotionally intelligent digital tools. These findings directly informed the hobby-based personalization item in the deployment checklist (Section 7.2).

5.5 CollectiveEyes and CollectiveEars

Exploring platforms for collaborative sharing of vision and hearing, the CollectiveEyes and CollectiveEars Project analyzed them from the perspectives of sociomateriality and pleasure [22]. The analysis highlighted the importance of the hedonic perspective for design, opening new opportunities for the CollectiveEars platform.

Lessons Learned

The annotated portfolio analysis of CollectiveEyes and CollectiveEars revealed that incorporating hedonic perspectives—such as socio-, ideo-, and psycho-pleasures—is essential for designing platforms that engage emotional and cultural depth in elderly users. The platforms emphasized shared sensory experiences through collaborative visual and auditory perceptions, fostering empathy and connection even in digitally mediated environments.

From a sociomaterial standpoint, the projects demonstrated that digital artifacts which symbolically "rent out" human capabilities (like sight and hearing) evoke nuanced reflections a bout a gency, privacy, and embodiment. Users appreciated features that allowed immersive experiences without requiring physical movement, such as head gestures for sound focusing or keyword-based visual searches.

Critically, the study found an absence of physio-pleasure in the human perspective, revealing a design opportunity to reintegrate bodily movement and exploration. By linking auditory or visual perspectives to geographic locations, designers could reintroduce physicality into digital experiences—encouraging older users to move toward nearby sources and reconnect with real environments.

Incorporating design annotations rooted in sociomateriality enabled interdisciplinary collaboration and the identification of previously overlooked use cases—particularly within CollectiveEars, whose domain annotations were initially sparse. This approach helped restructure the platform into more emotionally expressive forms, including artful reinterpretations of soundscapes.

5.6 EMPATHIC-VC Project

In the EMPATHIC-VC Project, the interaction with virtual coaching agents was investigated using a Wizard of Oz (WebWOZ) platform [6]. The platform was extended with audio/video functions to simulate interactions based on the GROW model, focusing on nutrition and social engagement. A pilot study showed that older audiences preferred female virtual agents, personalizing EMPATHIC-VC for the target population.

Lessons Learned

The EMPATHIC-VC project, funded by the European Union, developed emotionally intelligent virtual coaching systems aimed at enhancing healthy aging. Within this initiative, the Chatto platform was created as a testbed for multimodal empathetic interaction using Wizard of Oz (WebWOZ) techniques. Chatto integrated facial expression recognition (DeepFace), voice sentiment analysis, and customizable avatars driven by the GROW coaching model.

Usability studies revealed that older adults responded positively to emotionally expressive agents, preferring female avatars with gentle voice tones and socially adaptive behaviors. Caregivers appreciated configuration options that allowed tuning of animations, gestures, and emotional repertoire. The system's ability to deliver empathetic prompts based on real-time emotion input led to increased engagement and reduced loneliness.

Challenges included optimizing latency in natural language responses, selecting culturally sensitive avatar appearances (e.g., animal vs humanoid), and managing the fusion of multimodal emotional signals into coherent reactions. Technical feedback also emphasized the importance of simplifying interfaces and reducing dependency on high-bandwidth connections.

The EMPATHIC-VC/Chatto experience demonstrates that personalized, empathy-aware coaching systems—when co-designed and tested iteratively—can offer s calable e motional s upport f or o lder a dults in both institutional and domestic contexts. These findings underscore the value of emotional adaptability and real-time response in building trust and long-term user acceptance.

5.7 PERGAMEX Project

Another relevant initiative is the PERGAMEX Project (PERvasive GAming EXperiences for @ll), which focuses on designing personalized pervasive gaming experiences for older adults [23]. The project was conducted by research groups from several Spanish universities to promote active aging by enhancing social interactions, particularly intergenerational connections, and improving overall well-being. Throughout the development of gaming experiences, co-creation techniques and affective user experience evaluation methods were applied. Ethical, gender-sensitive, and value-sensitive design aspects were considered during all stages, from study and design to implementation and deployment.

The project provided design and evaluation guidelines for games and resulted in the development of various pervasive gaming experiences, some specifically t argeting o lder a dults a nd o thers f ostering intergenerational socialization. The technologies involved ranged from traditional mobile devices, tablets, and personal computers to more advanced systems such as interactive tables (tangible interaction), Kinect sensors (gesture interaction), virtual assistants (voice interaction), wearables (affective i nteraction), a nd social robots.

Lessons Learned

The PERGAMEX project demonstrated that designing pervasive gaming experiences for older adults requires balancing empathy, inclusivity, and adaptability. Across intergenerational workshops, users expressed a strong emotional connection when the games enabled them to share meaningful stories, collaborate toward common goals, and recognize each other as experts in different d omains. A ctivities b ased o n familiar tasks—like cooking or gardening—empowered older users and helped reverse stereotypical roles.

Online gameplay during the pandemic revealed technological access barriers, especially for grandparents unfamiliar with mobile interfaces. Children often took on facilitative roles, but older users required simplified video conferencing tools and preparatory sessions to engage confidently. Despite these challenges, both groups reported deeper emotional bonds and mutual learning.

Physical interfaces—such as tangible tables, gesture-based Kinects, and social robots—were well received, especially when combined with voice interaction and aesthetic narratives. Experimental tools like CuyAlexa showed that cultural adaptation and physical personalization improve acceptance, particularly in multicultural contexts.

The project also introduced ethical co-design toolkits (ADC-Toolkit and ETHIX) that guided the inclusion of gender-sensitive, value-based frameworks throughout development. Emotional evaluation using facial

expressions, physiological sensors, and affective interaction with Pepper robots revealed promising results for motor rehabilitation and storytelling applications.

These findings support designing intergenerational serious games that are narrative-driven, emotionally resonant, and technologically accessible—offering new paths for empathy, autonomy, and shared joy in aging societies.

6 Practical Tools for Implementation

To complement the findings of the literature review and case studies [6, 7, 8, 21, 10, 22, 23], two practical tools were developed: an Evaluation Matrix and a Deployment Checklist. These instruments aim to support designers, developers, and healthcare professionals in assessing and implementing empathetic assistive technologies in real-world contexts. The tools are designed to be modular and adaptable to different contexts, helping bridge the gap between conceptual empathy and technological deployment.

The Evaluation Matrix (Table 1) provides a structured framework for assessing the key dimensions of empathetic assistive technologies. It was developed by synthesizing the challenges, risks, and successful mitigation strategies identified across the literature and case studies (such as EMPATHIC-VC, PERGAMEX, MATUROLIFE, COMODAL, and Ommetje). Each row in the matrix corresponds to a critical dimension of implementation (e.g., Usability, Aesthetic & Stigma Reduction, Emotional Adaptation, Cultural Sensitivity, Privacy & Autonomy, and Economic Viability). For each dimension, the matrix outlines a design insight, a potential risk, and a recommended mitigation strategy. This matrix serves as a diagnostic tool to evaluate existing or proposed technologies and to identify areas requiring attention during the design and deployment phases.

Table 1: Evaluation Matrix for Empathetic Assistive Technologies

Dimension	**Design Insight**	**Risk**	**Mitigation Strategy**
Usability	Interfaces must accommodate low digital literacy and sensorimotor limitations	Abandonment due to complexity	Guided navigation, multimodal input
Aesthetic & Stigma Reduction	Devices should avoid medicalized appearance through co-designed neutral styles	Social rejection	Wearable formats, empowerment narratives
Emotional Adaptation	Systems must respond to affective signals and measure impact via well-being metrics	Emotional mismatch or misinterpretation	Iterative tuning with sentiment feedback
Cultural Sensitivity	Interfaces and avatars should respect identities with local validation	Low engagement or resistance	Localized symbolic narratives, customizable avatars
Privacy & Autonomy	Emotional data must be transparent, manageable, and algorithmically audited	Perceived surveillance or bias	Consent mechanisms, algorithmic auditing
Economic Viability	Costs should align with socioeconomic realities of target users	High production costs or low adoption in underserved regions	Public health partnerships, modular scalable design

The Deployment Checklist complements the matrix by providing a set of actionable requirements that should be met during the implementation of empathetic assistive technologies. This checklist was derived from the lessons learned in the case studies and is intended to ensure that the technologies are not only empathetic by design but also practical and effective in real-world settings. The checklist includes the following items:

- Multimodal interaction (e.g., voice, gesture, touch) available by default
- Customization of appearance, tone, and interaction speed (including cultural adaptation of avatars)

- Transparent data usage explanation in user-friendly language
- Iterative co-design cycles with diverse older adult groups (e.g., participatory workshops)
- Stigma-reduction strategy (e.g., neutral design, empowerment narrative)
- Support for offline operation or low-bandwidth environments
- Durability & energy consumption testing under real-world conditions
- Training protocols for older adults/caregivers (e.g., simplified manuals, in-person sessions)
- Hobby-based personalization (e.g., walking routes, gardening activities)

Each item in the checklist addresses a critical aspect of deployment that has been shown to influence the acceptance and long-term use of the technology by older adults. For instance, the inclusion of multimodal interaction ensures accessibility for users with varying abilities, while hobby-based personalization enhances engagement by aligning the technology with the user's personal interests.

To measure the effectiveness of empathetic assistive technologies post-deployment, we also recommend tracking the following metrics on an ongoing basis:

- Emotional retention rate ($> 70\%$ as in EMPATHIC-VC)
- Measurable reduction in loneliness scales (e.g., UCLA Loneliness Scale)
- Emotional support satisfaction indices (e.g., Likert scales)
- Adoption rates in low-digital-literacy groups

These metrics provide quantifiable indicators of success and can inform iterative improvements to the technology.

Together, the Evaluation Matrix and Deployment Checklist provide a comprehensive set of guidelines for the design, evaluation, and implementation of empathetic assistive technologies, ensuring that they are not only theoretically sound but also practically viable and culturally sensitive.

7 General Design Recommendations for Empathetic Assistive Technology

This section organizes design recommendations into three dimensions: Usability and Accessibility, Personalization and Adaptation, and Ethical and Social Considerations. These recommendations complement the findings from the case studies and the implementation matrix presented in Section 6, offering conceptual support to the deployment checklist. Together, they establish a foundation for both theoretical and applied advancements in empathetic assistive technologies.

Usability and Accessibility

Interfaces should follow universal design principles, ensuring that senior individuals with varying levels of digital literacy can use them efficiently. Support for multimodal interaction—including voice, gesture, and touch—is essential to accommodate motor and visual limitations. The PERGAMEX and MATUROLIFE projects demonstrated the effectiveness of tangible devices and textile-based sensors, which were preferred for their discretion and simplicity. Designs must minimize cognitive load by avoiding clutter and prioritizing guided layouts with clear navigation.

Personalization and Adaptation

Systems must adapt to individual preferences in tone, speed, interaction style, and visual appearance. Chatto and EMPATHIC-VC showed that older adults value expressive virtual agents tailored to personal needs. Emotion recognition systems should evolve through user interaction, refining responses and offering more natural conversations over time. Compatibility with familiar technologies—such as smartphones and smart speakers—is critical for adoption. The CuyAlexa prototype from PERGAMEX highlights the importance of cultural adaptation for successful implementation.

Ethical and Social Considerations

Empathetic technologies must ensure transparency in data collection and processing. Users should retain control over their emotional and biometric information, with interfaces that explain usage clearly. Multiple projects—like PERGAMEX, COMODAL, and EMPATHIC-VC—revealed that older users fear being replaced rather than supported. Technologies must emphasize that digital tools enhance and complement human relationships, not substitute them. Reducing stigma is key: appearance and language should affirm dignity and avoid age-based stereotypes. Furthermore, economic accessibility must be prioritized through public-private partnerships, as reflected in the Economic Viability dimension of the evaluation matrix. Incorporating narrative-based experiences, as shown in Ommetje and "El Jardín de tus sueños," helps foster shared identity and emotional connection.

8 Limitations and Scope

This study is based on a narrative literature review, which prioritizes thematic synthesis and conceptual depth over quantitative exhaustiveness. As such, while the findings are grounded in peer-reviewed sources and case studies, the analysis of 42 articles, though sufficient for identifying key themes and patterns, may not encompass the entire breadth of the rapidly evolving field. The focus was on relevance and quality within a five-year window, which necessarily limits the volume of included studies. Future work could benefit from a systematic review with broader coverage to validate and extend these findings.

Additionally, the scope of this work emphasizes assistive technologies designed for older adults in digitally advanced regions. The cultural applicability and scalability of empathetic systems in under-resourced or rural settings remain open research questions. Some cited projects were exploratory or piloted on small participant groups, which may not fully represent heterogeneous aging populations. The proposed metrics for continuous evaluation (e.g., emotional retention rates) also require validation in diverse socio-cultural contexts.

Finally, while the article integrates ethical and usability considerations, deeper exploration into privacy regulation compliance, long-term psychological effects, and cost modeling was beyond the scope and should be considered for future interdisciplinary studies.

9 Conclusion

This article explored the role of empathetic assistive technologies in elderly care, highlighting challenges, opportunities, and design principles derived from Human-Computer Interaction research. The analysis indicated that such technologies can significantly improve older adults' quality of life by offering emotional and functional support. However, technological and ethical barriers must be addressed to increase acceptance and effectiveness. Involving older adults through co-design and user-centered methods is essential for creating meaningful and usable solutions.

The case studies analyze provided lessons grounded in real-world implementations. These insights informed the development of two enhanced practical tools: a comprehensive evaluation matrix, and an expanded deployment checklist. Together, they offer actionable guidance for designers, developers, and healthcare professionals aiming to integrate empathy-aware systems in elderly care environments.

Considering identified gaps, several directions for future research are proposed. First, experimental studies should assess the emotional impact of empathetic technologies in residential and domestic settings. Second, the development of more precise models for emotion recognition and adaptive behavior is necessary. Third, strategies for data transparency and user autonomy must be prioritized to address ethical concerns. Fourth, digital inclusion must be promoted by improving accessibility for users with low technical literacy.

Beyond literature synthesis, future work should emphasize prototype development and field testing of empathetic systems. Evaluating emotional engagement, usability, and social outcomes will validate the frameworks proposed. Integrating empathy into assistive technology presents both challenges and opportunities—but with a multidisciplinary, ethical, and inclusive approach, these solutions can foster autonomy, connection, and dignity for aging populations.

Acknowledgment

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Appendix A: Articles used in the Review

Articles used in the Review

Item	Title	Authors	Year	Review
1	World Report on Ageing and Health	World Health Organization (WHO)	2015	This report provides a global overview of ageing and health, emphasizing functional ability, intrinsic capacity, and healthy ageing as policy priorities. It discusses challenges such as chronic disease, social inclusion, and long-term care, offering strategies for integrated health systems and supportive environments. Although not focused on specific technologies, it establishes foundational principles for developing empathy-driven assistive technologies that enhance autonomy, dignity, and social participation among older adults.
2	Global strategy and action plan on ageing and health	World Health Organization	2017	Provides foundational global context on population ageing, highlighting the need for assistive technologies to maintain functional ability and well-being in older adults. It underscores the importance of technology in public health strategies for ageing populations, setting the stage for empathy-driven approaches.
3	Impact of Aging on Empathy: Review of Psychological and Neural Mechanisms	Janelle N. Beadle, Christine E. de la Vega	2019	Review synthesizing evidence that older adults tend to have lower cognitive empathy (understanding others' thoughts) but similar or even higher levels of emotional empathy (feeling compassion) compared to younger adults. Discusses the neural bases for these differences.
4	Midoriko Chatbot: LSTM-based Emotional 3D Avatar	Yu-Ting Wan, Cheng-Chun Chiu, Kai-Wen Liang, Pao-Chi Chang	2019	Presents an emotionally expressive 3D avatar chatbot using LSTM and sentiment analysis for companionship. Focuses on enhancing user experience through multimodal interaction and emotional responsiveness, relevant for empathetic virtual agents.
5	Seniors' Acceptance of Virtual Humanoid Agents	Anna Esposito, Terry Amorese, MariaLucia Cuciniello, Antonietta M. Esposito, Alda Troncone, Maria Inés Torres, Stephan Schlögl, Gennaro Cordasco	2019	Investigates older adults' preferences for virtual agents within the EMPATHIC project. Finds strong preference for female agents, especially for long-term interaction. Highlights the impact of cultural background and technological experience on acceptance and hedonic perceptions.
6	The Dependability of Voice on Elders' Acceptance of Humanoid Agents	Anna Esposito, Terry Amorese, Marialucia Cuciniello, Maria Teresa Riviello, Antonietta M. Esposito, Alda Troncone, Gennaro Cordasco	2019	This conference paper investigates the critical role of voice in older adults' acceptance of virtual agents, comparing preferences across different age groups. Findings show that voice is significantly more important for elders than for younger users, strongly influencing their willingness to interact and their preference for female agents, which is crucial for designing empathetic and accepted assistive interfaces.
7	Voice Assistants and Older People: Some Open Issues	Sergio Sayago, Barbara Barbosa Neves, Benjamin R. Cowan	2019	Identifies key research gaps in Voice Assistants (VAs) for older adults, focusing on user perceptions, interaction barriers, conversational UX, and anthropomorphic design. Aligns with the review's themes of Adaptive Interaction and User-Centered Design.

Articles used in the Review (continued)

Item	Title	Authors	Year	Review
8	The EMPATHIC Project: Mid-term Achievements	Torres, M.I., Olaso, J.M., Schlogl, S., et al.	2019	Presents the mid-term development of an emotionally intelligent virtual coach (EMPATHIC-VC) for elderly users, focusing on multi-modal emotion recognition, spoken dialogue systems, and user acceptance studies which revealed a preference for female agents.
9	A User-Centred Approach to Digitalising Care Homes	Philippa Hedley-Takhar, Angel Jimenez-Aranda, Vitaveska Lanfranchi, Sue Pownall, Lise Sproson, Wendy B. Tindale	2020	This chapter presents a user-centred approach to implementing digital technologies in care homes through two case studies. The "Digital Care Home" project used a tablet app for remote monitoring of residents' vital signs, while the "Care Homes Guide for Dysphagia" developed a co-designed digital tool for managing swallowing difficulties. Key findings emphasize that successful implementation requires co-design with all stakeholders (residents, staff, families), addressing usability barriers, providing continuous training, and ensuring technology complements rather than replaces human care. The study highlights that empathy in design involves understanding the care home's daily rhythms and creating tools that empower staff and reduce distress for residents.
10	Analysis of the interaction between elderly people and a simulated virtual coach	Raquel Justo, Leila Ben Letaifa, Cristina Palmero, et al.	2020	Presents findings from the EMPATHIC project, using a Wizard-of-Oz simulated virtual coach and the GROW model. Analyses show seniors exhibited calm and positive emotional states during interactions, with a preference for female agents. Highlights the importance of co-design, user-centered iterative design, and multimodal emotion analysis (speech, language, face) for building trustworthy human-agent relationships.
11	Applying Design Methods to Promote Older Adults' Walking Activities Based on Their Hobbies and Personal Interests	Marjolein C. den Haan, Rens G. A. Brankaert, Yuan Lu	2020	Presents the "Leisure Time Canvas" tool and the "Ommetje" walking app case study. Shows how designing around personal hobbies and interests (rather than generic health metrics) provides intrinsic motivation for physical activity, emphasizing walk quality and personal meaning over quantity.
12	Assistive Technology (AT) Usability and Adoption: Future Drivers	Avril D. McCarthy and Louise Moody	2020	Examines the critical role of usability engineering and human factors in reducing AT abandonment and ensuring safety. Discusses regulatory standards (e.g., IEC 62366) and analyzes adverse events from poor design. Uses case studies from the Devices for Dignity portfolio to illustrate methods for improving user acceptance and safety in medical and assistive technologies.

Articles used in the Review (continued)

Item	Title	Authors	Year	Review
13	Contemporary Themes in the Design of AT for the Ageing Population: Materiality, Co-design and Cultural Influences	Gabriella Spinelli, Massimo Micocci, Emmanuel Tsekleves, Yu-Han Wang, Wendy Martin, Yonghun Lim, Umber Shamim	2020	This chapter explores key non-functional reasons for the high abandonment rate of Assistive Technologies (ATs) among older adults. It identifies aesthetics, stigma, and lack of emotional connection as critical barriers to adoption. The study advocates for three main design approaches to address these issues: Co-design (designing with older adults), consideration of Materiality (ATs as identity-shaping objects), and Cultural Sensitivity (understanding how cultural frameworks influence AT perception and use). It argues that moving beyond a purely functional view is essential for creating ATs that are desired, emotionally resonant, and effectively adopted.
14	Designing with and for Older People	Joe Langley, Gemma Wheeler, Rebecca Partridge, Remi Bec, Dan Wolstenholme, Lise Sproson	2020	Presents principles and practical guidance for co-designing assistive technologies with older adults, emphasizing valuing different perspectives, adapting methods, visibility, and "less talking, more doing." Illustrates with a Parkinson's service case study to overcome abandonment and "one-size-fits-all" issues.
15	Development of a Wheelchair Stability Assessment System: Design Tools and Approaches	Louise Moody, Paul Magee, Dimitar Stefanov	2020	Presents the design and development of the WheelSense® system, a load-cell based platform for assessing wheelchair stability. Highlights a user-centered, multidisciplinary design approach, the use of tools like the CUbe for ideation, and the importance of aesthetics and emotional resonance (e.g., reducing client anxiety) in assistive technology.
16	Dignity in Ageing: Living Well for Longer	Katherine Jeays-Ward, Vitaveska Lanfranchi, Avril D. McCarthy, Liz Pryde, Lise Sproson, Wendy B. Tindale	2020	Presents the NIHR Devices for Dignity (D4D) development model, a 6-stage framework for creating medical technologies that uphold dignity and independence for ageing populations. Uses case studies (e.g., REACH assistive device, cervical orthosis, portable dialysis) to illustrate the model's application from need identification to adoption, emphasizing co-design and holistic patient needs.
17	Domestic Robots for Older Adults: Design Approaches and Recommendations	Rebecca Wiczorek, Megan A. Bayles, Wendy A. Rogers	2020	provides a comprehensive human-factors framework for designing domestic robots for older adults. It details age-related changes in sensory, cognitive, and motor functions and their implications for Human-Robot Interaction (HRI). The study classifies robot support into three categories: Activities of Daily Living (ADLs), Instrumental ADLs (IADLs), and Enhanced ADLs (EADLs), and categorizes robots as assistive, social, or social-assistive. It strongly advocates for a user-centered design process, including iterative prototyping and Wizard of Oz techniques. Critical ethical considerations such as safety, privacy, and autonomy are emphasized as foundational to building trust and ensuring the robot complements, rather than undermines, the user's independence and emotional well-being.

Articles used in the Review (continued)

Item	Title	Authors	Year	Review
18	Experiencing Aging: Analogue Versus Virtual	Deana McDonagh and Debra Reardanz	2020	Compares physical aging suits (GERT) and Virtual Reality (VR) simulations for building empathy and understanding of aging challenges. Highlights the emotional impact of VR for end-of-life scenarios and the physical realism of suits for daily tasks, advocating for a blended approach in design research.
19	MATUROLIFE: Using Advanced Material Science to Develop the Future of Assistive Technology	Louise Moody and Andrew J. Cobley	2020	Describes an EU project using selective metallization of textiles to create discrete, aesthetically pleasing smart assistive products (furniture, clothing, footwear) for older adults. Emphasizes a user-centered, co-design approach to overcome stigma and abandonment of traditional assistive technology.
20	Promoting Personhood for People with Dementia Through Shared Social Touchscreen Interactions	Sonja Pedell, Stu Favilla, Andrew Murphy, Jeanie Beh, Tanya Petrovich	2020	This book chapter presents a co-design and interest-based approach to developing touchscreen applications (games and music) for people with dementia. It emphasizes promoting personhood, social interaction, and well-being through shared, empathetic technology use. The work aligns with empathetic AT principles by focusing on emotional engagement, user-centered design, and reducing stigma through meaningful, interest-driven activities.
21	Strategies for Mitigating the Injury Risks of Using Motorised Mobility Scooters	Selby Coxon, Jennie Oxley	2020	Examines safety risks and injury data related to Motorised Mobility Scooters (MMS). Proposes a three-tiered mitigation strategy focusing on age-friendly infrastructure design, MMS vehicle design that upholds user dignity and avoids misleading vehicular aesthetics, and the development of regulations, standards, and user assessment guidelines.
22	The Development of a Feature Matrix for the Design of Assistive Technology Products for Young Older People	Andree Woodcock, Jane Osmond, Nikki Holliday	2020	Presents a design feature matrix developed from the COMODAL project, identifying key factors (e.g., aesthetics, stigma reduction, usability, pleasure) to prevent abandonment and increase adoption of Assistive Technology Products (ATPs) among "Young Older People" (aged 50-70).
23	The Value and Place for Empathy in Designing for Older People	Andree Woodcock, Deana McDonagh, Paul Magee, Mike Tovey	2020	This work explores the use of Discrete Learning Interventions (DLIs) and experiential, empathetic modelling—such as aging suits or gerontology suits—to enhance design students' understanding of older adults' experiences. The approach aims to expand the students' "empathic horizon," positing that developing empathy through direct, felt experiences leads to more sensitive, inclusive, and emotionally resonant designs that move beyond mere functional solutions. This methodology directly supports and exemplifies the principles of Empathy-Driven Design and Co-Design methodologies.

Articles used in the Review (continued)

Item	Title	Authors	Year	Review
24	Unlocking Service Flow—Fast and Frugal Digital Healthcare Design	John Knight, Elliot Ross, Chris Gibbons, Tom McEwan	2020	This chapter presents the "Flow Methodology," an agile, user-centered service design framework developed through an e-consultation project for the UK NHS. It emphasizes rapid prototyping, co-design with stakeholders (patients, GPs, administrators), and the use of the Technology Acceptance Model (TAM) to understand adoption barriers. Key findings highlight that perceived usefulness and ease of use are critical for staff acceptance, while concerns about internet connectivity and maintaining patient-GP rapport are significant for older adults. The methodology advocates for designing "Minimum Viable Services" that incrementally improve based on real usage data, balancing technological innovation with practical, frugal implementation to create sustainable and empathetic digital health services.
25	Co-designing Strategies to Provide Telecare Through an Intelligent Assistant for Caregivers of Elderly Individuals	Mateus Monteiro, Luciana Salgado, Flavio Seixas, Rosimere Santana	2020	Presents a co-design methodology for creating an intelligent conversational agent (MarIANA) to support informal caregivers of older adults with chronic diseases. The study, involving health professionals, identifies communicative strategies, emphasizes the need for personalized, clear, and imperative dialogues, and highlights the agent's role in bridging caregivers and healthcare teams within a challenging socio-economic context.
26	Improving the Quality of Life of Individuals with Dementia Using Personal Digital Media	Nayer, K., Coxon, S.	2020	Presents the development and testing of a personalized multimedia system ("MemoryBox") with adaptable interfaces for people with dementia, demonstrating reduced depression and anxiety while increasing autonomy and quality of life through non-medicinal intervention.
27	Elder user's attitude toward assistive virtual agents: the role of voice and gender	Anna Esposito, Terry Amorese, MariaLucia Cuciniello, Maria Teresa Riviello, Antonietta M. Esposito, Alda Troncone, Maria Inés Torres, Stephan Schlögl, Gennaro Cordasco	2021	This study examines how gender and voice interaction capabilities influence older adults' acceptance of and attitudes toward virtual agents. The findings reveal a strong preference for female agents, which is particularly pronounced when they utilize a voice interface. This combination is shown to be critical for user engagement, perceived usefulness, and the design of empathetic agents. Furthermore, the study reveals that an individual's prior experience with technology moderates their perceptions of the agent's attractiveness and their overall level of engagement.
28	Intergenerational computer interaction in a co-creation application	Manel Díaz Llobet, Eva Cerezo, Mercè Teixidó Cairol, Rosa M. Gil Iranzo	2021	This paper presents the design and development of a web-based co-creation application for intergenerational interaction between children and older adults. It highlights the importance of user-centered design and adapting interaction styles (e.g., button-based for seniors) to different user groups' needs and digital literacy, directly contributing to the design of empathetic and accessible technologies that foster social connection.

Articles used in the Review (continued)

Item	Title	Authors	Year	Review
29	Artificial intelligence for older people receiving long-term care: a systematic review of acceptability and effectiveness studies	Kate Loveys, Matthew Prina, Chloe Axford, et al.	2022	A systematic review of AI-enhanced interventions (social robots, environmental/wearable sensors) in long-term care. Found mixed acceptability and effectiveness, with high risk of bias in studies. Informs the review's analysis of real-world effectiveness and ethical considerations.
30	A Proposal for a Taxonomy of Augmented Humanity Based on Current Needs, Topics and Challenges	Graciela Guerrero, Fernando Jose Mateus da Silva, António Pereira, Antonio Fernández-Caballero	2023	This paper proposes a comprehensive taxonomy for Augmented Humanity (AH), categorizing technologies that enhance human physical, intellectual, and social capabilities. It is highly relevant to empathetic ATs, as it provides a conceptual framework for understanding how technology can augment social skills like empathy and communication, directly aligning with the goals of designing systems that support the emotional and social well-being of older adults.
31	Chatto: An Emotionally Intelligent Avatar for Elderly Care in Ambient Assisted Living	Carla Mendes, Rafael Pereira, José Ribeiro, Nuno Rodrigues, António Pereira	2023	Presents "Chatto", a conversational avatar that uses facial expression recognition (DeepFace) and voice sentiment analysis to adapt its responses and animations. Caregiver customization and usability tests with older adults showed a positive and emotionally supportive experience.
32	Ethical Challenges in the Development of Virtual Assistants Powered by Large Language Models	Andrés Piñeiro-Martín, Carmen García-Mateo, Laura Docío-Fernández, María del Carmen López-Pérez	2023	Analyzes ethical risks (bias, privacy, misinformation) of LLM-powered virtual assistants for public services, proposing guidelines for transparency, fairness, and user autonomy, with implications for elderly care.
33	Human-in-the-loop AAL Approach to Emotion Capture and Classification	Rafael Pereira, Carla Mendes, Roberto Ribeiro, Jose Ribeiro, António Pereira	2023	Proposes a human-in-the-loop system for emotion recognition in Ambient Assisted Living, using user-labeled facial images to improve model accuracy and personalization. Addresses data scarcity and ethical concerns in emotion detection for older adults.
34	Projecte PERGAMEX: jocs pervasius per a tothom	Eva Cerezo Bagdasari, Francisco Luís Gutiérrez Vela, Francisco José Perales López	2023	Presents the PERGAMEX project, focusing on designing personalized pervasive gaming experiences for older adults to promote active aging, social interaction (especially intergenerational), and well-being using co-design and affective evaluation methods.
35	Sharing Human Seeing and Hearing and Their Annotated Portfolio	Risa Kimura, Tatsuo Nakajima	2023	Proposes an annotated portfolio method to analyze empathetic platforms (CollectiveEyes/CollectiveEars), highlighting hedonic (pleasure) and sociomaterial perspectives to enhance user experience and identify design opportunities for the elderly.
36	Stress monitoring using wearable sensors: IoT techniques in medical field	Talaat, F. M., El-Balka, R. M.	2023	Proposes a technical framework for stress detection using IoT and machine learning, comparing algorithms like Random Forest and XGBoost. Contributes to the technological foundation for emotion recognition in empathetic technologies, particularly relevant for health monitoring in older adults.

Articles used in the Review (continued)

Item	Title	Authors	Year	Review
37	Do you like me? Behavioral and physical features for socially and emotionally engaging interactive systems	Anna Esposito, Terry Amorese, Marialucia Cucinello, Antonietta M. Esposito, Gennaro Cordasco	2023	Provides an overview of factors affecting user acceptance of virtual agents, robots, and chatbots, focusing on appearance, gender, behavior, and emotional expressions. Introduces and details specialized questionnaires (VAAQ, RAQ, VAVAQ) for evaluating acceptance, developed within EU projects like EMPATHIC, to guide the design of empathetic assistive technologies for older adults.
38	ElliQ, an AI-Driven Social Robot to Alleviate Loneliness: Progress and Lessons Learned	Broadbent, E., Loveys, K., Ilan, G., Chen, G., Chilukuri, M.M., Boardman, S.G., Doraiswamy, P.M., Skuler, D.	2024	Presents a real-world case study of an empathetic AI-driven social robot designed to combat loneliness in older adults. Demonstrates high user engagement, a 95% reduction in loneliness in some pilots, and provides practical insights into implementation challenges and the development of clinical reporting tools.
39	Empathy in Virtual Agents: How Emotional Expressions can Influence User Perception	S. Rings, S. Schmidt, J. Janßen, N. Lehmann-Willenbrock, F. Steinicke	2024	Investigates how emotionally expressive virtual agents induce emotional contagion in users, finding that empathetic facial feedback increases user expressiveness, particularly for more empathetic individuals, with implications for therapeutic applications.
40	Exploring the Role of Empathy in Designing Social Robots for Elderly People	Berardina De Carolis, Giuseppe Palestra, Giovanna Castellano	2024	This study proposes a human-in-the-loop system for emotion recognition in Ambient Assisted Living environments to enhance interactions for older adults. The system addresses key challenges of data scarcity and ethical concerns by incorporating user-labeled facial images, which improves model accuracy and personalization. An evaluation with 30 older adults, using a social robot equipped with this empathetic dialog system (driven by text and facial emotion recognition), demonstrated that it was perceived as significantly more usable and provided a more positive user experience compared to a non-empathetic version.
41	Perceived Empathy in Mixed Reality: Assessing the Impact of Empathic Agents' Awareness of User Physiological States	Zhuang Chang, Zirui Xiao, Kangsoo Kim, et al.	2024	Investigates how Empathic Mixed Reality Agents (EMIRAs) with accurate awareness of user physiological states (via skin conductance) significantly enhance perceived empathy, trust, social connectedness, and social presence compared to unaware or inaccurately aware agents. Provides design implications for using physiological sensing to foster empathy while addressing privacy concerns.
42	The Illusion of Empathy? Notes on Displays of Emotion in Human-Computer Interaction	Andrea Cuadra, Malte F. Jung, Maria Wang, Lynn Andrea Stein, Nicola Dell, Deborah Estrin, James A. Landay	2024	Critically examines how Conversational Agents (CAs) and Large Language Models (LLMs) display empathy, revealing shortcomings such as inconsistent, flippant, and hollow empathetic responses, indiscriminate empathy towards harmful ideologies, and potential to exploit user trust and marginalize vulnerable groups.