

Designing Ethical and Inclusive Voice Assistants Through Co-creation with Older Adults

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Abstract—Voice assistants are becoming increasingly significant in promoting active aging and digital skills to utilize these technologies fully. This study investigates the acceptance of standalone voice-only assistants among digitally competent older adults in Spain. Besides, it identifies features deemed significant by older adults, providing insights for designers of voice assistants. The research addresses three key questions: the impact of the co-creation process on technological acceptance, factors influencing adoption, and ethical considerations in developing voice-only assistants for older adults. The method employed was an exploratory mixed-methods design in an online co-creation process comprising three stages: an initial session for familiarization, a game-based co-creation session utilizing the Activity Design Cards Toolkit to extract primary requirements for prototype design considering ethics and inclusive values, and a final session to evaluate and refine the prototypes. Findings indicate that the co-creation process significantly enhances technology acceptance among older adults with high digital competence.

Keywords: older adults, co-creation, voice assistants, technological acceptance.

1. Introduction

The global population of individuals aged 65 years and older is expected to increase by 25.1% by 2050 [1]. In Spain, older adults comprise 19.65% of the population, aligning with European trends [2]. As the aging population grows, there is an urgent need to promote healthy aging and wellbeing, goals aligned with the 2030 Sustainable Development Agenda [3]. Active aging, which aims to optimize health, participation, and security, is a key approach to enhancing the quality of life for older adults [4]. In Spain, the "Operational Framework for Elderly People" outlines four key areas to promote active aging: employment, social participation, independent living, and non-discrimination [5]. Despite these efforts, older adults frequently face social and health challenges, such as loneliness and social isolation, which negatively impact their physical and mental health [6,7]. Various factors, including sociodemographic, economic, and educational conditions, contribute to this isolation and impede active aging [8]. The COVID-19 pandemic has further exacerbated these challenges while highlighting the potential of technology to improve the lives of older adults [9,10].

In recent decades, studies on digital competencies in adult populations have predominantly focused on individuals with limited technological skills [11, 12]. However, this approach has introduced a bias by overlooking older adults with higher levels of digital competence [13]. Current and future generations of older adults are increasingly digitally adept, demanding greater access to digital services, learning resources, leisure activities, and assistive technologies [11]. Given the growing digital competence among older adults, there is a pressing need to rethink how technological services targeting this group are designed and delivered. Unlike the numerous studies on adults with limited technological skills, this study provides a fresh perspective by focusing on digitally competent older adults. This demographic remains underexplored but is experiencing rapid expansion.

Additionally, there is an increasing need for personalized digital leisure experiences, crucial for promoting social inclusion and emotional wellbeing. The co-creation of digital leisure experiences using standalone voice-only assistants may offer an innovative solution for this demographic. This exploratory study aims to understand new forms of interaction with these technologies, thereby contributing to an improved quality of life for digitally competent older adults. By focusing on this population, the study aims to address a gap in existing research and contribute to developing advanced technological solutions tailored to the needs of a generation that demands personalized digital services.

This study explores technology acceptance in terms of usage, intention, attitude, perceived usefulness, and perceived ease of use among older adults using digital technologies, specifically standalone voice-only assistants. We focus on standalone voice-only assistants, devices that facilitate interaction solely through voice input and output, without a visual screen component, and are hands- and eyes-free. We aim to identify the features that older adults perceive as most significant for voice assistants. These features can be helpful for designers of voice assistants for older adults. In this sense, our research questions were:

- RQ1. How does the co-creation process impact the technological acceptance of standalone voice-only virtual assistants among older adults?
- RQ2. What key factors influence older adults' adoption of standalone voice-only virtual assistants?
- RQ3. What are the key ethical considerations in developing standalone voice-only virtual assistants for older adults?

To provide a more integrated view of the study's scope, it is important to clarify that understanding the new forms of interaction enabled by standalone voice-only virtual assistants among older adults involves more than analyzing interaction patterns alone. It requires a comprehensive examination of the factors that facilitate or hinder technology acceptance (usage, intention, attitude, perceived usefulness, and ease of use), as well as the ethical considerations that may influence both adoption and daily use. These elements are inherently linked: the way older adults perceive and adopt these technologies directly shapes how they experience and engage in new forms of voice-based interaction. Therefore, our research questions, focusing on the co-creation process, adoption factors, and ethical considerations, are intentionally formulated to explore these interconnected dimensions and support the design of more inclusive and responsible voice assistant technologies for older adults.

This study makes a distinct contribution to the existing body of knowledge by addressing a critical and underrepresented demographic: digitally competent older adults. While much of the previous research on technology adoption among aging populations has focused on individuals with limited digital skills, this study shifts the perspective to a generation increasingly familiar with and demanding of advanced digital services. By exploring this group, we uncover new patterns of technology acceptance and interaction that challenge traditional assumptions about older adults' engagement with digital technologies. Furthermore, the use of a co-creation methodology allows participants to actively influence the identification of functional and ethical design requirements for standalone voice-only virtual assistants. This participatory approach generates novel insights into user expectations and ethical concerns, providing actionable guidance for the development of more personalized, inclusive, and responsible voice-based technologies. In doing so, the study not only extends existing models of technology adoption but also contributes to integrating ethical considerations directly into the design process, a critical but often overlooked aspect in this research domain.

The paper is organized as follows: the background and related work are explained, followed by a description of the methods and materials, and then a presentation and discussion of the results. Finally, the main conclusions and limitations of the study are presented.

2. Background and related works

This section provides a structured overview of key concepts and findings relevant to this study. First, foundational frameworks, such as the Technology Acceptance Model (TAM) [14] and its adaptations, are presented. Second, the role of co-creation in designing user-centered technologies is examined. Lastly, a review of prior research on voice assistants is presented.

2.1. Technology Acceptance Models

The acceptance and adoption of new technologies among older adults has increased research interest over recent decades, driven by the growing integration of digital tools in everyday life, including healthcare, entertainment, and communication technologies. The TAM, first introduced by [14], is one of the most widely recognized frameworks for understanding user behavior toward technology. According to TAM, two key variables — perceived usefulness and perceived ease of use — determine users' attitudes toward a technology, which subsequently influence their intention to use and actual usage behavior [15, 16].

In the context of older adults, perceived usefulness is directly related to how effectively a technology supports their daily activities, promotes autonomy, and enhances quality of life. For instance, older adults might find voice assistants useful if these devices can help them manage health-related tasks, communicate with family, or provide reminders for medication. On the other hand, perceived ease of use relates to how intuitive and accessible the technology is, a crucial factor given that older adults might face cognitive and physical challenges that could impact their ability to engage with complex interfaces.

TAM has been adapted for use in various domains across different user groups and technological contexts. For instance, the Healthcare Technology Acceptance Model (H-TAM) [17] has been employed to explore the acceptance of healthcare technologies among older adults. H-TAM expands on the original TAM by considering the specific needs and challenges older adults face, particularly in managing chronic health conditions such as hypertension [17]. Studies employing H-TAM have shown that older adults are more likely to adopt healthcare technologies when they perceive them as beneficial for their health and easy to integrate into their daily routines, emphasizing the importance of usability and perceived health benefits.

Complementing TAM, the Unified Theory of Acceptance and Use of Technology (UTAUT) extends the understanding of technology adoption by incorporating additional constructs such as performance expectancy, effort expectancy, social influence, and facilitating conditions [18]. UTAUT offers a more comprehensive framework by acknowledging the impact of external factors, including social norms and resource availability, on user behavior. In the case of older adults, social influence—the encouragement or support from family, friends, or caregivers—often plays a critical role in their decision to adopt or reject new technologies [19].

Research has shown that the social environment of older adults can significantly affect their interaction with new technologies. For instance, Murciano et al. (2022) [20] conducted a systematic review examining digital technology acceptance models applied to older adults and identified factors such as health status, emotional responses (e.g., anxiety or enjoyment), and previous experience as significant determinants of technology adoption. Similarly, Cubillos and Rienzo [21] highlighted the need for more nuanced approaches in designing cognitive assessment tools for older adults. These studies suggest that technology acceptance models, such as TAM and UTAUT, provide valuable frameworks. However, the growing heterogeneity among older adults, particularly in digital competence, necessitates adaptations considering these evolving dynamics.

Beyond general technology acceptance models, specific instruments have been developed to assess older adults' attitudes and competencies related to technology. For instance, the TechPH [22] measures attitudes toward technology through two dimensions: enthusiasm for technology and anxiety or distrust toward technology. Developed in the context of health technology adoption, TechPH offers a broad measure of general attitudes rather than assessing skills or proficiency with specific devices. Although TechPH resembles TAM in its emphasis on attitudinal aspects, it differs in that it provides a general evaluation of technological attitudes rather than focusing on a particular technology.

Additionally, the Mobile Device Proficiency Questionnaire (MDPQ) [23] and the Computer Proficiency Questionnaire (CPQ) [24] are valuable tools for assessing specific computer and mobile device skills, respectively. The CPQ focuses on computer skills, including internet navigation, e-mail communication, and file management. Meanwhile, the MDPQ

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evaluates competencies in operating smartphones and tablets across various domains, including communication, entertainment, privacy, and troubleshooting. These instruments are particularly useful for quantifying skill levels across various digital domains, especially among older adults with diverse technology experiences. However, it is important to clarify why we did not employ these instruments in the present study. While the CPQ and MDPQ are validated and reliable tools, they were not designed to assess digital competence specifically related to voice assistant interaction. The CPQ and MDPQ measure proficiency in using computers and mobile devices, respectively, but do not address the unique interaction skills required for voice-based systems. These skills include formulating effective voice commands, understanding verbal feedback, adapting to speech recognition errors, and managing conversational interactions. These capabilities are crucial for assessing competence with voice assistants but are not captured by the CPQ or MDPQ.

Given that our study aimed to explore the acceptance of standalone voice-only assistants among older adults who were already proficient in digital technologies, we adopted a pragmatic approach to confirm participants' skills through self-reported high competence and practical verification. This approach ensured that participants met the required digital competence threshold without relying on instruments not designed for the specific context of voice assistant interaction.

In this regard, the TAM and related frameworks remain relevant for understanding the acceptance of standalone voice-only assistants. However, they must be adapted or supplemented to account for the distinctive competencies required for voice interaction with standalone voice-only assistants, in contrast to broader studies focusing on computers or mobile devices.

2.2. The Importance of Co-Creation in Technology Design

Co-creation represents a critical approach in modern technology development, particularly for user groups with specific needs, such as older adults. The concept of co-creation is rooted in the idea that users should actively participate in designing and developing the products or services they will eventually use [25]. This methodology contrasts with traditional top-down approaches, where users are passive recipients of a final product. Co-creation allows users to contribute their insights, preferences, and values throughout the design process, ensuring that the final product aligns with their real-world needs and expectations [25].

The relevance of co-creation in the context of older adults and digital technologies has been explored in several studies. For example, Colombo-Ruano et al. (2021) [26] investigated how older adults' participation in online co-creation sessions influenced their acceptance of voice assistants. This study found that participants who directly engaged in the design process were likely to feel a sense of ownership over the technology, resulting in greater motivation to use the final product. Such participatory approaches enable older adults to provide feedback on interface design, language settings, and privacy controls, which is crucial for addressing the usability and trust concerns often accompanying new technologies.

Co-creation is particularly valuable when designing technologies for older adults because it helps address the accessibility and usability challenges often overlooked in standard design processes. Studies have shown that older adults adopt technologies tailored to their cognitive and physical abilities. In this regard, Glover et al. (2020) [27] conducted workshops to co-create health technologies with older adults, finding that participants were more engaged when the design process took into account their unique limitations and preferences [28]. Co-creation not only enhances the usability of the final product but also empowers older adults by making them active contributors to the development of the technology. This empowerment can significantly increase their willingness to adopt and use the technology.

Moreover, co-creation has fostered intergenerational collaboration in technology design, where older adults and younger users co-design products that appeal to both groups. For instance, Havukainen et al. (2020) [29] explored the co-creation of digital games between older adults and younger participants. This study emphasized that co-designing across generations helped bridge the digital divide, with older adults benefiting from the digital expertise of younger users and vice versa, enhancing the usability and enjoyment of the final product.

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The co-creation approach also enables the integration of ethical considerations, such as privacy, security, and data ownership, which are particularly relevant concerns in designing voice assistants and other smart technologies. Older adults often express concern about how their data will be used, especially concerning personal or health-related information [30]. By involving older adults in the design process, developers can better address these ethical concerns, ensuring that technologies align with users' values and provide transparent, user-friendly options for managing data. The Activity Design Cards (ADC) Toolkit [31], used in the present study, was crucial in facilitating discussions around ethical issues and enabling participants to voice their preferences regarding how their data should be collected and used.

2.3. Prior Research on Voice Assistants and Older Adults

Voice assistants such as Amazon Alexa, Google Home, and Apple Siri have gained prominence recently due to their ability to provide hands-free assistance, deliver information, and manage daily tasks through simple voice commands [32]. For older adults who may experience difficulties with traditional input methods, such as keyboards or touchscreens, voice assistants offer a potentially transformative technology that could enhance accessibility and autonomy.

Several studies have investigated how older adults perceive and use voice assistants, with mixed results. While many older adults recognize the potential benefits of these devices, concerns about usability, privacy, and reliability often limit their widespread adoption. For example, Bolaños et al. (2021) [33] found that older adults in Colombia expressed a strong interest in using voice assistants for tasks such as setting reminders, managing health appointments, and accessing entertainment. However, the study also highlighted significant concerns about privacy and the potential for technology misuse.

Another key finding from research in this area is the role of motivation and user experience in determining whether older adults will adopt voice assistants. Studies show that older adults are more likely to engage with technologies when they perceive them as enhancing their independence and quality of life. Valera et al. (2021) [34] demonstrated that smart home technologies, including voice assistants, can help older adults maintain active lifestyles by monitoring physical activity, managing health-related tasks, and staying connected with loved ones. Their findings suggest that voice assistants have the potential to promote active aging, particularly when designed with the specific needs of older adults in mind.

Nevertheless, these technologies must be perceived as trustworthy and user-friendly so that older adults can fully adopt voice assistants, emphasizing the importance of personalization and feedback mechanisms in designing technologies for this demographic. Havukainen et al. (2020) [29] found that when older users could customize their voice assistants and receive clear, timely feedback on their commands, they were more likely to trust and use the technology. Customization allows users to feel that the technology adapts to their preferences rather than forcing them to adapt to the technology, which is crucial for promoting long-term engagement.

The literature on voice assistants and older adults highlights several factors influencing adoption, including usability, personalization, privacy concerns, and social influence [35]. While voice assistants hold great promise for improving the lives of older adults, their design must carefully consider these factors to ensure that they are accessible, trustworthy, and aligned with the needs and values of this diverse population [36]. Additionally, voice assistants can enhance the digital competencies of older adults by providing intuitive, voice-based interfaces that simplify technology interaction. This accessibility encourages engagement with digital tools, fostering skills such as information retrieval and task management [12].

A particularly important aspect of these studies is the influence of cognitive or physical limitations. Chen et al. (2023) [37] and Chen et al. (2021) [38] identified difficulties related to mobility, hearing, and cognitive decline as significant

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barriers to effective use of virtual assistants. Trajkova and Martin-Hammond (2020) [39] noted that technological unfamiliarity contributed to a limited perception of the devices' usefulness. The predominant focus on accessibility improvements reflects the challenges faced by older adults with various physical or cognitive impairments. However, previous research has primarily focused on participants with limited technological proficiency and age-related impairments. At the same time, less attention has been given to those with higher digital competence and distinct professional needs.

3. Method

3.1. Study Design

This study employed an exploratory mixed-methods design to investigate the technological acceptance of standalone voice-only assistants among digitally competent older adults. Given their evolving digital competencies, an exploratory approach enabled us to capture diverse perspectives and responses, which is critical for forming a comprehensive understanding of their interaction with emerging technologies. The study was framed within co-creation, which refers to collaborative design processes that involve users at all stages of product or service development. Co-creation ensures that participants are not just passive subjects but actively contribute to creating technological solutions tailored to their needs [40]. The design incorporated both qualitative and quantitative elements, enabling a rich, multidimensional understanding of how older adults perceive and interact with voice assistants [41].

The co-creation process consisted of three main stages: an initial session and familiarization, a game-based co-creation session with the ADC Toolkit [31], an ethical design toolkit to extract the main requirements for the prototype design, and a final session to evaluate and refine the prototypes (Figure 1). Each stage informed the subsequent one, allowing for continuous refinement of the design process and adaptation of the methods used. This flexible design accommodated the participants' evolving perspectives as they became more deeply engaged with the co-creation process and the voice assistant technology.

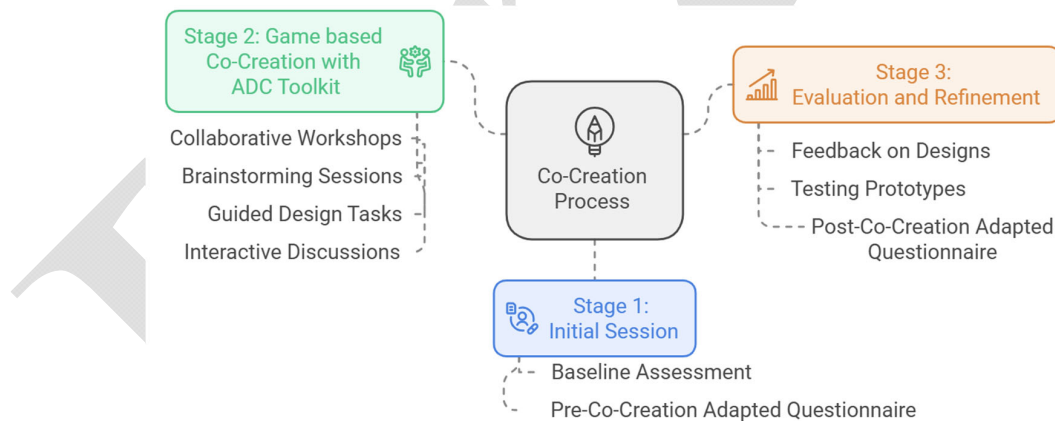


Fig. 1. Different stages of the co-creation process.

3.2. Participants

Recruitment was conducted using non-probabilistic purposive sampling, which is appropriate when the goal is to explore a specific subgroup within a population. In our case, participants were intentionally selected based on their high level of digital competence. This criterion was central to our study, as our objective was to understand the technological acceptance of standalone voice-only assistants among older adults who already possess digital skills. This focus contrasts with the dominant approach in the literature, which often centers on older adults with little or no technological proficiency [11, 13, 42].

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To ensure participants met this profile, they first completed an ad hoc characterization questionnaire addressing three key dimensions: (1) demographic variables; (2) digital habits and competence; and (3) self-perceived sensory abilities and self-esteem, including auditory perception, particularly relevant for interaction with standalone voice-only assistants. All self-reported scores are on a scale of 1 to 5. All participants reported high levels of technological proficiency, with maximum scores (5/5) on self-assessed scales measuring technology use, self-esteem, visual and auditory perception, and manual motor skills. Additionally, a pre-session was conducted before the co-creation activities to test each participant's internet connectivity and ability to utilize the digital tools required. This practical step enabled us to confirm that their equipment functioned properly and that they possessed the necessary digital skills to participate effectively in a virtual environment. This procedure ensured the presence of advanced digital competence, even if self-reported, by verifying the practical abilities required for the study.

Participants were included based on the following criteria:

- Demonstrable digital skills, as assessed via self-reported experience with digital technologies and through practical pre-session tasks.
- Access to a computer with internet connectivity, webcam, and audio functionality.
- Willingness to complete a pre-session equipment test to verify readiness for online participation.
- Informed consent for participation in all study phases, including completion of pre- and post-session questionnaires.

Eleven participants were recruited for the exploratory study, representing a diverse group regarding geographical location within Spain and professional background. The participants included seven men and four women, aged 62 to 79 (average age: 67.5 years). All participants held at least a bachelor's degree, with the majority (7 out of 11) holding doctoral degrees. Their professional backgrounds were predominantly academic, with university professors in computer science, physics, medicine, psychology, and education. The diversity of the expertise of the sample allowed us to explore the various ways in which older adults with advanced digital competencies interact with standalone voice-only assistants.

Despite the small sample size, typical in exploratory studies, the participants provided rich qualitative data that contributed to the depth of the findings. Moreover, using small samples in co-creation methodologies, particularly when involving older adults, can be scientifically justified based on several key principles prioritizing the depth of engagement, contextual specificity, and ethical considerations. This approach aligns with the qualitative and iterative nature of co-creation, where the primary aim is to produce user-centered designs that reflect the unique needs and experiences of the participants rather than generalizable findings [43].

Besides, designing technologies for older adults reveals biases rooted in ageism and assumptions about their low digital skills [42]. Ageist stereotypes portray older adults as frail, cognitively limited, or incapable of engaging with technology, influencing design language and decisions [42]. This results in their exclusion from critical stages, particularly prototyping, under the misconception that their input is unnecessary. Older adults are not homogeneous; they differ significantly regarding health status, cognitive abilities, technological literacy, and personal experiences. Co-creation with small samples enables the inclusion of diverse voices while maintaining a manageable scale for iterative design processes. Research has shown that diversity within a small, purposively selected sample can yield a wide range of insights, making the co-creation process both rich and representative of the population's variability [44, 45]. Co-creation is inherently iterative, requiring continuous feedback, refinement, and adaptation. Working with small groups facilitates the adaptability of the methodology, allowing researchers to tailor the co-creation activities to the evolving needs and feedback of older adult participants. This adaptability is particularly relevant in the context of older adults, who may have varying levels of participation due to their physical or cognitive limitations. Older adults often face logistical challenges, including mobility issues, health constraints, and limited time availability, which limit their capacity to participate in large-scale studies. Small samples in co-creation are more ethical, as they reduce participant burden, allowing for more flexible participation without compromising engagement quality. Logistically, smaller groups are easier to manage, ensuring that the sessions are meaningful, accessible, and productive for both the participants and researchers. Ethical considerations are crucial when working with older populations, as research must prioritize the wellbeing and comfort of participants throughout the entire process [30, 46].

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Co-creation methodologies often prioritize collecting rich, qualitative data, such as personal narratives, experiences, and opinions, over quantitative measures of generalizability. In this context, a small sample is appropriate for capturing the depth and complexity of older adults' experiences, which can inform more meaningful and user-centered designs. This qualitative depth is particularly important when designing for vulnerable or marginalized groups, as it ensures that the solutions are grounded in the real-world experiences of the participants [47, 48]. Thus, the value of small samples lies in their ability to provide detailed, actionable insights rather than statistically generalizable conclusions.

3.3. Instruments and materials

3.3.1. Adapted TAM Questionnaire

The study employed TAM questionnaire, providing pre-and post-session measures of participants' technology acceptance. The questionnaire was divided into three key phases:

- *Pre-Co-Creation*: Collected before the first session to establish baseline attitudes and technology acceptance levels.
- *Mid-Co-Creation*: Administered after the second session to assess participants' perceptions of the co-creation process and voice assistant designs.
- *Post-Co-Creation*: Collected after the final session to evaluate participants' overall acceptance of the technology and willingness to use the designed voice assistants in their daily lives.

We have used different types of closed predefined answers in these three phases, such as binary answers (yes/no), Likert scales (e.g., every day of the week, several times in a week, once in a week, once in a month or never; or always, usually, often, sometimes, never), and multiple choice answer (e. g., Do you use different digital technological devices efficiently, such as Smartphones (Yes/No), Computers (Yes/No), Tablets (Yes/No)). The TAM questionnaire was adapted to reflect the specific context of voice assistants and the older adult population. The adaptation of the TAM questionnaire was carried out through the Delphi technique in its phases: a) formulation of the problem, where the objective and the task to be performed by the experts were defined; b) selection of experts, chosen for their knowledge of the topic consulted: psychology, human-computer interaction, and education, ensuring the questions were relevant and understandable to the target population; c) preparation and launching of the questionnaires; d) the questions' validation of the degree of relevance from 1 to 10 (where one valued with very little and 10 with a lot); and e) validation results. Kendall's coefficient of concordance ($W = 0.2668$) was used to assess inter-judge reliability, ensuring that the adaptations were valid and reliable [26]. These adjustments concerning the formulation of the questions were made based on the experts' proposals. Each proposal involved a minor change in the formulation. Once the adjustments were made, the final questionnaire was reformulated for use with the participants.

3.3.2. Activity Design Cards (ADC) Toolkit

The ADC Toolkit was employed during the co-creation sessions to guide the design activities and ensure participants' contributions were structured and focused. The ADC Toolkit organizes design tasks according to thematic cards that prompt reflection on various aspects of technology design, including ethics, accessibility, diversity, gender perspective, and user engagement [31]. The toolkit's inclusive and participatory approach was particularly well-suited to this study, as it enabled older adults to express their design preferences and concerns in a structured yet creative manner. The thematic cards were used to facilitate discussions on topics such as ethical design considerations (including privacy and data security concerns), personalization (how voice assistants could adapt to individual users' preferences and needs), and long-term use (how voice assistants could be integrated into participants' daily routines).

3.3.3. Digital tools: Alexa, Amazon Echo Dot, Google Meet, and Jamboard

For this study, we selected the Amazon Echo Dot, a compact smart speaker featuring the voice-only assistant Alexa, as our voice assistant. This device enables a range of functionalities, including controlling smart home devices, playing music, retrieving information, and more, all through intuitive voice commands. Key features of the Echo Dot include robust voice control capabilities, allowing users to interact with Alexa to play music, set alarms, control compatible smart devices, and access information such as weather updates and news. Additionally, it connects seamlessly to

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streaming services like Amazon Music, Spotify, and Apple Music and pairs with other speakers via Bluetooth to enhance the audio experience. The device is compatible with various smart devices, such as lights, thermostats, and plugs, simplifying home automation with voice commands. Furthermore, it incorporates a microphone deactivation button to ensure user privacy when needed.

For online co-creation sessions, we utilized Google Meet, a video conferencing tool that facilitates online co-creation by enabling real-time participant collaboration. Its key features support co-creation, and its integration with Google Workspace applications, including Docs, Sheets, and Slides, allows participants to collaborate on editing documents during meetings. Participants can share their screens to present documents, spreadsheets, or presentations, ensuring all members are aligned and can contribute effectively.

Features like virtual whiteboarding through Jamboard enable brainstorming and idea sharing, fostering a collaborative environment. We used this functionality, in particular, for the game-based approach co-creation activity.

3.4. Procedure and Data Collection

The data collection process was divided into three phases, corresponding to the three stages of the co-creation process (Figure 1). Each phase was developed through two-hour online sessions, employing both qualitative and quantitative methods to comprehensively understand participants' experiences with voice assistants. We describe the three sessions (S1, S2, S3) corresponding to the three stages of the co-creation process (Figure 2).

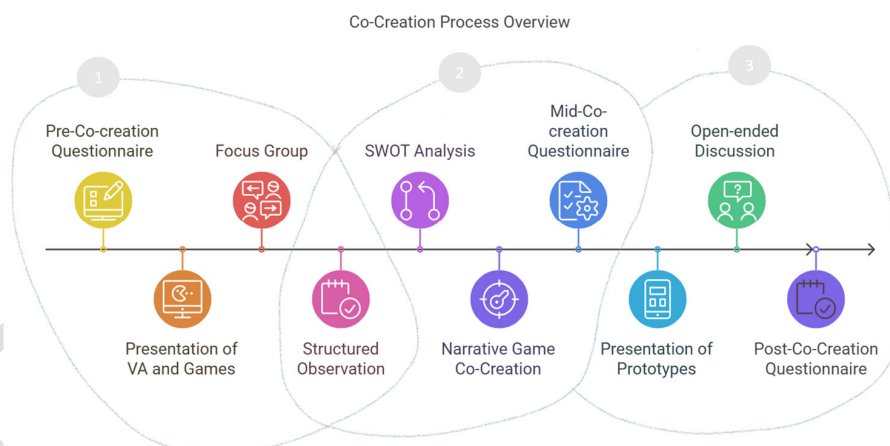


Fig. 2. Procedure and data collection through an online co-creation process.

- S1. Baseline Assessment and Initial Familiarization

The first session introduced participants to the study and collected baseline data. It was conducted online using Google Meet, a platform familiar to most participants. The primary goal of this session was to gather demographic information and assess participants' initial attitudes toward voice assistants using a pre-co-creation TAM-based questionnaire.

In addition to demographic data, the questionnaire captured key variables related to participants' intention to use, attitude toward technology, perceived usefulness, and perceived ease of use. Participants were also asked about their previous experience with digital technologies and voice assistants. The session included a guided discussion to familiarize participants with voice assistants, highlighting their potential applications in health management, daily life tasks, and leisure activities.

Alexa was introduced as our chosen voice assistant, and we presented two games and one application utilizing the Amazon Echo Dot device (Figure 3). The interaction with the device was made only with voice, without a visual interface. The two games were True or False, and Simon Says. Additionally, we presented an application named "Demo

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Caretaker" to demonstrate other possibilities for voice assistants to address health-related issues in everyday life. The two games ("True or False" and "Simon Says") and the health-related application ("Demo Caretaker") were selected based on their potential to elicit engagement across different dimensions of the TAM, including perceived usefulness, ease of use, and motivation. These tasks allowed us to observe user interaction with voice-only interfaces in contexts that combine entertainment, cognitive stimulation, and health-related functionality, which are commonly explored in studies of technology adoption by older adults.

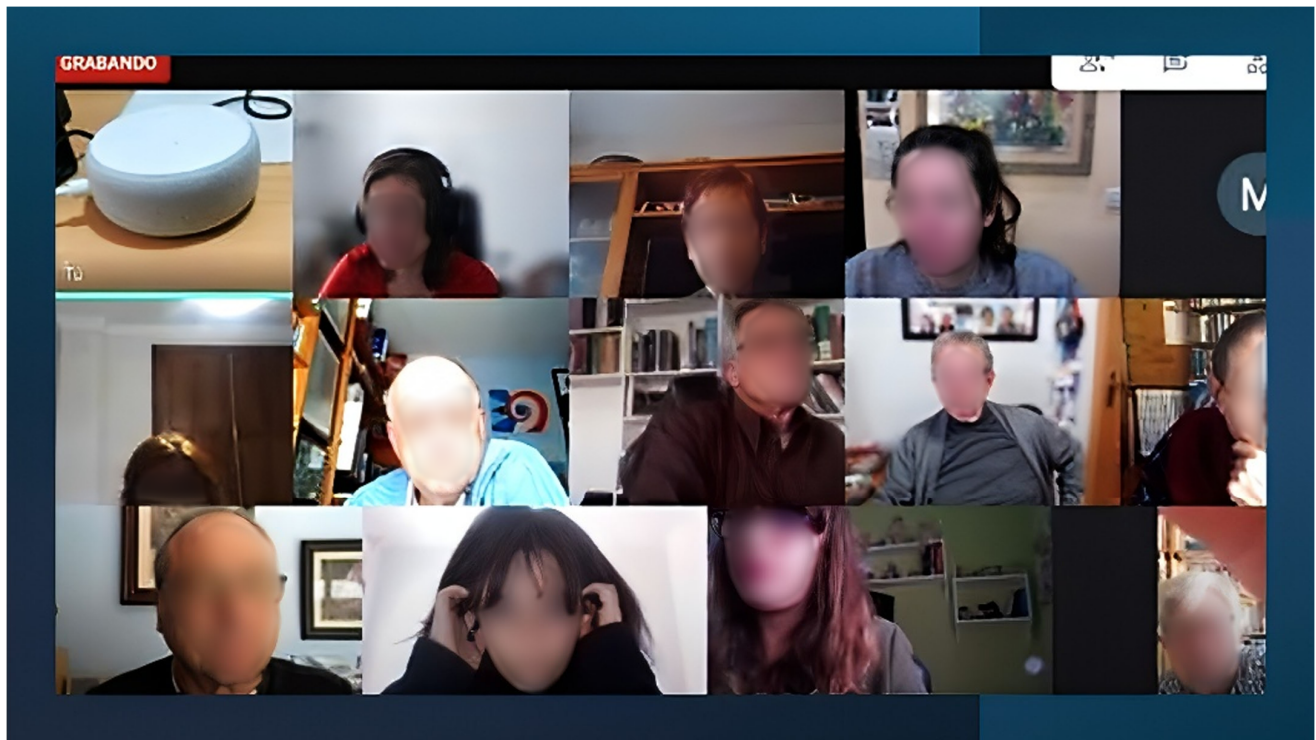


Fig. 3. The online session for game-based co-creation was conducted on Google Meet using Alexa running on the Amazon Echo Dot device.

We employed various techniques, including focus groups and observational instruments, and recorded the session on video. Additionally, a SWOT Analysis (Strengths, Weaknesses, Opportunities, and Threats) was conducted at the end of the session.

- S2. Game-Based Co-Creation Process and Design Participation

The second session was the heart of the co-creation process, and its main goal was to extract the requirements for creating the prototype. It was designed as a participatory workshop in which participants were actively involved in the ideation and design of voice-assisted digital experiences. The session lasted approximately two hours and employed a game approach developed using the ADC Toolkit. This interactive method allowed participants to explore potential uses of voice assistants playfully and engagingly (Figure 4).

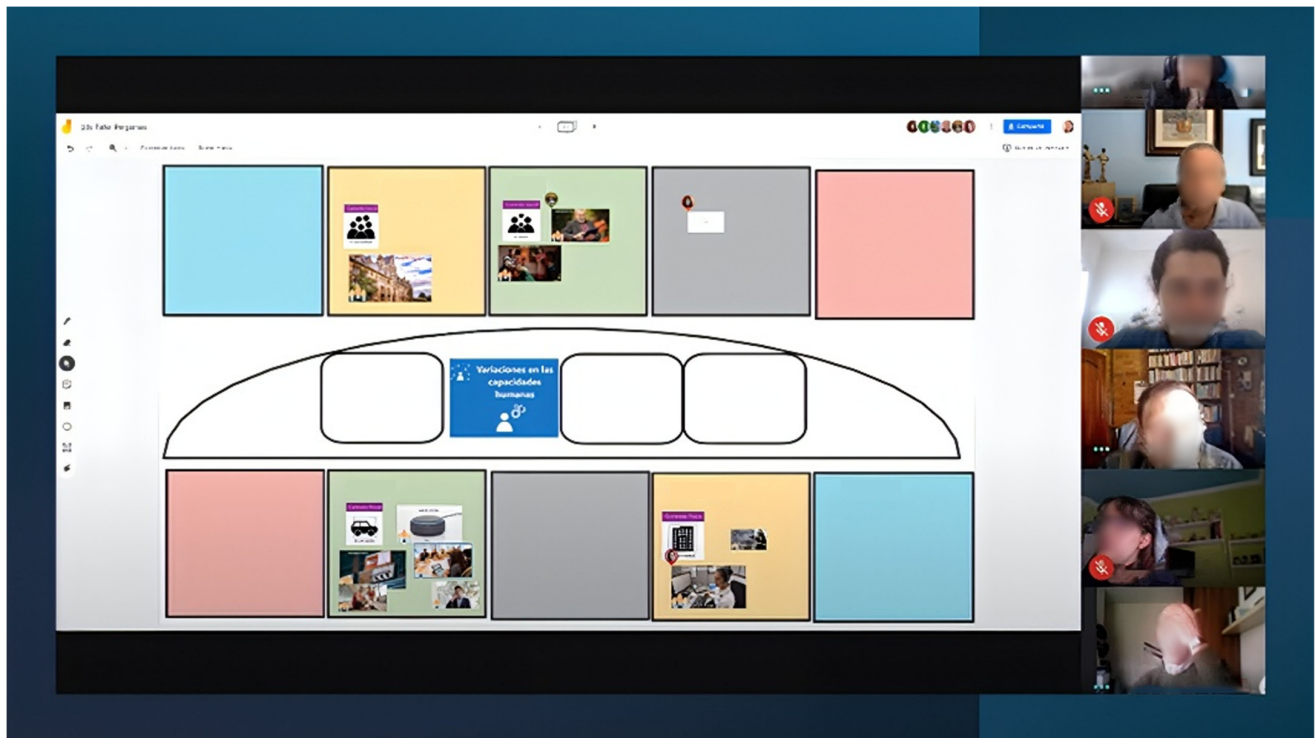


Fig. 4. The online session for game-based co-creation was conducted on Jamboard in Google Meet.

The ADC Toolkit facilitated the structuring of activities around key themes such as:

- *Reliance on machines*: Examining how older adults feel about entrusting daily tasks to automated systems.
- *Design of micro-interactions*: Exploring the design of seamless, intuitive interactions between users and voice assistants.
- *Variation in human capabilities*: ensuring that the voice assistant design is inclusive and accessible to individuals with varying cognitive and physical abilities.
- *Extended use scenarios*: investigating long-term engagement with voice assistants and their potential integration into participants' routines.

During the co-creation session, we employed a structured storytelling game called “Once upon a time...” as part of the ADC Toolkit. The storytelling game aims to promote creativity and collaboration. It allows participants to articulate their ideas and preferences regarding voice assistant functionalities. The game structure allowed participants to explore various use cases in a playful yet structured environment, including health monitoring, entertainment, information retrieval, and social connectivity. The game's design encouraged participants to explore and discuss various functionalities of the voice assistant while promoting collaborative storytelling.

The game “Once Upon a Time...” is a collaborative and competitive storytelling structured as follows (Figure 5): The participants were divided into two teams facing each other in a one-on-one format. The purpose of this division was to encourage creativity and engagement while maintaining a friendly, competitive environment. A designated narrator initiated the game by beginning the story with the phrase, “Once upon a time.” The narrator's role was crucial for maintaining the narrative's coherence, ensuring the rules were followed, and scoring the participants' interventions. Participants were given cards individually, including various topics, scenarios, or keywords related to voice assistants. The objective was to continue the story logically and engagingly, incorporating the themes and concepts presented on each card. Each participant had to link their narrative to the previous intervention, ensuring a coherent and flowing storyline. The narrator assessed whether the participants' contributions were relevant to the card's theme and the

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ongoing storyline. Points were awarded based on creativity, coherence, and adherence to the topic. The team with the highest score at the end of the session was declared the winner.

Additionally, the competitive element added motivation and excitement to the co-creation process, enhancing engagement and participation.

Through this game, participants were encouraged to reflect on the functionalities of voice assistants, expressing preferences, frustrations, and suggestions. The storytelling framework enabled participants to describe real-life scenarios where voice assistants could enhance their daily routines, revealing valuable insights into desired features and ethical concerns.

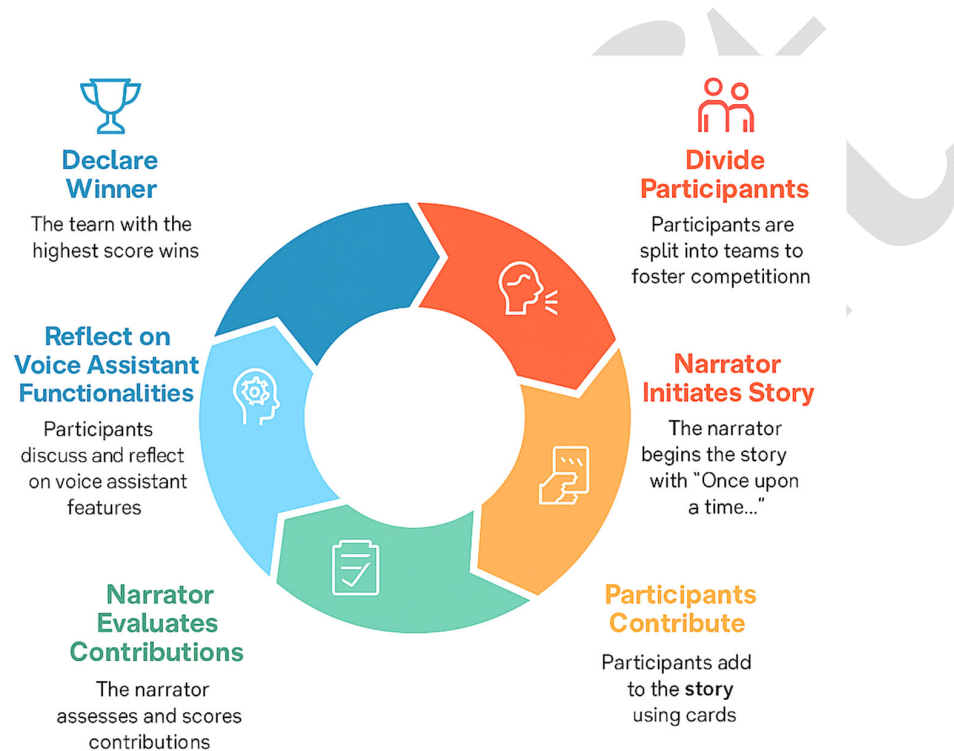


Fig. 5. Conceptual Diagram of the "Once Upon a Time..." Storytelling Game.

Structured observation was employed throughout the co-creation sessions. Researchers documented participants' verbal and nonverbal feedback, including their preferences, frustrations, and suggestions. This qualitative data provided insight into the features that older adults prioritized in the design of voice assistants, such as personalization, ease of use, and privacy safeguards.

- S3. Evaluation and Post-Co-Creation Assessment

The final session evaluated the prototypes and digital experiences developed during co-creation. Participants interacted with the co-created voice assistant prototypes developed for this session and provided feedback on their experiences. The evaluation focused on the practical usability of the prototypes and whether the voice assistants met participants' expectations and preferences. Participants completed a post-co-creation TAM-based questionnaire designed to measure changes in their attitudes toward the technology, their intention to use the voice assistants, and their perceptions of the technology's usefulness and ease of use following direct engagement with the prototypes. This session also allowed for open-ended discussions, where participants could provide detailed feedback on what they liked and disliked and how they envisioned future improvements.

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3.5. Ethical standards

This study adhered to rigorous ethical standards, ensuring the protection of participants' rights and data privacy. The research protocol was approved by the Bioethics Commission of the University of La Laguna (Ref. CEIBA2020-0416), and all procedures were conducted in accordance with the principles outlined in the Declaration of Helsinki. Special care was taken to comply with the General Data Protection Regulation (GDPR) 2016/679 of the European Union and Spanish Law 3/2018, which protects personal data and digital rights. Participants were informed of their rights regarding collecting, storing, and using their personal data, and explicit informed consent was obtained before participating in the study. Confidentiality was maintained throughout the study, and all data were anonymized before analysis.

4. Results

Table 1 summarizes the key findings of the co-creation sessions organized around the research questions presented in Section 1. This table provides a structured overview of the results related to technological acceptance (RQ1), factors influencing adoption (RQ2), and ethical considerations (RQ3). Each key finding is supported by direct participant comments and complemented with observations and implications derived from their advanced digital competence. This comprehensive analysis helps identify critical improvement areas and highlights participants' expectations for adaptability, personalization, ethical safeguards, and broader functional utility of standalone voice-only assistants.

Table 1. Research questions (RQs), key findings, examples of supporting participant comments, and observations

RQs	Key findings	Examples of supporting participant comments	Observations / Implications
RQ1	Increased perceived usefulness post-co-creation	<i>"I would recommend the health applications co-created."</i>	Co-creation enhances understanding and appreciation of usefulness; design participation fosters greater acceptance.
	Enhanced autonomy and confidence using voice assistants	<i>"I feel autonomous and secure using Alexa."</i>	Digital familiarity enhances control and independence, reinforcing confidence and usability.
	High intention to use voice assistants	<i>"Learning to use a new tool improves my self-esteem."</i>	Positive interaction encourages a willingness to adopt; familiarity aids integration in daily life.
	Improved perception of digital devices after co-creation	<i>"Participating in these sessions improved my vision of digital devices."</i>	Co-creation has a positive impact on attitudes, helping participants recognize the broader technological value.
	Ease of use compared to traditional devices	<i>"Voice interaction is simpler than using a keyboard or mouse."</i>	Voice interfaces reduce barriers; digitally savvy users compare and prefer efficient modalities.
RQ2	Demand for flexibility, adaptability, and natural dialogue	<i>"The answers are very rigid, very limited. I would say the lack of versatility."</i>	Advanced users expect adaptive, fluent systems; they reveal gaps in natural language interaction.
	Expectation of personalization and contextual awareness	<i>"Alexa, instead of saying the blood pressure pill, can you tell me the name of the pill?"</i>	Participants expect AI to handle real-world complexity and personalization, especially in health.
	Broader functional utility: health, leisure, education, social connectivity	<i>"This interaction... allows you to explain concepts that can be complex." / "A great tool for the association..."</i>	Tech-savvy users recognize broader application potential; design should go beyond simple tasks.
	Entertainment and mental stimulation potential	<i>"It would also help as entertainment, especially for older adults. So, perhaps, they would not feel so lonely."</i>	Adoption is driven by perceived emotional and cognitive benefits; design should include leisure elements.
	Reliability and technical performance as critical factors	<i>"The interaction is often limited by technical failures or lack of connectivity."</i>	Higher expectations demand robust systems; technical failure undermines trust in the technology.
	Voice assistants as tools for education, research, and training	<i>"This interaction... allows you to explain concepts that can be complex."</i>	Digitally competent users see potential for cognitive enhancement, research, and education. Adapting voice assistants to these scenarios may increase acceptance and engagement.
	Concerns about privacy, data control, and transparency	<i>"Now do not listen, this is private. And that it disconnects." / "That is recorded in the cloud."</i>	Digital awareness drives the desire for data control and security; privacy management must be built in.

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RQ3	Risk of over-reliance and dependence	<i>“An overreliance on this item could cause some problems until it is detected.”</i>	Awareness of tech dependence necessitates balance in design to preserve autonomy.
	Desire for user agency and control over technology	<i>“I feel safer when I can control what the device stores or records.”</i>	User control is central to trust; systems must offer intuitive, robust data and interaction settings.
	Concerns about data storage and potential misuse	<i>“That [data] is recorded in the cloud.”</i>	Transparency and protection are key to adoption; ethical data handling is critical for trust.

Below, the detailed results of this study are presented in three parts, corresponding to the phases of data collection: (1) the baseline assessment of participants' attitudes and technology acceptance before the co-creation process, (2) insights gained from the game-based co-creation sessions using the ADC Toolkit, and (3) post-co-creation evaluation of the voice assistant prototypes and participants' final technology acceptance.

4.1. Baseline Assessment

At the study's outset, participants completed the pre-co-creation TAM-based questionnaire to assess their initial perceptions of voice assistants and general attitudes toward technology. This questionnaire served as a baseline for comparison with later measures and helped characterize participants' readiness to engage with voice assistants.

The results revealed that participants generally had a positive attitude towards digital technologies, affirming their daily use and the facilitation of their daily activities through digital devices, including mobile phones, computers, tablets, and other electronic devices (Figure 6). They also claimed to use such devices while communicating and entertaining themselves, such as listening to music, reading news, or watching videos. This prior experience with digital devices was also complemented by an expressed willingness to learn how to use digital devices efficiently. However, when asked about their handling of different digital devices, their response frequency is only 50% in the case of voice assistants, while it is 100% in the case of computers and smartphones.

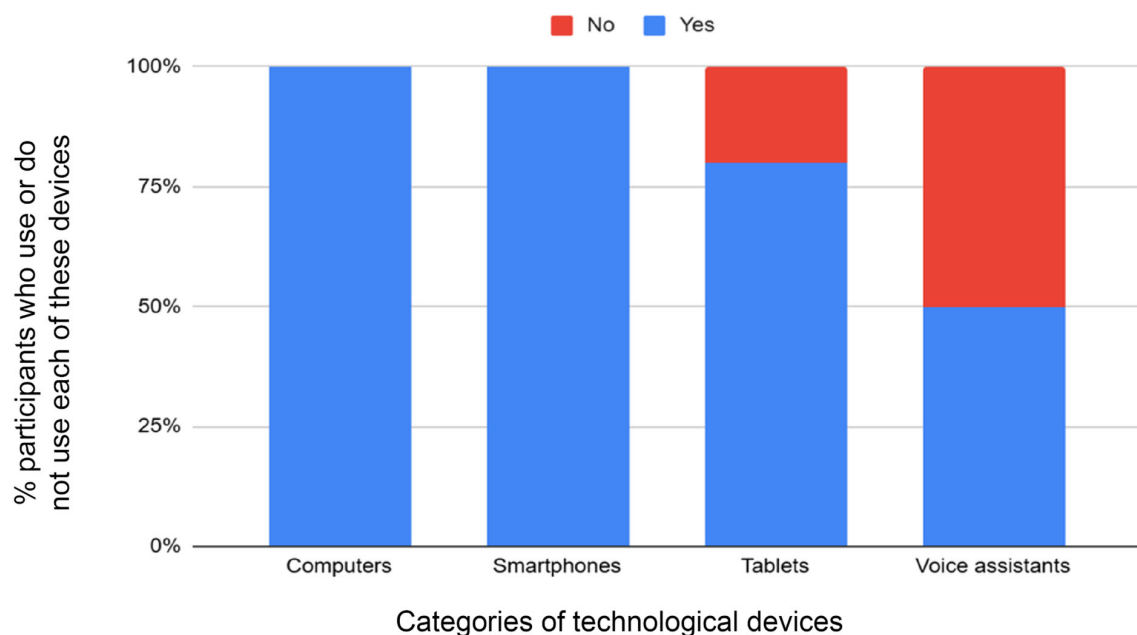


Fig. 6. Answers to the question “Do you use different electronic devices such as computers, tablets, mobile phones..?” of the pre-co-creation phase TAM-based questionnaire.

As per the results of our SWOT Analysis at the end of our first co-creation session, after presenting some possibilities of use for our chosen voice assistant, we resumed the following key factors indicated by the participants:

- *Strengths* to the perceived usefulness, as the participants said, could be useful for vulnerable people such as older adults, people with learning barriers, people with disabilities, or people living in a supervised situation, such as in a “supervised flat” by the government. A “supervised flat” suggests a context of assisted or semi-independent living, where structured guidance (e.g., reminders, routine instructions, or task sequencing) provided by a voice assistant could support users with cognitive disabilities like Down syndrome. As an example for the latest issue, we would exemplify it using the words of one participant: *“I am the president of a Down syndrome Association, and I see this intelligent system as very useful for the association, especially for the supervised flat, not only to play but also to give you the tasks.”* [Participant 11]. This insight reflects the participant’s professional experience rather than direct use by individuals with disabilities.
- *Weaknesses* were identified in the interaction mechanism, such as the perceived limitations of the low versatility of the voice assistant, the necessity of having a very good connection for making the interaction possible, possible technical shortcomings, or the slowness of the interaction. As one of the participants addressed: *“The answers are very rigid, very limited. I would say the lack of versatility.”* [Participant 1].
- *Opportunities* were found for the voice assistants related to care and companionship, such as remembering medicine intake. *“Regarding the opportunities, one of the most important things [we considered] was the care of people. There were also other important considerations: it could enhance the children's education and facilitate activities promoting positive interaction. The memory would also be enhanced. It would also help as entertainment, especially for older adults. So, perhaps, they would not feel so lonely, or doing repetitive tasks such as watching television, so in a way, it would also be a matter of companionship.”* [Participant 4].
- *Threats* to their privacy and intimacy are due to their recording and storage in the cloud, and their independence and autonomy are due to a possible excess of trust. As one of our participants said, *“Over-reliance and dependence on this element could become a problem. Maybe I am contradicting myself now, but when I was telling him if he wanted the red pill or the blue pill, maybe an overreliance on this item somehow had some dysfunction that could cause some problems until it is detected. So, I do not know if dependency could become a problem.”* [Participant 4].

Overall, the baseline data indicated that participants were open to adopting standalone voice-only assistants and could easily identify their strengths and opportunities for use. Nevertheless, there were also clear areas of hesitancy regarding privacy, security, and ease of use in interactions with the voice assistants.

4.2. Insights from the Game-based Co-Creation Process

The game-based co-creation session served as the central phase of this study, during which participants actively designed and ideated ways to integrate standalone voice-only assistants into their daily lives. Throughout this process, participants were encouraged to reflect on their needs, preferences, and concerns, which provided valuable insights into how older adults with advanced digital competence envision their interactions with voice assistants.

Our analysis revealed that participants' advanced digital literacy influenced their interaction preferences, expectations for adaptability, and critical awareness of technological limitations. Several themes emerged from the co-creation sessions, as follows:

- *Desire for Flexibility and Adaptability:* Many participants expressed frustration with the perceived rigidity and limited versatility of Alexa’s responses, reflecting their expectation for more natural, fluid, and adaptable interactions. For instance, Participant 1 stated: *“The answers are very rigid, very limited. I would say the lack of versatility.”* Similarly, Participant 10 emphasized the need for greater flexibility and fluidity in communication, noting that voice interactions should approximate natural language to be effective: *“In general, the technologies of this type, at least verbally, lack fluency. It needs to be refined a bit more to approximate our language.”*
- *Expectation of Personalization and Contextual Awareness:* The participants' high digital competence was also evident in their desire for customized interactions, particularly in contexts requiring specificity and contextual

awareness. For example, Participant 4, reflecting on the use of Alexa for medication reminders, mentioned: *"If Alexa tells them: 'Did you take the blood pressure pill?', my father would say: 'Alexa, instead of saying the blood pressure pill, can you tell me the name of the pill?'. Because it is a constant struggle at home to avoid confusion between pills."* This comment suggests an expectation for the assistant to adapt to user preferences and provide precise information based on the user's context. This advanced requirement differs from typical voice assistant use cases reported in the literature.

- *Concerns about Privacy and Ethical Use:* While privacy concerns are common across all age groups, our participants, due to their digital competence, displayed a more nuanced understanding of privacy risks and desired greater control over data management. Participant 5 mentioned: *"I find that threat tremendous, right? That someone, for example, and that, that is recorded in the cloud, right?"*. Additionally, Participant 11 raised concerns about how to disable the assistant to ensure privacy during sensitive conversations temporarily: *"Now, do not listen; this is private. And it disconnects."* Rather than rejecting the technology, participants suggested ways to enhance transparency, control, and customization of privacy settings, which contrasts with more generalized concerns about privacy found in other studies involving less digitally proficient populations.
- *Perceived Utility for Diverse Use Cases:* Due to their familiarity with technology, participants envisioned more sophisticated and varied use cases beyond typical functions such as playing music or checking the weather. Participant 1 identified educational and research opportunities: *"This interaction, I see it as a great opportunity because it allows you to explain concepts that can be complex. So, I see this interaction as a great opportunity."* Likewise, Participant 11 highlighted the potential for voice assistants to support task management and reminders for older adults and individuals with cognitive disabilities: *"I also see it as a great tool for the association, especially for the supervised flat... not only to play but also to give you tasks."* These comments illustrate how our participants' high level of digital competence influenced their perceptions and expectations of voice assistants. Unlike studies involving broader populations with varying technological skills, our participants exhibited a proactive and critical approach, identifying opportunities for improvement and expressing clear requirements for enhanced functionality, flexibility, and privacy.

Also, during the game-based co-creation session, participants identified several key functionalities they would like to see in a voice assistant, specifically those that could enhance their daily routines and promote active aging. These included:

- *Health Monitoring:* Many participants expressed interest in using voice assistants to manage their health, particularly for medication reminders, tracking physical activity, and scheduling appointments with healthcare providers. This functionality was considered essential, especially for maintaining independence as they aged.
- *Leisure and Entertainment:* Another frequently mentioned feature was the potential for voice assistants to offer entertainment options, such as playing music, providing access to audiobooks, and suggesting new hobbies or activities. Participants emphasized that these features could reduce feelings of isolation and promote mental wellbeing.
- *Social Connectivity:* Participants desired voice assistants to facilitate communication with family and friends, including sending messages, making calls, and organizing virtual meetings.
- *Information Retrieval:* The ability to quickly access information, such as news, weather updates, and directions, was highly valuable. Participants indicated that standalone voice-only assistants could be a convenient tool for accessing information, eliminating the need for more complex devices like smartphones or computers.
- *Education and Research:* Participants acknowledge the potential of voice assistants for cognitive stimulation, academic research, and educational purposes.

4.3. Insights from the Post-Co-Creation Evaluation

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Following the completion of the co-creation, participants were asked to interact with the prototypes of the standalone voice-only assistants developed based on their input. The post-co-creation TAM-based questionnaire assessed changes in participants' attitudes toward the technology, their intention to use the voice assistants, and their overall satisfaction with the co-creation process.

4.3.1. Increased Perceived Usefulness and Ease of Use

The post-co-creation questionnaire results indicated a marked increase in participants' perceived usefulness of voice assistants. 83.3% of participants reported agreeing or strongly agreeing to recommend the co-created applications from the previous session, which we find to be very significant. Participants now believed they could use the voice commands efficiently, answering that they could always do it in 16.7% and almost always in 83.3%. Furthermore, all of them declared that they almost always recognize the functions of the chosen voice assistant. All of them also reported feeling autonomous and secure when interacting with devices such as Alexa. This result represented a notable shift from the baseline assessment, in which participants had been more uncertain about handling various digital devices. In addition, participants stated that it was easier to interact with a voice assistant device than with other digital devices (such as a mouse or keyboard) in 66.7% of cases.

4.3.2. Intention to Use

Similarly, there was a significant improvement in the intention to use, with 66.7% of participants indicating that they planned to automate some of their tasks using digital devices, such as those referenced below (Figure 7). This change can be attributed to the participatory nature of the co-creation process, which enabled participants to design and utilize standalone voice-only assistants tailored to their specific needs and preferences.

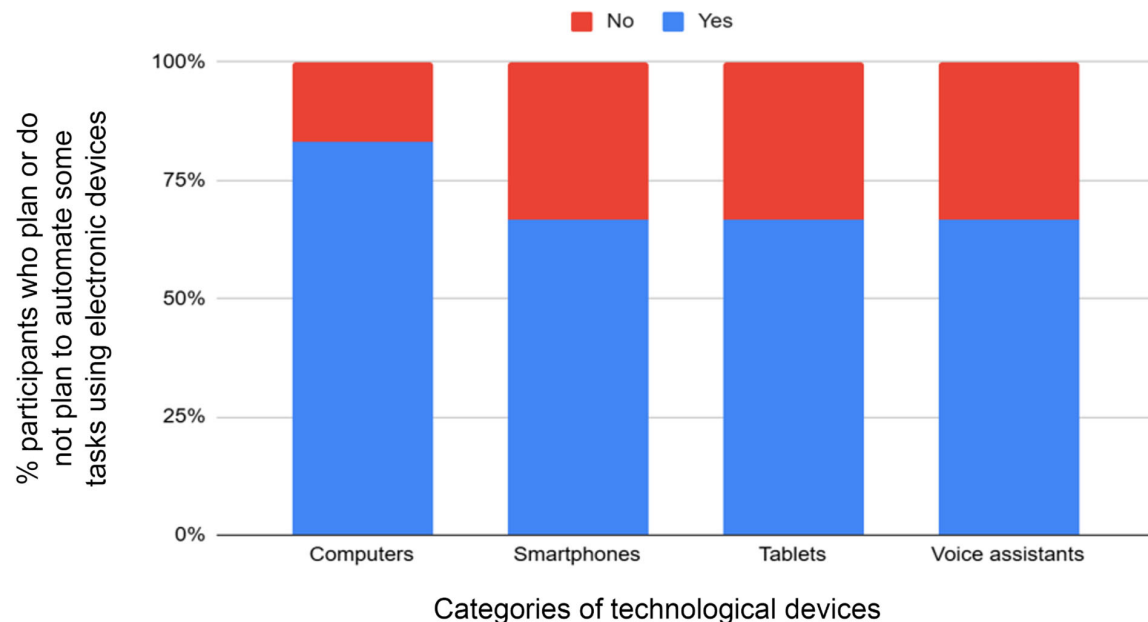


Fig. 7. Answers to the question “Do you plan to automate some of your tasks using electronic devices such as...?” of the post-co-creation phase TAM-based questionnaire.

4.3.3. Benefits of participating in a co-creation process mediated by voice assistants

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Although participants remained somewhat cautious about the ethical implications of using voice assistants, 83,3% indicated that participating in these co-creation sessions improved their digital device vision. In addition, when asked if learning a new tool improves their self-esteem, the majority responded affirmatively, which can lead to healthier mental health and foster more positive habits in older adults.

5. Discussion

The results obtained in this study provide a detailed understanding of the technological acceptance of voice assistants among older adults with advanced digital competence. The co-creation approach helped identify participants' initial perceptions of voice assistants. It revealed how these perceptions evolved as they became actively involved in the design and use of the technology. This section presents key findings, compares them with existing literature, and attempts to address the research questions. Additionally, we examine the theoretical and practical implications for the future development of voice assistants targeting older populations and insights that diverge from previous literature.

A. Insights about the co-creation, adoption, and ethical considerations for voice assistants for older adults

Regarding the first research question, *RQ1. How does the co-creation process impact the technological acceptance of standalone voice-only assistants among older adults?* One of the most significant findings of this study was the substantial increase in perceived usefulness and perceived ease of use of voice assistants among older adults following their participation in the co-creation process.

Initially, participants expressed doubts about the practical benefits and ease of use of standalone voice-only assistants, citing concerns about complexity and the potential irrelevance of the technology to their daily lives. However, their perceptions shifted as they became involved in designing the voice assistants and saw their specific needs reflected in the prototypes. This finding is consistent with previous research in user-centered design and participatory design. It has demonstrated that active user involvement in developing technological solutions can significantly enhance their acceptance and engagement [45, 46, 47, 48]. For older adults, co-creation presents a unique opportunity to share their perspectives, particularly concerning accessibility and functionality. In this study, the co-creation process facilitated a deeper understanding of participants' technological needs, resulting in designs they found intuitive and useful. Also, our findings are consistent with previous studies [49], illustrating the pedagogical aspect of such participatory research interventions, which also addresses the need to expand digital literacy [47, 50] regarding the functioning of voice assistants, as per the increase in both perceived usefulness and perceived ease of use of voice assistants. Moreover, the co-creation process addressed barriers that older adults often face when adopting new technologies, such as a lack of technical support, fear of making errors, and perceived complexity in using new tools. Allowing participants to contribute to designing interaction patterns and key features of voice assistants resulted in devices better suited to their cognitive and physical abilities, significantly reducing their apprehension about using the technology. These results reinforce prior studies indicating that usability issues significantly deter older adults from adopting new technologies [51].

Concerning the second research question *RQ2. What key factors influence older adults' adoption of standalone voice-only assistants?* A crucial aspect revealed by this study is the importance of customizing and adapting voice assistants. Participants repeatedly expressed the need for devices that could adjust to their preferences and needs. This finding aligns with previous research, emphasizing that older adults are more likely to adopt personalized experiences, as these technologies are perceived as more responsive and relevant to their daily routines [49]. In this study, participants highlighted several aspects of personalization they deemed important, including customizable voice settings (tone, speed, language); personalized interaction histories that allow the assistant to learn from previous interactions and provide more relevant suggestions and context-aware interactions, where the voice assistant adapts based on the user's routines and preferences.

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Some participants suggested that voice assistants simplify interactions for tasks such as setting reminders or managing appointments. In contrast, others sought more advanced functionalities, such as personalized entertainment options or health monitoring features. This strong preference for personalization also reflects the heterogeneity of the older adult population. While much of the literature on older adults and technology focuses on their limitations or difficulties in adopting new technologies, this study highlights that older adults are a diverse group with varying levels of digital competence, preferences, and needs. For some, the ability to customize their interaction with a voice assistant increases their sense of control and autonomy, which are key factors in promoting technology engagement. Additionally, integrating virtual assistants with learning technologies offers older adults immediate access to educational content, supports continuous learning without the complexities of traditional computer interfaces, and can assist with daily activities such as setting reminders and managing schedules, thereby promoting autonomy and cognitive engagement [47]. Therefore, voice assistants should be flexible and adaptable to accommodate this diversity of needs, ensuring the technology is accessible to a broader range of users [47, 52, 53].

Another important aspect revealed by this study is the role of social influence in adopting voice assistants. Several participants indicated that their interest in exploring the technology was partly motivated by support from family members or peers, particularly younger family members who encouraged them to try new technologies. This finding aligns with previous research, which indicates that social support plays a significant role in adopting technology among older adults [54]. In this context, family members often serve as technology facilitators, introducing older adults to new devices and assisting them with troubleshooting issues. In addition, family members and dear ones also play a role as motivators for older adults to use such digital technologies to participate in “digital gathering places” [55]. Furthermore, this experience also enables opportunities for intergenerational learning [56].

In the case of voice assistants, participants saw potential in using the technology to enhance their social connectivity. Functions allowing virtual communication were perceived as valuable tools for staying in touch with family and friends, especially during the COVID-19 pandemic, when physical interactions were limited. This finding suggests that voice assistants play a dual role as tools for managing daily tasks and as devices facilitating intergenerational interaction and emotional support. This aspect also aligns with previous research on the potential of voice assistants to address the emotional needs of older adults and enhance their quality of life [51].

About the *RQ3. What are the key ethical considerations in developing standalone voice-only virtual assistants for older adults?* We identified that while the co-creation process significantly improved participants’ attitudes toward voice assistants, privacy and data security concerns persisted throughout the study. This finding is consistent with the existing literature, which identifies privacy as a major barrier to adopting voice assistants and other smart technologies among older adults [57, 58, 59].

Concerns about data privacy are a recurring theme in studies on technology adoption, and voice assistants are no exception. Participants in this study expressed a strong desire for clear and transparent information regarding data collection practices. They wanted to know what data was being collected, how it would be used, and who could access it. Moreover, they emphasized the importance of controlling their data, including the ability to delete information or adjust privacy settings easily. Despite these concerns, participants’ comfort levels regarding privacy noticeably improved by the end of the co-creation process. Many indicated that the ability to customize privacy settings and receive clear feedback about data usage increased their trust in the technology. This finding suggests that while privacy concerns remain a significant barrier, they can be mitigated through thoughtful design that prioritizes data transparency and user control.

B. Implications for Future Standalone Voice-only Assistant Development

The findings of this study have significant implications for the future development of voice assistants targeting older adults. First, the success of the co-creation process demonstrates the value of directly involving older adults in designing and developing technologies intended for their use. The co-creation methodology provided valuable insights

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into user preferences, empowering participants to shape the technology. Future research and development efforts must continue to employ user-centered design and co-creation methods to ensure that technologies for older adults align with their needs and expectations.

Furthermore, the strong preference for personalization highlights the need to develop voice assistants that can be adapted to individual user needs. Personalization includes offering customizable features, such as adjustable voice settings, and more advanced options, including context-aware interactions. Participants particularly valued the ability of voice assistants to learn from previous interactions and provide personalized recommendations, suggesting that future developments should focus on enhancing the adaptive capabilities of these technologies. Ultimately, this study underscores the importance of addressing ethical considerations, particularly privacy and data security. To promote greater acceptance, developers should ensure that voice assistants offer transparent data practices and provide users with easy-to-use tools for managing their privacy settings.

C. Divergences from Previous Research: The Role of Digital Competence

A key aspect that differentiates our findings from previous research [37, 38, 39] is the advanced digital competence of our participants, which shaped both their expectations and their interaction with the voice assistant. This distinction is particularly evident when comparing our findings with those of Chen et al. (2023) [37], whose study involved a significantly older cohort (mean age, 82.5 years) with varied levels of digital skills. Additionally, unlike studies that report common barriers among older adults, such as difficulty setting up the device, understanding voice commands, or a lack of motivation to explore new functionalities, our participants consistently demonstrated high autonomy, technological confidence, and a proactive attitude toward adopting and using the device. This was particularly evident in the post-co-creation evaluation, where all participants reported feeling secure and autonomous using Alexa, and a significant majority (83.3%) stated they could recognize its functions almost always.

Additionally, it is essential to acknowledge that our decision to use the Echo Dot was deliberate, as we sought to explore how digitally literate older adults, who are often early adopters or peer influencers, interact with standalone, voice-first assistants in domestic settings without the influence of visual cues. This participant profile contrasts with those in other studies, such as Chen et al. [37], which is part of the VOLI project [60]. Older adults with more diverse technology experience and a wider age range demonstrated different preferences and usability needs, particularly benefiting from visual guidance during device setup and diary completion. These studies suggest that screen-based voice assistants may offer improved accessibility and lower cognitive load, especially in populations with less technological experience or physical limitations.

The advanced digital competence of our participants also shaped their perceptions of usability and interaction. 66.7% of participants reported finding voice-based interaction easier than traditional input methods (e.g., keyboards or mice). Our findings also contrast with those reported by Trajkova and Martin-Hammond (2020) [39], who explored the reasons older adults (65 years and older) with lower technological proficiency limited or discontinued the use of voice assistants like Alexa. Their study revealed that participants frequently perceived Alexa as a "toy" with limited practical value, mainly because they struggled to identify essential use cases aligned with their needs or interests. This perception of limited utility was particularly evident among participants who lacked the necessary technological skills to fully explore or personalize the device's functionalities.

In contrast, our participants, with advanced digital skills and academic backgrounds, demonstrated a greater awareness of potential use cases, including educational and research applications. Their higher technological proficiency enabled them to integrate Alexa into their daily routines more effectively and to identify valuable functions beyond basic or entertainment-oriented uses. For example, participants reported using Alexa for tasks related to information retrieval, organizing schedules, and even experimenting with voice technologies as part of their academic work.

Another divergence from prior work is our participants' nuanced view regarding privacy. While ethical concerns were

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acknowledged, these did not deter interest or engagement; instead, participants emphasized the importance of transparency, control over data, and the ability to manage privacy settings, suggesting a mature digital mindset rather than apprehension or rejection. These insights suggest that digitally literate older adults are more likely to adopt voice assistants and raise more complex expectations regarding personalization, ethics, and utility, positioning them as informed co-creators rather than less digitally skilled end-users.

The selection of digitally competent older adults as participants was a critical factor that shaped the outcomes of this study and revealed findings not commonly identified in prior research focused on less digitally skilled populations. Their advanced digital literacy enabled them to engage more proactively in the co-creation process and equipped them with the necessary critical thinking to articulate nuanced requirements regarding personalization, usability, and ethical considerations. Unlike participants in studies characterized by digital exclusion, our cohort demonstrated an ability to envision complex, value-added use cases for voice assistants, extending beyond basic functionalities to applications in learning, health monitoring, and productivity support.

Moreover, their familiarity with digital ecosystems allowed for a more informed critique of privacy practices and data governance, shifting the ethical discussion from generalized concerns to specific demands for transparency, user agency, and granular control over data management. This contrasts sharply with the passive acceptance or outright rejection of such technologies frequently reported in studies involving participants with limited digital competence. As a result, the inclusion of this emerging demographic provided richer, more forward-looking insights into how voice-only assistants can evolve to meet the expectations of future generations of older adults who are increasingly digitally adept and actively seek meaningful, ethical, and personalized technological experiences.

4. Conclusions

This study provides insights into the technological acceptance of standalone voice-only assistants among digitally competent older adults, emphasizing the pivotal role of co-creation in shaping user engagement and adoption. This research also helps technology creators understand and create technology using human-centered and value-driven approaches. The work demonstrates the importance of involving users, particularly older adults, in the design of new technology. The primary contribution is to assist technology designers in building user-friendly and inclusive voice virtual assistants.

The results of this study demonstrate that the co-creation process was highly effective in fostering technology acceptance among older adults with high digital competence.

The key findings about the key factors influencing the adoption of voice virtual assistants include:

- *Demand for Customization and Personalization:* Digitally skilled participants expected advanced personalization features, including context-aware interactions and customized settings for voice, speed, and language.
- *Heterogeneity in Needs and Preferences:* High digital competence highlighted diverse preferences among participants, underscoring the need for flexible systems that accommodate varying cognitive and physical abilities.
- *Autonomy and Control:* Participants valued voice assistants that enhanced their control over daily tasks, demonstrating a desire for systems that support rather than hinder their independence.
- *Broader Functional Utility Recognition:* Technologically proficient participants identified complex use cases, such as educational applications, health monitoring, and research, beyond entertainment or basic communication.

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- *Social Influence as a Motivator:* Participants were receptive to voice assistants partly due to encouragement from younger family members, suggesting that intergenerational support can drive adoption among digitally skilled older adults.
- *Preference for Seamless Interaction:* High digital competence increased participants' expectations for natural, fluid conversations with voice assistants, revealing dissatisfaction with rigid or limited responses.
- *Desire for Enhanced Learning Opportunities:* Digitally competent participants recognized the potential for integrating voice assistants with learning tools to support continuous education and cognitive stimulation.

The co-creation process proved crucial in improving the perceived usefulness and ease of use of voice assistants among older adults. By involving participants directly in the design and development stages, this study highlights the importance of user involvement in mitigating common concerns about the complexity and irrelevance of new technologies. The co-creation methodology fostered a sense of ownership among participants, ensuring that the voice assistants were tailored to their specific preferences, enhancing their intention to use the technology. The engagement of older adults in this iterative, participatory process facilitated the development of voice assistants that aligned more closely with their actual needs, helping to address usability barriers often reported in previous studies. This finding aligns with broader research on user-centered and participatory design, emphasizing that active involvement in the design process enhances the functionality and adoption of technological solutions, particularly for populations with specific accessibility requirements.

A critical finding of this study is the strong preference for customization and personalization in voice assistant design. Participants clearly desired devices adapted to their needs, preferences, and routines. The ability to customize features, such as voice settings, interaction styles, and personalized feedback, emerged as a fundamental factor in the participants' willingness to adopt the technology. This highlights the importance of future voice assistant technology developments in prioritizing flexibility and user adaptability. The study showed that personalized technologies meet practical needs and significantly foster a sense of control and autonomy among older adults, essential for promoting sustained engagement. The finding suggests that voice assistants designed for older adults should not rely on a one-size-fits-all approach. Still, it should offer a range of customizable features, allowing users to tailor the device to their unique needs. This aspect of personalization may enhance long-term adoption and regular use.

Despite the overall positive response to voice assistants, this study highlights that privacy and data security remain significant barriers to adoption among older adults. Participants expressed ongoing concerns regarding the potential misuse of personal data, particularly health-related information, underscoring the need for transparent data practices and easily manageable privacy controls in voice assistant technologies.

The findings suggest that while older adults may recognize the practical benefits of standalone voice-only assistants, their willingness to adopt the technology is heavily influenced by their confidence in the device's data protection capabilities. To address this, future designs should prioritize user control over personal data, offering simple and accessible options for managing data collection and privacy settings. Voice assistants who communicate their data usage policies and allow users to control or delete their information are more likely to be trusted and adopted by older adults.

The study also revealed that social influence, particularly from family members, plays a significant role in shaping older adults' attitudes toward voice assistants. Participants reported that encouragement from younger relatives or peers often influenced their decision to explore and adopt new technologies. The social dimension of technology use suggests that voice assistants could be further developed to enhance social connectivity and facilitate intergenerational communication. Features that enable older adults to easily connect with family members, organize virtual meetings, or share experiences across generations may enhance the usability of voice assistants and reduce social isolation, a growing concern among older populations.

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Regarding the limitations of this exploratory study, it is worth noting that the sample size was relatively small locally and limited to digitally competent older adults, which may restrict the generalizability of the findings to other subgroups within the older adult population, such as those with lower levels of digital literacy. Future research should include a broader and more diverse population of older adults to ensure that voice assistants can be designed to meet the varying needs and abilities of this group. Additionally, the study's time frame was relatively short, and further research is needed to assess the long-term adoption and sustained use of voice assistants by older adults.

Another limitation pertains to using Alexa, specifically the Amazon Echo Dot, which supports interaction solely through voice. While this design aligns with real-world use cases due to the device's affordability, accessibility, and ease of deployment, it restricts our study to voice-only, screenless interactions. Alexa also offers devices such as the Echo Show, which incorporate a touchscreen for multimodal interaction [61]. These visual and tactile elements may be more accessible and user-friendly for older adults with varying sensory, motor, or cognitive needs, thereby promoting greater digital inclusion and enhancing user satisfaction.

Accordingly, our findings should represent interactions with standalone, voice-only virtual assistants by a specific, digitally literate segment of the older adult population. Future work should broaden this scope by comparing the usability and user experience of a wider range of voice assistant devices, including screen-based alternatives like Echo Show, Google Nest Hub, and mobile-based assistants such as Siri (Apple), Bixby (Samsung), Cortana (Microsoft), and Celia (Huawei) [62]. In addition, emerging conversational agents powered by large language models (LLMs), such as Gemini Live and ChatGPT with voice capabilities, present promising avenues for further exploring how natural, adaptive dialogue systems can support older adults' everyday routines, healthcare management, and digital inclusion.

Ultimately, this study demonstrates that voice assistants have considerable potential to enhance the daily lives of older adults, particularly when designed with their specific needs in mind. Through co-creation, older adults could actively contribute to the design process, resulting in voice assistants that are more functional and more acceptable to the users. The emphasis on personalization, combined with careful attention to privacy and security concerns, provides a pathway for developing voice assistants that support older adults in maintaining their independence, staying socially connected, and enhancing their overall quality of life. Future research and development efforts should continue to prioritize user-centered design and ethical data practices, ensuring that voice assistants for older adults are both technically advanced and socially responsible.

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Disclosure of interest

The authors report that there are no competing interests to declare.

References

- [1] V. Atella et al., "The future of the elderly population health status: Filling a knowledge gap," *Heal. Econ. (United Kingdom)*, vol. 30, no. S1, pp. 11–29, 2021, doi: 10.1002/hecl.4258.
- [2] P. Zhao and J. Xie, "Aging: A Global Challenge," 2023, pp. 25–41.
- [3] F. S. Nino, *Sustainable Development Goals—United Nations*. 2015.
- [4] E. Portegijs, C. Lee, and X. Zhu, "Activity-friendly environments for active aging: The physical, social, and technology environments," *Front. Public Heal.*, vol. 10, 2023, doi: 10.3389/fpubh.2022.1080148.
- [5] A. Zaidi, "Active Aging and Active Aging Index BT - Encyclopedia of Gerontology and Population Aging," D. Gu and M. E. Dupre, Eds. Cham: Springer International Publishing, 2020, pp. 1–5.
- [6] N. G. Rodrigues, C. Q. Y. Han, Y. Su, P. Klainin-Yobas, and X. V. Wu, "Psychological impacts and online interventions of social isolation amongst older adults during COVID-19 pandemic: A scoping review," *J. Adv. Nurs.*, vol. 78, no. 3, pp. 609–644, 2022, doi: 10.1111/jan.15063.
- [7] F. Ibarra, M. Baez, L. Cernuzzi, and F. Casati, "A Systematic Review on Technology-Supported Interventions to Improve Old-Age Social Wellbeing: Loneliness, Social Isolation, and Connectedness," *J. Healthc. Eng.*, vol. 2020, 2020, doi: 10.1155/2020/2036842.

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- [8] P. A. Bezerra, J. W. Nunes, and L. B. de A. Moura, “Envelhecimento e isolamento social: uma revisão integrativa,” *Acta Paul. Enferm.*, vol. 34, pp. 1–9, 2021, doi: 10.37689/acta-ape/2021ar02661.
- [9] N. Morrow-Howell, N. Galucia, and E. Swinford, “Recovering from the COVID-19 Pandemic: A Focus on Older Adults,” *J. Aging Soc. Policy*, vol. 32, no. 4–5, pp. 526–535, 2020, doi: 10.1080/08959420.2020.1759758.
- [10] L. K. Chen, “Older adults and COVID-19 pandemic: Resilience matters,” *Arch. Gerontol. Geriatr.*, vol. 89, no. January, 2020, doi: 10.1016/j.archger.2020.104124.
- [11] L. Colombo-Ruano & C. S. González-González (2024). Inclusión tecnológica y competencias digitales en personas mayores: hacia un envejecimiento activo y conectado. *Campus Virtuales*, 13(2), 199-213.
- [12] A. Pradhan, A. Lazar, and L. Findlater, “Use of intelligent voice assistants by older adults with low technology use,” *ACM Trans. Comput. Interact.*, vol. 27, no. 4, 2020, doi: 10.1145/3373759.
- [13] I. Mannheim, E. J. M. Wouters, H. Köttl, L. C. van Boekel, R. Brankaert R, Y. van Zaaen. Ageism in the Discourse and Practice of Designing Digital Technology for Older Persons: A Scoping Review. *Gerontologist*. 2023 Aug 24;63(7):1188-1200. doi: 10.1093/geront/gnac144.
- [14] F. D. Davis, “Perceived usefulness, perceived ease of use, and user acceptance of information technology,” *MIS Q. Manag. Inf. Syst.*, vol. 13, no. 3, pp. 319–339, 1989, doi: 10.2307/249008.
- [15] A. Troncone et al., “Advanced assistive technologies for elderly people: A psychological perspective on seniors’ needs and preferences (part A),” *Acta Polytech. Hungarica*, vol. 17, no. 2, pp. 163–189, 2020, doi: 10.12700/APH.17.2.2020.2.10.
- [16] P. Surendran, “Technology Acceptance Model: A Survey of Literature,” vol. 2, no. 4(August), pp. 175–178, 2012, [Online]. Available: <https://thejournalofbusiness.org/index.php/site/article/view/161>.
- [17] M. T. Harris and W. A. Rogers, “Developing a Healthcare Technology Acceptance Model (H-TAM) for Older Adults with Hypertension,” *Ageing Soc.*, vol. 43, no. 4, pp. 814–834, 2023, doi: 10.1017/S0144686X21001069.
- [19] V. Venkatesh, M. G. Morris, G. B. Davis, F. D. Davis (2003). User acceptance of information technology: Toward a unified view. *MIS quarterly*, 425-478.
- [20] A. Murciano Hueso, A.V. Martín García & P. Torrijos Fincias (2022). Revisión sistemática de aceptación de la tecnología digital en personas mayores. Perspectiva de los modelos TAM. *Rev. esp. geriatr. gerontol.* (Ed. impr.), 105-117.
- [21] Cubillos, C., & Rienzo, A. (2023). Digital cognitive assessment tests for older adults: a systematic literature review. *JMIR Mental Health*, 10(1), e47487.
- [22] Anderberg P, Eivazzadeh S, Berglund JS. A Novel Instrument for Measuring Older People's Attitudes Toward Technology (TechPH): Development and Validation. *J Med Internet Res*. 2019 May 23;21(5):e13951. doi: 10.2196/13951. PMID: 31124467; PMCID: PMC6552448.
- [23] Roque NA, Boot WR. A New Tool for Assessing Mobile Device Proficiency in Older Adults: The Mobile Device Proficiency Questionnaire. *J Appl Gerontol*. 2018 Feb;37(2):131-156. doi: 10.1177/0733464816642582. Epub 2016 Apr 11. PMID: 27255686; PMCID: PMC9394541.
- [24] Walter R. Boot, Neil Charness, Sara J. Czaja, Joseph Sharit, Wendy A. Rogers, Arthur D. Fisk, Tracy Mitzner, Chin Chin Lee, Sankaran Nair, Computer Proficiency Questionnaire: Assessing Low and High Computer Proficient Seniors, *The Gerontologist*, Volume 55, Issue 3, June 2015, Pages 404–411, <https://doi.org/10.1093/geront/gnt117>
- [25] M. Galvagno and D. Dalli, “Theory of value co-creation: A systematic literature review,” *Manag. Serv. Qual.*, vol. 24, no. 6, pp. 643–683, 2014, doi: 10.1108/MSQ-09-2013-0187.
- [26] L. Colombo-Ruano, C. Rodríguez-Silva, V. Violant-Holz, and C. S. González-González, “Technological acceptance of voice assistants in older adults: An online co-creation experience,” *ACM Int. Conf. Proceeding Ser.*, pp. 1–5, 2021, doi: 10.1145/3471391.3471432.
- [27] L. Glover, J. Dyson, F. Cowdell & D. Kinsey (2020). Healthy ageing in a deprived northern UK city: A Co-Creation study. *Health & Social Care in the Community*, 28(6), 2233-2242.
- [28] M. Blusi, I. Nilsson, and H. Lindgren, “Older adults Co-creating meaningful individualized social activities online for healthy ageing,” *Stud. ° Technol. Inform.*, vol. 247, pp. 775–779, 2018, doi: 10.3233/978-1-61499-852-5-775.
- [29] M. Havukainen, T.H. Laine, T. Martikainen et al. A Case Study on Co-designing Digital Games with Older Adults and Children: Game Elements, Assets, and Challenges. *Comput Game J* 9, 163–188 (2020). <https://doi.org/10.1007/s40869-020-00100-w>
- [30] P. Pirzada, A. Wilde, G. H. Doherty & D. Harris-Birtill (2021). Ethics and acceptance of smart homes for older adults. *Informatics for Health and Social Care*, 47(1), 10–37. <https://doi.org/10.1080/17538157.2021.1923500>
- [31] C. González-González, R. G. Iranzo, and D. F. Viera, “ACD Toolkit : Considerando principios éticos , género , diversidad y sostenibilidad en el proceso de diseño de tecnologías,” no. September, 2021.
- [32] E. Nacimiento-García, C.S. González-González & Futiérrez-Vela, F. L. (2020). Free software virtual assistants for designing pervasive gaming experiences to promote active aging: State of the art. *CEUR-WS. org*, 2747.
- [33] M. Bolaños, C. Collazos, and F. Gutiérrez, “Experiences in the application of some models of technology acceptance: Adaptation for the elderly people,” *ACM Int. Conf. Proceeding Ser.*, pp. 20–24, 2021, doi: 10.1145/3471391.3471413.
- [34] A. Valera Román, D. Pato Martínez, A. Lozano Murciego, D.M Jiménez-Bravo & J. F. de Paz (2021). Voice assistant application for avoiding sedentarism in elderly people based on IoT technologies. *Electronics*, 10(8), 980.
- [35] K. Bonilla and A. Martin-Hammond, “Older Adults’ Perceptions of Intelligent Voice Assistant Privacy, Transparency, and Online Privacy Guidelines,” *Sixt. Symp. Usable Priv. Secur. (SOUPS 2020)*, 2020, [Online]. Available: https://www.usenix.org/system/files/soups2020_poster_bonilla.pdf.
- [36] A. Arnold, S. Kolody, A. Comeau, & A. Miguel Cruz (2024). What does the literature say about the use of personal voice assistants in older adults? A scoping review. *Disability and Rehabilitation: Assistive Technology*, 19(1), 100-111.
- [37] Chen Chen, Ella T Lifset, Yichen Han, Arkajyoti Roy, Michael Hogarth, Alison A Moore, Emilia Farcas, and Nadir Weibel. 2023. Screen or No Screen? Lessons Learnt from a Real-World Deployment Study of Using Voice Assistants With and Without Touchscreen for Older Adults. In *Proceedings of the 25th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '23)*. Association for Computing Machinery, New York, NY, USA, Article 52, 1–21. <https://doi.org/10.1145/3597638.3608378>.

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- [38] Chen Chen, Janet G Johnson, Kemeberly Charles, Alice Lee, Ella T Lifset, Michael Hogarth, Alison A Moore, Emilia Farcas, and Nadir Weibel. 2021. Understanding Barriers and Design Opportunities to Improve Healthcare and QOL for Older Adults through Voice Assistants. In Proceedings of the 23rd International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '21). Association for Computing Machinery, New York, NY, USA, Article 9, 1–16. <https://doi.org/10.1145/3441852.3471218>
- [39] Milka Trajkova and Aqueasha Martin-Hammond. 2020. "Alexa is a Toy": Exploring Older Adults' Reasons for Using, Limiting, and Abandoning Echo. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20). Association for Computing Machinery, New York, NY, USA, 1–13. <https://doi.org/10.1145/3313831.3376760>
- [40] E. B. N. Sanders & P. J. Stappers (2014). Probes, toolkits, and prototypes: Three approaches to making in co-designing. *CoDesign*, 10(1), 5–14.
- [41] Dickinson, A., Arnott, J., & Prior, S. (2007). Methods for human-computer interaction research with older people. *Behaviour and Information Technology*, 26(4), 343–352. <https://doi.org/10.1080/01449290601176948>
- [42] J. Vines, G. Pritchard, P. Wright, P. Olivier & K. Brittain (2015). An age-old problem: Examining the discourses of ageing in HCI and strategies for future research. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 22(1), 1–27.
- [43] A. Pirinen (2016). The barriers and enablers of co-design for services. *International Journal of Design*, 10(3), 27–42.
- [44] U. Mukhtar, C. Grönroos, P. Hilletoft, M. L. Pimenta, and A. C. Ferreira, "Inter-functional value co-creation as an antecedent of supply chain performance: a study based on the coordination theory," *J. Bus. Ind. Mark.*, no. December 2021, 2023, doi: 10.1108/JBIM-12-2021-0549.
- [45] M. Blusi, I. Nilsson, and H. Lindgren, "Older adults Co-creating meaningful individualized social activities online for healthy ageing," *Stud. Health Technol. Inform.*, vol. 247, pp. 775–779, 2018, doi: 10.3233/978-1-61499-852-5-775.
- [46] S. Kim, "Exploring how older adults use a smart speaker-based voice assistant in their first interactions: Qualitative study," *JMIR mHealth uHealth*, vol. 9, no. 1, 2021, doi: 10.2196/20427.
- [47] A. Schlomann, H. W. Wahl, P. Zentel, V. Heyl, L. Knapp, C. Opfermann, ... & Rietz, C. (2021). Potential and pitfalls of digital voice assistants in older adults with and without intellectual disabilities: relevance of participatory design elements and ecologically valid field studies. *Frontiers in Psychology*, 12, 684012. <https://doi.org/10.3389/fpsyg.2021.684012>
- [48] J. Jarke, "Open government for all? Co-creating digital public services for older adults through data walks," *Online Inf. Rev.*, vol. 43, no. 6, pp. 1003–1020, 2019, doi: 10.1108/OIR-02-2018-0059.
- [49] A. Arnold, S. Kolody, A. Comeau & A. Miguel Cruz (2022). What does the literature say about the use of personal voice assistants in older adults? A scoping review. *Disability and Rehabilitation: Assistive Technology*, 19(1), 100–111. <https://doi.org/10.1080/17483107.2022.2065369>
- [50] A. Vercruyssen, W. Schirmer, N. Geerts & D. Mortelmans (2023). How "basic" is basic digital literacy for older adults? Insights from digital skills instructors. *Frontiers in education*, 8(1231701). doi: 10.3389/educ.2023.1231701
- [51] M. Liu, C. Wang & J. Hu (2023). Older adults' intention to use voice assistants: Usability and emotional needs. *Heliyon*, 9(11), e21932. <https://doi.org/10.1016/j.heliyon.2023.e21932>
- [52] K. Maswadi, N. A. Ghani, and S. Hamid, "Factors influencing the elderly's behavioural intention to use smart home technologies in Saudi Arabia," *PLoS One*, vol. 17, no. 8 August, pp. 1–30, 2022, doi: 10.1371/journal.pone.0272525.
- [53] A. V. Román, D. P. Martínez, Á. L. Murciego, D. M. Jiménez-Bravo, and J. F. de Paz, "Voice assistant application for avoiding sedentarism in elderly people based on IoT technologies," *Electron.*, vol. 10, no. 8, 2021, doi: 10.3390/electronics10080980.
- [54] X. Cao, H. Zhang, B. Zhou, D. Wang, C. Cui & X. Bai (2024). Factors influencing older adults' acceptance of voice assistants. *Frontiers in Psychology*, 15, 1376207.
- [55] H. R. Marston & C. B. A. Musselwhite (2021). Improving Older People's Lives Through Digital Technology and Practices. *Gerontology & geriatric medicine*, 7, 23337214211036255. <https://doi.org/10.1177/23337214211036255>
- [56] S. Freeman, H. R. Marston, J. Olynick, C. Musselwhite, C. Kulczycki, R. Genoe & B. Xiong. (2020). Intergenerational Effects on the Impacts of Technology Use in Later Life: Insights from an International, Multi-Site Study. *International journal of environmental research and public health*, 17(16), 5711. <https://doi.org/10.3390/ijerph17165711>
- [57] N. Fruchter and I. Liccardi, "Consumer attitudes towards privacy and security in home assistants," *Conf. Hum. Factors Comput. Syst. - Proc.*, vol. 2018-April, pp. 1–6, 2018, doi: 10.1145/3170427.3188448.
- [58] D. Fröhlich, M. Ehrlich, and C. Müller, "Attitudes and perceptions of older adults on digital devices," *Comput. Human Behav.*, vol. 73, no. 226–233, 2017, doi: <https://doi.org/10.1016/j.chb.2017.02.007>.
- [59] A. Bhattacharya, M. Frolov, and R. Oberg, "Older adults' attitudes toward digital devices: A comparative study," *Comput. Human Behav.*, vol. 85, pp. 104–112, 2018, doi: <https://doi.org/10.1016/j.chb.2018.02.025>.
- [60] Project VOLI: <http://voli.ucsd.edu>
- [61] A. Cuadra, H. Baek, D. Estrin, M. Jung & N. Dell (2022, June). On Inclusion: Video Analysis of Older Adult Interactions with a Multimodal Voice Assistant in a Public Setting. In *Proceedings of the 2022 International Conference on Information and Communication Technologies and Development* (pp. 1–17). <https://doi.org/10.1145/3572334.3572371>
- [62] Brewer, R., Pierce, C., Upadhyay, P., & Park, L. (2022). An empirical study of older adult's voice assistant use for health information seeking. *ACM Transactions on Interactive Intelligent Systems (TiiS)*, 12(2), 1–32. <https://doi.org/10.1145/3484507>