

OPEN ACCESS

EDITED BY

Koen Smit,
HU University of Applied Sciences
Utrecht, Netherlands

REVIEWED BY

Akshith Ullal,
Vanderbilt University, United States
Joana Bernardo Loureiro,
Polytechnic Institute of Leiria, Portugal

*CORRESPONDENCE

Muhannad Ismael
✉ muhannad.ismael@list.lu

RECEIVED 09 December 2025

REVISED 22 January 2026

ACCEPTED 29 January 2026

PUBLISHED 23 February 2026

CITATION

Ismael M, Maquil V, Hoffmann M, Mc Call R, Hadj Sassi MS and Tobias E (2026) Intergenerational workshop for co-designing XR application storyboard to support older adults in daily tasks: methodology and preliminary results. *Front. Comput. Sci.* 8:1763935. doi: 10.3389/fcomp.2026.1763935

COPYRIGHT

© 2026 Ismael, Maquil, Hoffmann, Mc Call, Hadj Sassi and Tobias. This is an open-access article distributed under the terms of the [Creative Commons Attribution License \(CC BY\)](https://creativecommons.org/licenses/by/4.0/). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

Intergenerational workshop for co-designing XR application storyboard to support older adults in daily tasks: methodology and preliminary results

Muhannad Ismael^{1*}, Valérie Maquil¹, Martine Hoffmann², Roderick Mc Call¹, Mohamed Saifeddine Hadj Sassi¹ and Eric Tobias³

¹VISINT Group, HANDS Unit, Luxembourg Institute of Science and Technology (LIST), Esch-sur-Alzette, Luxembourg, ²GERO - Kompetenzzentrum für den Alter, Bonnevoie, Luxembourg, ³Lycée des Arts et Métiers, Limpertsberg, Luxembourg

In the accelerating pace of technological change such as Extended Reality (XR), ensuring that emerging technologies meet the diverse needs of all population groups, including older adults, is increasingly urgent. XR technologies hold significant promise for older adults through applications in health monitoring, cognitive stimulation, physical rehabilitation, and social connection. However, realizing this potential requires that future developers deeply understand the needs, preferences, and lived experiences of older adult users knowledge best gained through direct engagement. Recent research in Human-Computer Interaction (HCI) has highlighted the value of engaging and empowering older adults in the design of creative technologies, often through intergenerational workshops. However, existing research on such workshops emphasizes outcomes for older adults, with limited insight into impacts on future developers, best practices and replicable methodologies for XR intergenerational workshops, as well as XR application areas tailored to older adults. This paper addresses these gaps through XR co-design workshops with older adults and future developers, providing a clear methodology and highlighting mutual benefits and implications for inclusive XR design for aging populations. Therefore, the main contributions of this paper are: (1) A methodology for an intergenerational workshop on XR involving participants from different age groups. (2) The results of conducting such workshops aiming to understand what participants gain or experience through the process. (3) A range of potential application areas for XR, based on storyboards co-designed by older adults and students. Furthermore, we recommend that educational technology institutions integrate such intergenerational workshops into their annual curricula. This approach would help students become more aware of and sensitive to the specific needs of older adults within society particularly in understanding the challenges and requirements older generations may face when using new technologies such as XR.

KEYWORDS

Human Computer Interaction (HCI), intergenerational workshops, participatory design (PD), usability & user experience, Extended Reality (XR)

1 Introduction

The world's population is aging; from 2015 to 2050 there is an estimated increase of people over the age of 65 from 8.5% to 16.7% (U.S. Census Bureau, 2016). Developed regions have higher population estimates for people over the age of 65, with 27% of Europeans and 21.4% of North Americans by 2050 (U.S. Census Bureau, 2016). Despite the commitment of developed regions to encouraging an inclusive and technologically advanced society (Otjacques et al., 2009), the rapid pace of technological advancements can unintentionally disconnect older populations from new developments (McDonough, 2016). Many of applications are designed without considering older adults' routines or context of use, resulting in limited perceived usefulness and low technology adoption (Amouzadeh et al., 2025). This is particularly relevant in fields such as Extended Reality (XR), which has potential benefits for health (Aruanno and Garzotto, 2019; Rohrbach et al., 2019), cognitive stimulation (Wang and Zhang, 2024), and physical activity (Blomqvist et al., 2021), but remains underexplored among older populations. Therefore, older adults remain underrepresented in the development of XR applications that could support daily life.

GERO (2024) carried out a pilot project to test and evaluate commercial Virtual Reality (VR) applications including (Beat Saber, 2019) among nursing home residents aged 84 to 92 in Luxembourg. Overall, the technology was met with great enthusiasm from the residents, with particularly activating and participatory VR fitness applications, such as Beat Saber (2019), being especially well received. These experiences simultaneously stimulate physical movement as well as cognitive and motor functions. This study shows that modern technologies and old age including among non-tech users, are not contradictory. However, there is still a lack of specifically adapted applications for older adults with particular needs. Work in HCI increasingly emphasizes the benefits of engaging older adults in both the design and use of creative technologies (Lindsay et al., 2012; Rogers et al., 2014). Older adults bring creativity, accumulated wisdom, and a rich variety of life skills to the invention of future technologies (Pradhan et al., 2020; Rogers et al., 2014). A recent review Mannheim et al. (2023) highlighted an interesting discrepancy: while the literature consistently stresses the value of including older adults in design processes, only 47% of studies actually engaged them during design and prototyping. This exclusion appears to be driven by multiple factors like as ageist assumptions, negative stereotypes (Mannheim et al., 2019, 2023; Ienca et al., 2021), and practical concerns such as difficulties with comprehension or communication, as well as the broader marginalization of certain populations (Mannheim et al., 2019; Diaz-Orueta et al., 2020).

To address these shortcomings, intergenerational workshops in which younger participants, especially future developers, and older adults collaboratively co-design emerging technologies such as XR applications offer a participatory approach that foregrounds lived experience and shared creativity. Studies on intergenerational and co-design workshops have shown that engaging with older adults can positively influence and broaden students perceptions of aging (Kalisch et al., 2013; Gutheil et al., 2006; Penick et al., 2014). One of the central values of such workshops lies in

encouraging older adults to actively participate in the co-design of emerging technologies and software development processes. While previous research has explored intergenerational workshops in technology co-design, most studies have primarily focused on outcomes for older adults, with only limited attention given to the experiences of both older adults and developers (Kopeć et al., 2018; Wang et al., 2024, 2025; Doyle et al., 2013). Moreover, prior work has not sufficiently addressed the development of clear, well-defined, and replicable methodologies for establishing intergenerational workshops in the technology domain in general, and in the XR domain specifically. This gap is particularly critical for two reasons. First, there has been increasing attention in recent years (Ng et al., 2025; Reis et al., 2021) to the importance of intergenerational workshops, alongside a growing need to identify clear guidelines that maximize benefits for both older adults and students. Second, defining a methodology for intergenerational workshops in the XR domain is particularly important, as XR technologies extend far beyond entertainment, offering significant potential to support older adults wellbeing (Mehrabian et al., 2022), physical activity (Margrett et al., 2022), and memory stimulation (Yang et al., 2025). In these areas, co-design with end users is especially important to ensure relevance, accessibility, and impact. We therefore see an opportunity to investigate best practices for conducting intergenerational workshops, particularly within the XR domain. In addition, we aim to examine how both older adults and future developers perceive and experience participation in XR-focused intergenerational workshops. Moreover, we argue that these workshops can bridge the gap between older adults needs and younger developers design practices, equipping future professionals with firsthand insights that can meaningfully inform their careers in technology design and development. Furthermore, beyond proposing a methodology for intergenerational workshops in the XR domain and emphasizing the importance of involving older adults and future developers in co-design processes, such workshops can also play a critical role in revealing potential application areas of XR technologies tailored to older adults. We argue that identifying and articulating a broad range of XR application domains can meaningfully inform and guide future research and development efforts. In contrast to prior studies (Ullal et al., 2024; Jin et al., 2024) on intergenerational workshops, the proposed workshop does not require older adults and students to co-design applications within predefined domains such as communication or health. Instead, the workshop deliberately leaves the scope open, allowing older adults, supported by students, to freely explore and define the XR application domains that they believe could support their everyday lives. This open-ended approach is intended to foster creativity and ensure that emerging application ideas are grounded in older adults lived experiences. Based on the storyboards collaboratively created by older adults and students, we derive a structured framework that outlines potential XR application areas specifically designed for older adults. Hence, in this paper, we explore the following fourth research questions:

RQ1: What are the impacts and perceived benefits of intergenerational learning emerging from workshops in which older and younger adults collaboratively co-design XR

application storyboards intended to support older adults in managing daily tasks?

RQ2: What is an effective methodology for organizing intergenerational workshops focused on XR?

RQ3: What potential application areas for XR can be identified from storyboards co-designed by older adults and students?

RQ4: Is it beneficial to integrate such intergenerational workshops into the annual curricula of educational technology institutions?

2 Related works

This paper focuses on technological intergenerational workshops rather than non-technological ones, such as those centered on cultural heritage or art like the work of Kanayama et al. (2025). Technological intergenerational workshops, particularly those involving virtual or augmented reality, have been widely investigated in the literature to analyse the impacts and benefits of such workshops on different generations. This paper falls within this domain, therefore, the following section illustrates its position within the current state of art of the domain of intergenerational workshops focused on technology.

2.1 Technological intergenerational workshops

A review of intergenerational workshop literature proposed by Reis et al. (2021) aimed to explore the technologies created or used to foster intergenerational interaction, identify overarching themes, and propose directions for future research. The review suggests that intergenerational connectivity through technology is an increasingly valuable area of inquiry, as evidenced by a notable rise in related studies in recent years. However, the field is still developing (Reis et al., 2021). In a previous study, researchers, older adults, and caregivers (Chan et al., 2024) collaboratively discussed, designed, and prototyped generative AI-based solutions to support older adults with cognitive challenges. Ullal et al. (2024) highlights the significance of iterative Participatory Design (PD) in creating XR activities tailored to the unique needs of older adults with cognitive and physical impairments. By considering older adults cognitive and physical capabilities, the potential of XR can be unlocked to enrich their lives. Through participatory workshops and interviews with older adults living independently, other work proposed by Zhao et al. (2024) shows that older adults were concerned not only with creating technologies in XR or AI that helps them do more right now. They were also concerned about the long-term continuity of their activities as they age. In a recent study Jin et al. (2024), researchers adopted a participatory design approach with nursing home residents, engaging older adults as co-designers in brainstorming and developing an innovative XR support tool. While these studies Chan et al. (2024), Ullal et al. (2024), Jin et al. (2024), and Zhao et al. (2024) engaged older adults with caregivers or developers,

the workshop presented in this paper follows a participatory design methodology that includes students as key contributors because this paper suggests that it would be important to evaluate the impact of intergenerational workshops on both older adults and future developers, and whether it would be beneficial to integrate them into students' annual curricula, as suggested in the fourth research question. Balcerzak et al. (2017) describe the creation of an online platform designed to connect individuals in need of assistance with volunteers willing to offer help. The platform was developed during a 24-hour hackathon involving both young programmers and older adults. The study shows that the PD process not only enhanced the platform's usability for older users but also promoted intergenerational collaboration and empathy. Rather than focusing on Generative AI (Chan et al., 2024), which is a very important and trending theme, or on online platforms that connect different generations (Balcerzak et al., 2017), the present study centers on an XR application as the theme for the intergenerational workshop, as XR has demonstrated strong potential for enhancing wellbeing (Aruanno and Garzotto, 2019; Rohrbach et al., 2019), cognitive stimulation (Wang and Zhang, 2024), and physical activity (Blomqvist et al., 2021). Therefore, this study highlights the potential application areas for XR that can be identified from storyboards co-designed by older adults and students.

Existing research on VR and video game intergenerational workshops has documented various outcomes, including reduced ageism among younger participants (Zou et al., 2024), improved intergenerational relationships (Wei et al., 2023), and enhanced creativity (Ng et al., 2025). Studies have also identified challenges such as uneven distribution of technical knowledge, role monopolization, and varying group dynamics (Cucinelli et al., 2018). While these findings are valuable, this paper addresses a gap in the literature by providing a replicable methodology for establishing technological intergenerational workshops. Despite a growing number of intergenerational co-design studies involving XR and other technologies, most work remains reflective and context-specific, offering insights and challenges from individual workshop series rather than a clear, standardized methodology for structuring intentional intergenerational XR workshops (Varella et al., 2022; Hagen et al., 2024). This absence of agreed-upon co-design methods in XR highlights the need for formalized processes that can support mutual benefits for older adults as well as future developers, and facilitate cross-generational knowledge exchange in XR design contexts.

Hence, one of the contributions of this study is a methodology for an intergenerational XR workshop. The workshop consists of two stages: a pre-workshop session with students enrolled in a college program focused on game design and programming, aimed at introducing the goals, XR concepts, and their support role; followed by a main workshop session involving both students and older adults, as described in detail in Section 3. Throughout both stages, the process is informed by psychogerontological expertise to ensure age sensitive facilitation and meaningful intergenerational engagement. The aim is to sensitize and equip future developers to co-create XR applications with, and for, older adults, fostering inclusivity and relevance in design. Hence, unlike previous studies, our approach places future developers

in a central role, supporting older adults in adopting emerging XR technologies while simultaneously gaining deeper insights into their needs and preferences. The paper provides insights that could be generalized as best practices for conducting intergenerational workshops. Moreover, we suggest a framework for future research and development in XR tailored for older adults.

3 Materials and methodology

In relation with the second research question (RQ2), this section outlines the methodology used to implement intergenerational workshops focused on XR. The methodology comprised two stages conducted on two different days: A pre-workshop session was conducted on campus with students enrolled in the game design and programming track to introduce the workshop goals, XR technology, and their supporting role; followed by the main workshop session on another day involving both students and older adults, held at the premises of a national gerontology competence center. To address the challenge of participants speaking different languages, groups were formed based on language preference to facilitate effective communication. The workshop was structured into four sequential sessions: a theoretical introduction, hands-on exploration of XR technologies, co-design activities using AI-generated content cards, and a final feedback collection phase. In order to answering RQ1, quantitative data were collected through a Likert scale questionnaire targeting three dimensions: Workshop Impact, Value of Intergenerational Learning, and Future Workshop Demand. The rationale for selecting these three dimensions is detailed in Section 3.4.1. Additionally, qualitative data were obtained by focus group discussions, analyzed using thematic coding to extract participant experiences and insights as described in Section 3.4.2. Facilitators provided only minimal guidance to preserve the authenticity of intergenerational collaboration. This methodological framework ensured a comprehensive assessment of the workshop's benefits and impact.

3.1 Ethics and data protection

Ethical considerations were strictly adhered to during the recruitment of older adults for the workshops. Participation was entirely voluntary, and no health records or cognitive information were requested during the recruitment process, ensuring privacy and respect for personal data. We followed the ethical guidelines and best practices provided by our research institute's ethics committee to safeguard the dignity, autonomy, and confidentiality of all participants. All workshop activities were based on informed consent, complying with GDPR rules. Each participant received a detailed consent form, which included information about the type of data collected, the process, the purpose, and the duration of data storage. Moreover, before collecting any data, we conducted a Data Protection Impact Assessment (DPIA) to analyze the main risks associated with data processing and to identify the most appropriate mitigation measures.

3.2 Participants

We recruited older adults who were living independently and were able to travel to the study site (GERO location) to participate in the workshop. We shared recruitment information through social media and sent invitation emails to people who had participated in previous studies conducted by the GERO research team. As mentioned in Section 3.1, health and cognitive status of older adult participants were not collected to avoid any formal cognitive or health screening that could lead to exclusion or stigmatization based on medical diagnoses. Instead, our functional inclusion criteria (independent living and autonomous travel to the study site) served as practical indicators that participants retained sufficient cognitive and physical abilities to actively engage in and contribute to the collaborative co-design activities required by the workshop. Thirteen participants, including students and older adults, participated in the study. Among them, six students (four women and two men) took part in this exploratory study as illustrated in Table 1. Additionally, seven older adults (three women and four men) were included in the research. The average age was 22 y/o for students and 72 y/o for older adults, with the oldest participant being 92 y/o.

Participants completed informed consent forms prior to taking part. The participants were informed that they were allowed to quit the experiment at any point without any repercussions. The older adults were asked to indicate their educational background. Two older adults stated that they had previously used Augmented Reality (AR) on a mobile phone, while another two reported having tested a Virtual Reality (VR) or AR Head-Mounted Displays (HMDs). Moreover, all older adults speak the Luxembourgish while one speaks only the English. As for the students, all of them speak the Luxembourgish while one speaks only the English.

3.3 Workshop organization and content

3.3.1 Pre-workshop session

One day before the main workshop, we met students for two and a half hours to prepare them for the main workshop session with older adults. We presented the students with the objectives, motivation, and structure of the main workshop session, including a walkthrough of the presentation prepared for use with the older adult participants. In doing so, specific attention was given to how best to communicate with and engage older adults, taking into account age-related changes in sensory function, such as hearing, vision, and processing speed, to ensure clarity, accessibility, and respectful interaction during the session. Moreover, two XR applications, planned to be presented to older adults, were demonstrated, as students were expected to support older adults in exploring these applications during the main workshop (see Figure 1). The first XR application, Placing Objects and Handling 3D Interaction, is distributed under the MIT License (© 2020 Apple Inc., Cupertino, CA, USA). It is deployed on a tablet and is designed to insert virtual objects (e.g., vases and chairs) into the real environment and enable users to manipulate their position and scale. The second XR application runs on the (Microsoft

TABLE 1 Participant characteristics.

Group	N	Gender	Age	Languages	AR/VR experience
Students	6	4 women, 2 men	Mean: 22 y/o	All LU; 1 only EN	None reported
Older adults	7	3 women, 4 men	Mean: 72 y/o; max 92	All LU; 1 only EN	2 used mobile AR; 2 tried VR/AR HMDs

HoloLens v2, Redmond, WA, USA) and was developed at LIST. The application allows users to discover the concept of a virtual supermarket, where they can purchase vegetables, fruits, and other items, and place orders seamlessly. Furthermore, the pre-workshop was intentionally designed only for students, aiming to minimize cognitive load during the main workshop and to enable students to effectively support older adults in technology adoption, animate discussions, and facilitate co-design activities, rather than focusing on their own learning.

3.3.2 Main workshop session

Participants were assigned to four tables according to their preferred language: English or Luxembourgish. Figure 2 describes the four tables, each represented by a flag indicating the language used by the participants. One table used English, while the others used Luxembourgish. Well-balanced distribution of students and older adults at each table was applied across all tables, except for one, due to the difference in the number of students and older adults. We set a maximum limit of four participants per table, ensuring an equal mix of both groups. This arrangement encouraged meaningful discussions and ensured that everyone had the opportunity to actively engage in the conversation. The study was divided into four sessions:

- 1) Theory session:** This 30-minute session provided an introduction to XR, including key definitions and an overview of its potential benefits for older adults. The primary objective was to familiarize participants, particularly the older adults, with fundamental XR concepts prior to the subsequent hands-on exploration session.
- 2) Hand on XR session:** The duration was roughly 60 minutes. Each table had one HoloLens device and one tablet. Two different XR applications mentioned in the previous section were deployed on HoloLens and the tablet (see Figure 1). Older adults, with the students support, manipulated and interacted with each application. The goal of this session is to allow older adults to explore two different examples of XR, inspiring them for the following session, where they will co-design a new storyboard for an XR application that differs from the ones they experienced in this session.
- 3) Co-Design session:** It lasted around 90 minutes. Content cards showcased six different examples of how older adults can use XR in their daily lives (see Figure 3). The examples were randomly selected and covered the following areas: (1) Social connection, (2) Support for exercise and physical activity, (3) Assistance with transportation and travel, (4) Cooking and meal preparation, (5) Memory aid for daily activities, and (6) Assistance with grocery shopping. The idea of these cards is inspired by Chan et al. (2024) and is designed to offer initial

inspiration for both older adults and students. They are printed and distributed to all the tables. The content cards are generated by AI model to avoid copyrights issues. A presentation on these cards and the concept of storyboarding as part of User Centered Design is delivered. Afterward, each table was asked to create a storyboard that represents a realistic scenario where XR could be beneficial for older adults in their daily tasks as illustrated in Figure 4. Following that, participants of each table were invited to present their storyboard in front of all participants.

4) Questionnaire and feedback session: It lasted approximately 45 minutes and included the administration of two separate surveys, one tailored for students and the other for older adults. These surveys include questionnaires assessing the benefits of the intergenerational workshops and overall satisfaction as detailed in the following section. Moreover, we collected qualitative data through Focus Group Discussions. Participants were divided into three groups: older adults who speak Luxembourgish, a single older adult who speaks only English, and students, all of whom speak English. Each group was asked to answer the same questions regarding their enjoyment of the workshop, aspects that could be improved, and any additional comments or suggestions for future workshops.

It's important to note that the facilitators (authors of this paper) provided an introduction for each session. However, they didn't intervene in the discussion between students and older adults except at the explicit demand of students or older adults. They were moving between the tables to observe and respond to any potential questions. On the other hand, the introduction was given in Luxembourgish, so one facilitator sat near an older adult located at the English table and translated the content.

3.4 Measurements and ratings

3.4.1 Questionnaires

To the best of our knowledge, while there are established evaluation instruments for intergenerational programs [e.g., the Best Practices Checklist to assess implementation fidelity (Jarrott et al., 2022), or the Intergenerational Contact Measure (Turner et al., 2025)], there is no widely used, generic questionnaire analogous to SUS (usability) (Brooke, 1996) or NASA-TLX (workload) (Hart and Staveland, 1988) that comprehensively evaluates the impact and benefits of intergenerational workshops, or the need for future intergenerational workshops. Existing toolkits [such as the Intergenerational Evaluation Toolkit by Generations United (United and Jarrott, 2019)] provide useful measures, but these are often quite program-specific or focus on process rather than perceived benefit. Therefore, we developed questionnaires specifically for this study to evaluate the impact and



FIGURE 1
Two XR applications were demonstrated during the Hands-on XR session: **Left** figure refers to a HoloLens V2 frame showing a virtual supermarket for purchasing items, and **right** figure is an iPad frame showing an app for placing virtual objects like a vase, candle, or cup of tea.

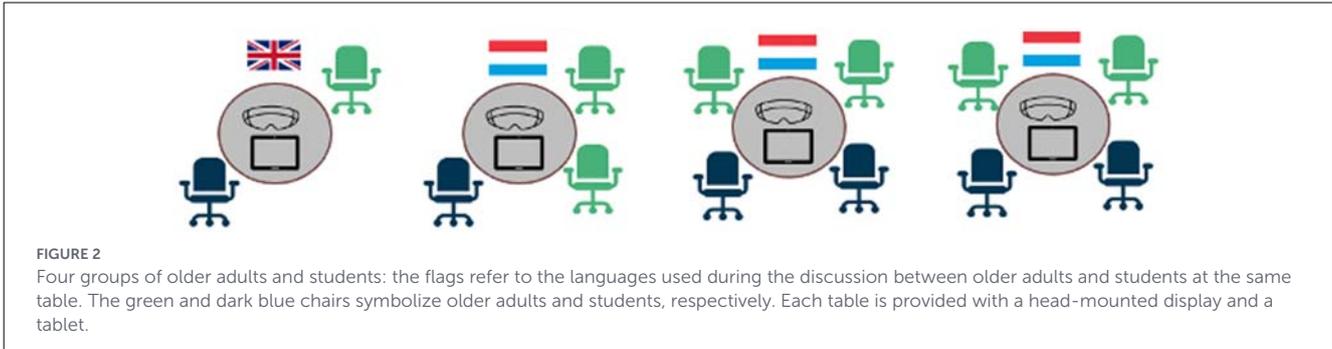


FIGURE 2
Four groups of older adults and students: the flags refer to the languages used during the discussion between older adults and students at the same table. The green and dark blue chairs symbolize older adults and students, respectively. Each table is provided with a head-mounted display and a tablet.



FIGURE 3
Content cards: Examples of content cards provided to participants, showing social connection applications using a head-mounted display (**left**) and a tablet (**right**). The Content cards are an AI-generated illustration created with ChatGPT’s DALL-E 3 model (OpenAI, https://openai.com/index/dall-e-3/?utm_source=chatgpt.com) using the prompts found in the **Supplementary material**. The images presented do not represent real experimental data.

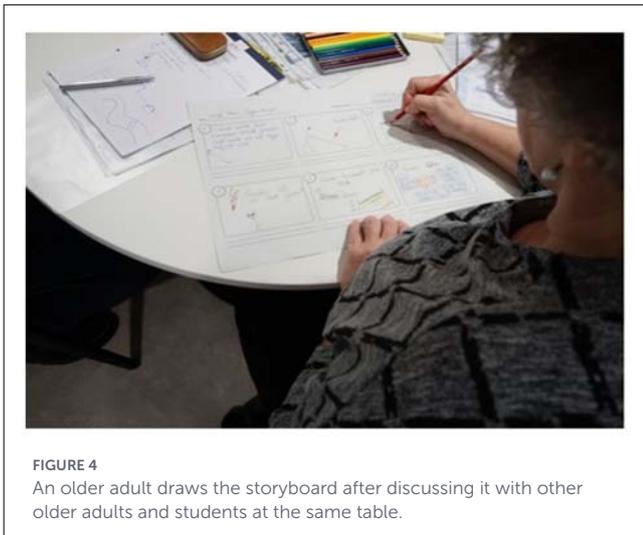


TABLE 2 Older adults questionnaire.

Dimensions	Questions
Workshop impact	Q1—I learned new things related to Augmented Reality during the workshop.
	Q2—I feel more confident about using technology related to Augmented Reality in the future.
Value of intergenerational learning	Q3—I found that working with students helped me think creatively about AR storyboards.
	Q4—The students provided adequate support and guidance during the activities.
	Q5—I like the idea of students assisting me in adopting new technology.
Future workshop demand	Q6—I would be interested in attending more workshops on Augmented Reality or other emerging technologies.
	Q7—I support creating a club where younger and older generations discuss technology that benefits both. Rest assured, your response will have no impact on your ability to join and participate in this future club.

benefits of intergenerational workshops and the need for future intergenerational workshops (see Tables 2, 3). These questions can be grouped into three independent dimensions: (1) Workshop Impact, (2) Value of Intergenerational Learning, and (3) Future Workshop Demand.

The same three dimensions are used for older adults questionnaire as well as students questionnaire with different questions. All questions in both questionnaires are presented on a 5-point Likert scale, ranging from 0 (Strongly disagree) to 4 (Strongly agree) except for Q6 in the older adults questionnaire which uses also a 5-point Likert scale ranging from 0 (poor) to 4 (Excellent).

Moreover, the older adults questionnaire contains three questions related to their background in AR and VR. The questions

TABLE 3 Students questionnaire.

Dimensions	Questions
Workshop impact	Q1—I believe such workshops are valuable for future developers to understand the needs and preferences of older adults.
	Q2—I think these workshops can help students improve collaboration skills like communication, teamwork, and project management.
	Q3—I think these workshops provide students with real-world experience, enhancing their resumes and career readiness.
Value of intergenerational learning	Q4—I was inspired by the input from older adults to explore new designs for AR usage.
Future workshop demand	Q5—I would be interested in attending more workshops on Augmented Reality or other emerging technologies.

are: (Q1) Before this day, have you ever used an Augmented Reality application on a mobile device or tablet?, (Q2) Before this day, have you ever tested a Virtual Reality or Augmented Reality head-mounted display?, and (Q3) Prior to this workshop, were you familiar with Augmented Reality and virtual reality? The older adults answered these questions with “yes” or “no.”

3.4.2 Focus group discussion

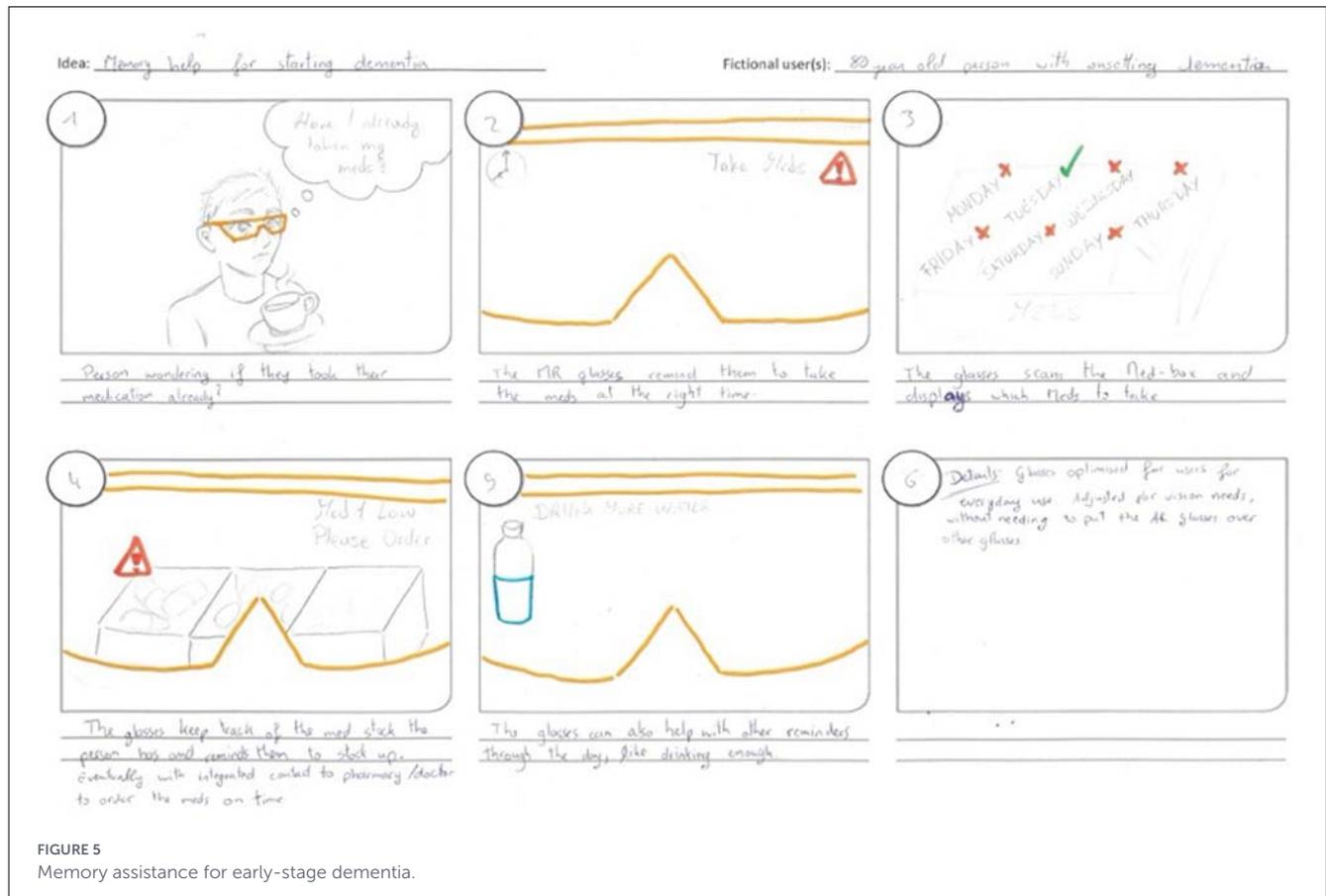
At the end of each session, participants were invited to provide qualitative feedback on the exploratory study. They were divided into three groups: students, older adults who spoke Luxembourgish, and older adults who did not. Each group was seated at a separate table, with a voice recorder placed at each table to capture the discussion.

A facilitator led the conversation at each table using a set of guiding questions. For both older adults and students, the following three identical questions were asked: (1) Did you enjoy participating in the co-design process? Why or why not? (2) Was the structure of the workshop well-organized and easy to follow? and (3) What aspects of the workshop would you improve or change?

Additionally, older adults were asked: Do you find the idea of students assisting you in adopting new technology to be useful?

Meanwhile, students were asked two further questions: (1) What did you learn from this workshop about working with older adults? and (2) What other technologies, like AI or VR, would you suggest for a workshop with older adults?

The responses were analyzed using the four-step process of Erlingsson and Brysiewicz (2017) as detailed in Section 4.3. The steps consisted of identifying meaning units from the discussion provided by the participants, coding the meaning units, creating categories for codes, and finally creating themes for sets of categories. The analysis was done across all participants.



4 Results

In this section, first, we present the storyboards that were co-designed by older adults and students. Second, the results of questionnaire data and the focus group discussion are described.

4.1 Storyboards

To assist older adults in their daily lives, participants suggest storyboards for XR applications. Four storyboards correspond to four different scenarios, collaboratively chosen by older adults and students. Following, we illustrate the scenarios:

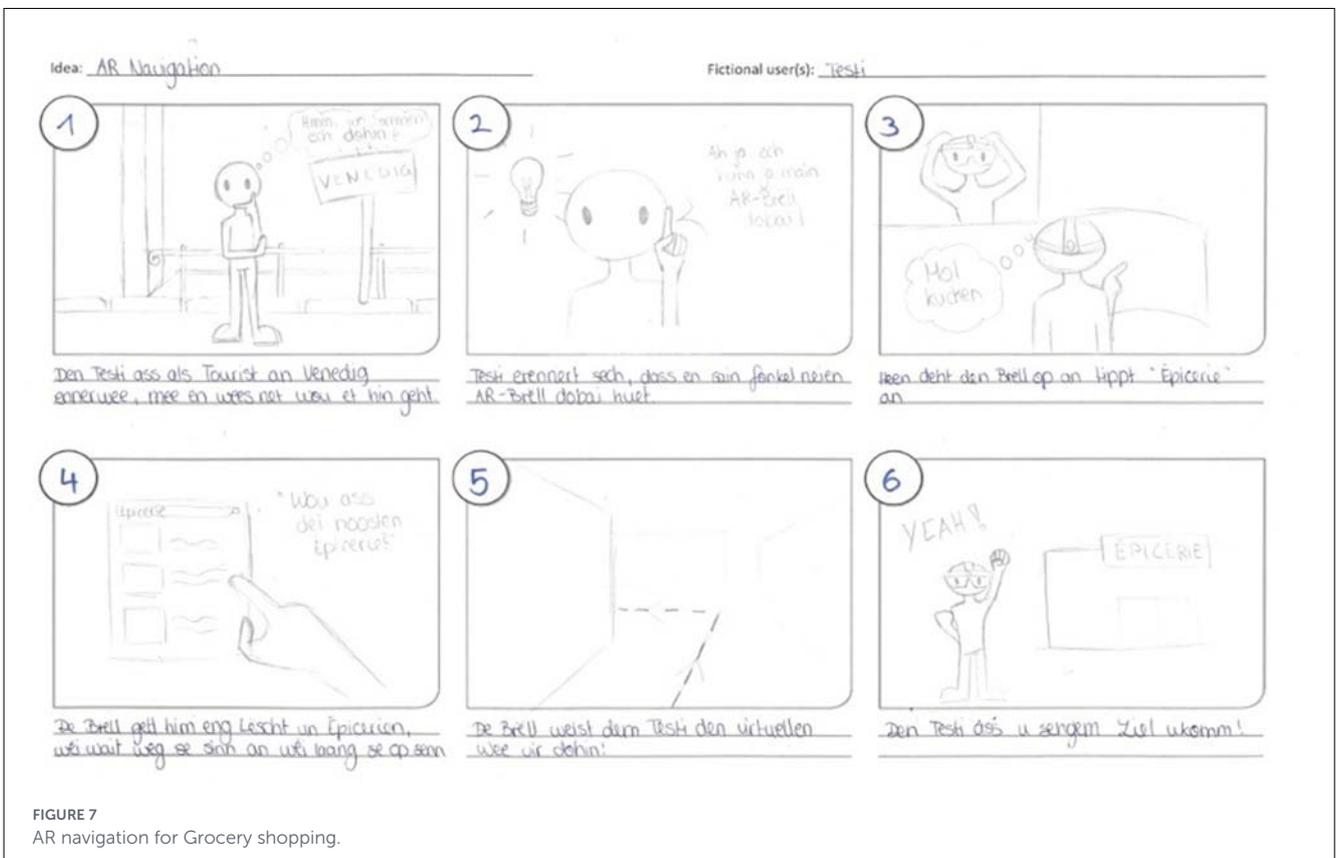
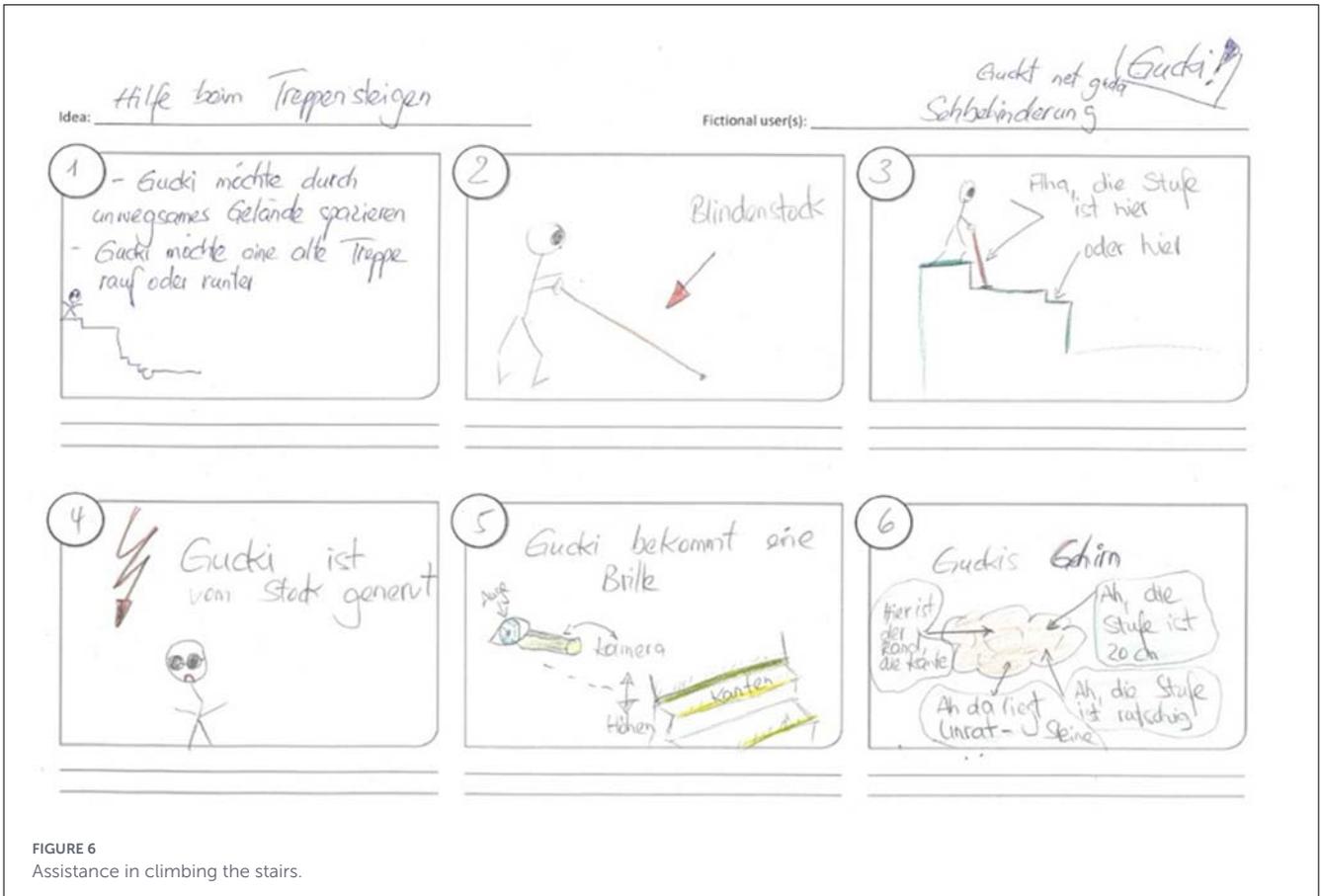
- Memory assistance for early-stage dementia (see Figure 5): The XR application provides multiple functionalities, including: (a) Medication Reminder: Alerts users when it's time to take their medications. (b) Medication Identification: scan a red-labeled box and helps select the correct medicine. (c) stock monitoring & alerts Notifies users when a refill is needed, promoting them to contact a doctor or pharmacist. (d) daily reminders: assists with other essential activities, such as drinking enough water.
- Assistance in climbing the stair (see Figure 6): The scenario is designed for older adults with visual impairments, helping them navigate stairs safely. The XR application enhances stair visibility with contrast markings or virtual overlays.

- AR navigation for Grocery shopping (see Figure 7): In this scenario, users use AR overlays to draw a clear route to the nearest grocery store. It ensures easy navigation even in unfamiliar environments, providing independence.
- Emergency assistance and AR navigation (see Figure 8): It allows user to visualize different restaurants via their HMD. The application supposes to also provide real-time AR navigation to guide users to their chosen restaurant or back home.

Hence, previous scenarios emphasize three broad areas of interest with the third and fourth scenarios overlapping in focus: Healthcare & wellbeing, Accessibility & Mobility, and Smart Living & Urban Navigation. The Table 4 consists of three main board areas, each associated with a core research topic and a specific application domain that describes how XR technology is applied. It answers the third research question and highlights the potential of XR to improve older adults daily lives. It serves as a framework for future research and development in XR tailored for older adults.

4.2 Questionnaire data

Table 5 presents descriptive statistics, including the mean and Standard Deviation (SD), for the three dimensions using the responses of older adults and students. The three dimensions, Workshop Impact, Value of intergenerational Learning, and Future



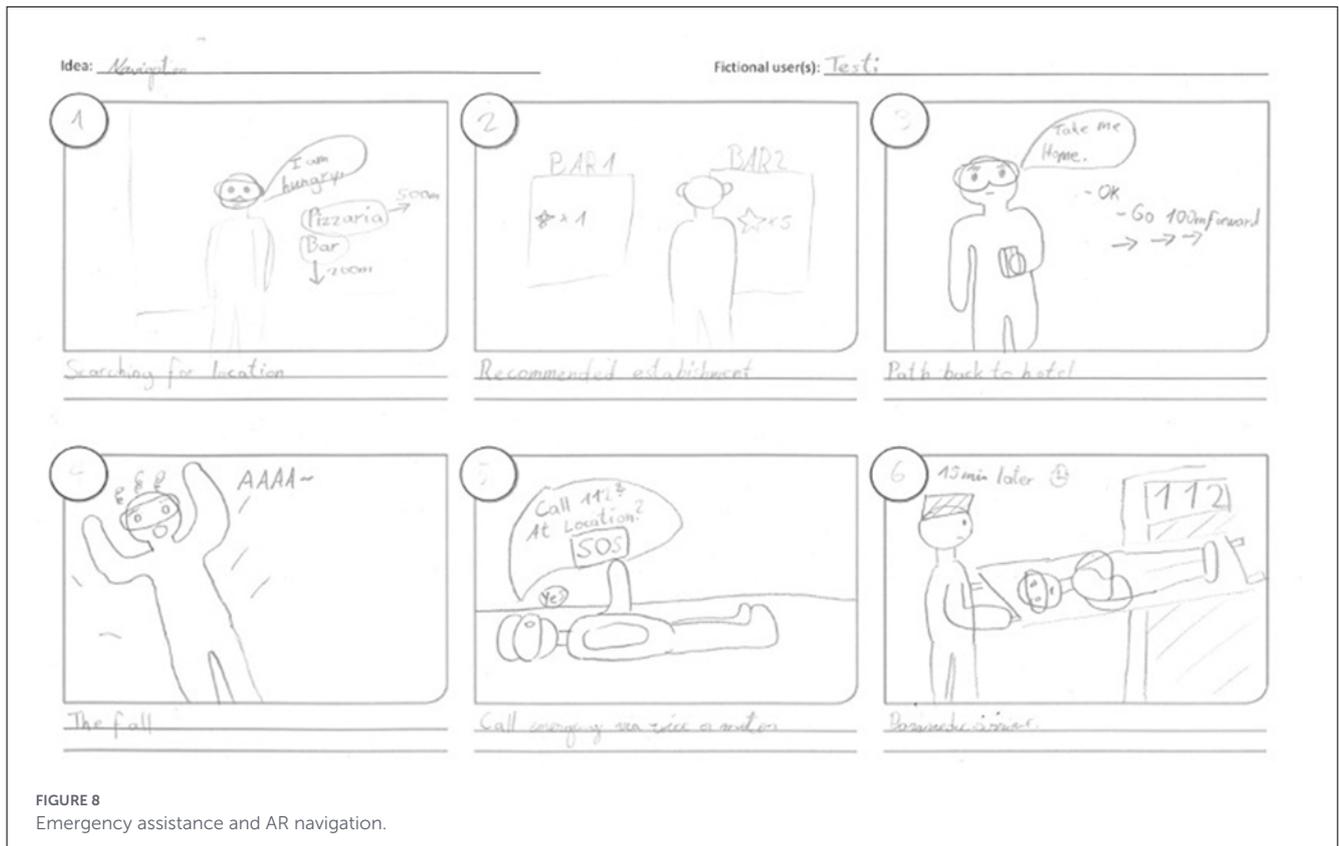


FIGURE 8
Emergency assistance and AR navigation.

TABLE 4 Framework for future research and development in XR tailored for older adults.

Board area	Core research topic	Application domain
Healthcare & wellbeing	Cognitive & memory assistance	Memory assistance for early-stage dementia
Accessibility & mobility	Physical assistance & navigation	Assistance in climbing the stairs
Smart living & urban navigation	Navigation & emergency support	Emergency assistance and outdoor AR navigation

Workshop Demand were generally well-rated by older adults, with average scores of 3.07, 3.47, and 3.57, respectively. These values suggest a favorable overall perception of the workshop across dimensions.

The highest score was about the necessity of proposing additional workshops represented by Future Workshop Demand, underscoring the importance of promoting such workshops to encourage the research community in different domains, such as AI, Robotics, etc. to involve older adults in co-design application via similar further workshops. Moreover, the older adults responses regarding questions Q3, Q4, and Q5 described under the Value of intergenerational Learning dimension provide insight into the benefits of intergenerational workshop and confirm the interest in assisting students in helping older adults adopt new technologies.

However, the SD for the Workshop Impact dimension is 0.87. It's relatively high compared to the SD of other dimensions and suggests the debate among older adults about their confidence in using technology related to Augmented Reality in the future after the workshop. To investigate this, we analyzed potential relationships between the three dimensions and three questions related to participants background in Augmented and Virtual Reality, as described in Section 3.4.1. We first applied the ShapiroWilk test (Hanusz et al., 2016) to check whether the data were normally distributed (see Table 5). The results indicated a normal distribution ($p > 0.05$) for the Workshop Impact ($p = 0.47$) and Value of Intergenerational Learning ($p = 0.61$) dimensions, while the Future Workshop Demand dimension followed a non-normal distribution ($p = 0.0015 < 0.05$). Therefore, we applied a t -test (Student, 1908) which assumes normally distributed data, to the normally distributed dimensions and Wilcoxon test (Wilson, 2024) which is used when the data is not normally distributed to the non-normal distribution dimension. The analysis revealed no clear ($p > 0.05$) or substantial patterns linking prior XR experience to any of the three dimensions. Given the small number of participants, these exploratory analyses should be interpreted cautiously and do not support definitive conclusions about the role of prior technology experience. Hence, the low scores noted by some older adults for the Workshop Impact dimension may be due to the content of the workshop and specifically the two XR applications. Some older adults raised their dissatisfaction with the XR applications crashing during the Hand-on session, as highlighted in the focus group discussion Section 4.3.

TABLE 5 Descriptive statistics and statistical test results for older adults and students across the three evaluation dimensions.

Dimension	Older adults		Students		Normality (Shapiro–Wilk)	Test	Sig. (ρ)
	Mean	SD	Mean	SD			
Workshop impact	3.07	0.87	3.50	0.39	0.47 (>0.05, Normal)	t-test	n.s. (>0.05)
Value of intergenerational learning	3.47	0.64	2.66	1.24	0.61 (>0.05, Normal)	t-test	n.s. (>0.05)
Future workshop demand	3.57	0.49	2.66	0.94	0.0015 (<0.05, Non-normal)	Wilcoxon	n.s. (>0.05)

n.s., not significant. Normality determined via Shapiro–Wilk test ($p > 0.05$ = normal distribution).

Unlike older adults, students scored the impact of the workshop highly 3.5 with a relatively homogeneous response among the students ($SD = 0.39$). Although the study involved a relatively small participant sample, this finding provides preliminary yet encouraging evidence in response to the fourth research question, suggesting potential benefits of integrating such a workshop into the annual curricula of educational technology institutions. However, the standard deviations for the Value of Intergenerational Learning and Future Workshop Demand dimensions are 1.24 and 0.94. These latter indicate high diversity in students responses to these two dimensions. These could be explained through the focus group discussion described in detail in the following section, as some students claim that older adults were very enthusiastic about Augmented/Virtual Reality and highly engaged in the discussion. However, other students found that communication with older adults was difficult. Therefore, these pieces of feedback could explain the debate in answering about the Value of Intergenerational Learning and the Future Workshop Demand dimensions.

4.3 Focus group discussion

We collected qualitative data through Focus Group Discussion method (Amestoy Alonso et al., 2024) as illustrated in Figure 9. Participants were divided into three groups, older adults who speak Luxembourgish, single older adult who speaks only English, and students, all of them speak English. The participants asked different questions regarding their enjoyment of the workshop, aspects that could be improved, and any additional comments or suggestions for future workshops.

4.3.1 Students group

As mentioned previously, the four steps outlined by Erlingsson and Brysiewicz (2017) have been implemented on the focus group discussion conducted with older adults and students at the end of the workshop. As described in Table 6, the analysis of the students focus group discussions revealed three categories, each supported by several meaning units:

- Intergenerational learning: Through the three meaning units described in this category, students appreciated the opportunity to gain new perspectives on how people of different ages think and approach problems.

- Technology acceptance: The discussion among students revealed a divide in older adults technology perception as illustrated in the three meaning units of this category. These results reflect the necessity for a differential view on older adults attitudes toward technology, highlighting both enthusiasm and skepticism within this population.
- Workshop structure and organization: The structure of the workshop was generally appreciated, with a preference for a slower pace and the inclusion of breaks for reflection. However, logistical issues such as unclear timelines, missing schedule display, and language barriers hindered full participation as illustrated through the five meaning units of this category.

The students' focus group discussion highlights the value of intergenerational engagement in challenging stereotypes and enhancing shared learning experiences. Coupled with the high Impact Dimension score reported in the previous section, we strongly recommend, despite the modest sample size, integrating such workshops into the annual curricula of educational technology institutions. Improving workshop organization by ensuring a clear timeline, visible schedules, and multilingual support is essential in cases where participants do not share the same language. Furthermore, based on the meaning units identified through the Technology Acceptance category, we recommend including personal attitudes toward technology in older adults questionnaire to explore any potential relationship between the Personal Innovativeness. Further elaboration on the results of the students' focus group discussion is illustrated in Section 5.

4.3.2 Older adults group

Similar to the students focus group discussion, The analysis of the older adults focus group discussion reveals three major categories (see Table 7), each grounded in several meaning units:

- Technology and practical application: This category is described through two meaning units. Older adults recognized the potential benefits of new technologies for improving daily life, particularly for older adults. However, technical issues, such as application crashes and unstable demos, led to frustration, reducing the effectiveness of hands-on experiences.
- Engagement and intergenerational learning: five meaning units illustrate this category. Older adults enjoyed



FIGURE 9
Co-designed XR storyboard workshop organized by LAM, GERO, and LIST. **Left** figure refers to focus group discussion with older adults, and **right** figure indicates a focus group discussion with students.

TABLE 6 Students' focus group discussion content analysis results.

Meaning unit	Code	Category
P2 = "It was really a nice experience to see how each person thinks differently depending on their age difference."	Gaining new perspectives	Intergenerational learning
P1 = "It's also interesting to get like, a new perspective on thing that we don't think about on the daily, but which is a daily struggle for other people, and in which our development expertise afterwards can help, where we can make an impact on society?"		
P4 = "I got to know what like other people were thinking at the moment, for example, I never would have thought that they suggested like a fitness idea, because I thought that older people would do less sport. But it's apparently the opposite. The more you age, the more apparently you have to move around, which is very interesting."	Challenging stereotypes about older adults	
P5 = "I feel like our group was not very enthusiastic about the whole technology, so it made it really hard to generate ideas that would help out them."	Interest in and enthusiasm for technology	Technology acceptance
P1 = "This stigma that the technology is not for old people, or that they are not interested in , at least for some cases, is definitely wrong, because they are interested in using them and in understanding them. And so there is a use case to cater the new technologies to the older generations?"		
P2 = "I learned today that it's mostly older people who don't need it (new technologies), if they have the right mindset. We could buy something through a VR application, but I could just walk there, what's the problem?"	Mindset influences technology use	
P1 = "I think that it's, for the most part, well organized. It's good that we had an introduction the day before"	Methodology	Workshop structure and organization
P2 = "The break time was pretty good, as older people need time to refresh their minds on what is going on."		
P3 = "I am very glad to have a slower pace rather than a fast one because, with more time, you actually have more opportunity to discuss things differently and explore the dynamics and potential of your idea. I think we has enough time."		
P1 = "It's hard to follow exact timelines,." "There was a timeline in the PowerPoint which was not displayed during the workshop. So we had to speculate, at what time was the pause?"	Lack of clear schedule	
P2 = "I think there should be, like, a translator or something or someone that could help translate to people like don't understand Luxembourgish."	Language barrier in discussion	

For anonymity, student participants are labeled as "P" with a corresponding number.

TABLE 7 Older adults' focus group discussion content analysis results.

Meaning unit	Code	Category
P1 = "It was interesting to think about how such glasses could help me in the future, and that maybe there are possibilities to make life easier for elderly people."	Potential benefits of technology	Technology and practical application
P2 = "There was a problem with the application, it was crashing," "I don't like it if demo applications are crashing."	Technical Issues with application	
P5 = "It was enjoyable."	Enjoyment of the workshop	Engagement and intergenerational learning
P1 = "I learned new things."	Learning experience	
P2 = "To learn a bit about the topic, I was passing the last days on the internet to inform myself what is AR, VR, MR, etc., what is possible today."		
P5 = "I like it (the workshop) because I was working well with two young people who supported me in understanding certain things." "The young people helped a lot, so that helped to bridge the divide on the topic. In that sense, as I said, if they were not there, I would be lost. I mean, absolutely lost, yeah, they guided me through. They helped me. They guided me through. They explained"	Value of intergenerational exchange	
P1 = "I found really important for instance, that we had the young student, and I could ask him many questions, and he could answer them all. I found this really great."		
P1 = "My student was rather shy. I didn't entirely understand the images (content cards) and also couldn't ask questions about it."	Limited communication	Workshop structure and organization
P5 = "English speaking person, it would have been nicer to have been completely integrated"		
P2 = "Workshop, and organization was great. Easy to follow.," "The presentation was a bit short for me. It should have been shown in a small workshop beforehand.," "Would like to have the slides in advance, to prepare and to take notes. Or say, that the slides will be provided in the end.," "Maybe add some small videos in the beginning to show what is possible."	Methodology	
P5 = "Well organized and no problem."		
P4 = "It was a bit short and not so convincing in the example we saw. It was a good experience but was a bit little."		
P3 = "I would have loved to have more time to test.," "It would be good to have more theory"		
P1 = "Maybe add a time where we can ask questions in the big group."		

For anonymity, older adults participants are labeled as "P" with a corresponding number.

brainstorming, collaborative idea generation, and learning new concepts. Intergenerational learning played a key role in knowledge exchange, with younger participants providing valuable guidance.

- Workshop structure and organization: Seven meaning units are grouped in this category. The workshop was well organized and participants valued the structure. However, there is a need for greater clarity to improve the presentation and its contents, including more theoretical material, pre-shared slides, and introductory videos. Furthermore, language barriers hindered full participation for English speakers.

Hence, we recommend continuing intergenerational collaborations to strengthen knowledge-sharing dynamics. For any intergenerational workshop, we recommend allowing more hands-on testing time to enhance older adults engagement. In the following section, we discuss in detail the results of the focus group discussion and link them to the results of the questionnaire data.

5 Discussion

In this section, we present a discussion based on qualitative and quantitative data from older adults and students, along with other observations regarding the content, structure, organization of the workshop, and limitations of this study.

5.1 Older adults

Older adults indicated a high satisfaction on the three dimensions: Workshop Impact, Value of Intergenerational Learning, and Future Workshop Demand with average scores of 3.07, 3.47, and 3.57, respectively, as illustrated in Table 5. These quantitative results, particularly regarding the Value of Intergenerational Learning dimension, find convergent support in the qualitative data obtained from the older adults' focus group discussion. During the content analysis (see Table 7), a

category called Engagement and Intergenerational Learning was identified. This category included five meaning units such as “I was working well with two young people” or “I found really important for instance, that we had the young student, and I could ask him many questions, and he could answer them all.” This study focuses on the co-design of XR applications. The high average score of 3.57 for the question “Would you be interested in attending more workshops on Augmented Reality or other emerging technologies?,” which corresponds to the Future Workshop Demand dimension, confirms the strong interest of older adults in participating in such intergenerational workshops focused on emerging technologies. Despite the limited sample of older adult participants, we advocate for institutions, associations, and municipalities offering activities for older adults to formally integrate such intergenerational workshops into their annual programming to capitalize on the observed benefits.

Moreover, we examined potential relationships between the three dimensions and three questions related to older adults’ backgrounds in augmented and virtual reality. No significant relationships were found. While these results cannot be generalized due to the limited number of participants, they nonetheless offer preliminary insights for future intergenerational workshop planning, indicating that regardless of participants’ prior experience with the technology used as the workshop topic may not substantively affect the workshop’s impact or the value of intergenerational learning for them. As mentioned previously in the state of art section, Cucinelli et al. (2018) identified the uneven distribution of technical knowledge as a challenge when older adults and younger generations work together in video game design workshops using Scratch. In our case, however, this challenge did not arise because our approach leverages the imagination of older adults and their ability to translate daily tasks into the storyboard. Therefore, prior technical knowledge does not appear to be required from the older adults. However, based on the different meaning units identified through the Technology Acceptance category (see Tables 6, 7) such as “Our group was not very enthusiastic about the whole technology, so it made it really hard to generate ideas that would help,” we recommend investigating any potential relationship between the Personal Innovativeness (Agarwal and Karahanna, 2000) and the three dimensions.

5.2 Students

There was more debate through students responses about the Value of Intergenerational Learning dimension with a standard deviation 1.24. Qualitative findings from the focus group discussions help explain this variability. Several students valued the chance to discuss technology and science with older adults, seeing clear benefits in intergenerational learning (see Table 6). However, others found communication difficult. Some students mentioned that older adults’ lack of enthusiasm for technology made it harder to connect, which likely reduced how much they valued these interactions. These qualitative findings shed light

on why the quantitative scores varied so much. Hence, one of the key challenges observed in the intergenerational workshop can be seen through the feedback provided by participants from both generations. An older adult shared that “Student was rather shy,” which suggests limited communication with the student. Therefore, we recommend providing students with guidance on how to effectively communicate with older adults before the intergenerational workshop. This could include being patient, and tailoring conversations for better understanding. Students rated the overall impact of the workshop highly 3.5 with relatively homogeneous responses (SD = 0.39). This consistency is echoed in the qualitative data from the student focus group discussions (see Table 6), where two codes are identified: Gaining new perspectives and Challenging stereotypes about older adults. Together, these qualitative insights help explain the convergence observed in the quantitative results, suggesting that intergenerational engagement contributed to both perspective-taking and the reconsideration of age-related assumptions. These insights highlight the potential of intergenerational initiatives to foster shared learning experiences and address stereotypical perceptions.

Hence, based on these exploratory findings, we tentatively suggest that institutions, associations, and municipalities consider integrating such intergenerational workshops into annual programs for older adults, while educational technology institutions may also benefit from exploring the incorporation of intergenerational workshops into their annual curricula. If validated through larger-scale studies, this approach could potentially help students become more aware of and sensitive to the specific needs of older adults within society, though further research is needed to confirm these preliminary observations.

5.3 Content, structure and organization of the workshop

The methodology consists of two different workshops: a pre-workshop with students to prepare them to animate the discussion, present two different XR applications and the co-design activities with older adults during the main workshop, and a main workshop with students and older adults with the main objective to provide a first hands-on XR experience for older adults and co-design a storyboard for potential XR applications. We acknowledge that this design introduces differences in familiarity and system understanding between the two groups. However, this asymmetry aligned with the study’s focus on intergenerational collaboration and shared expertise in co-designing XR applications, rather than requiring equal technical knowledge from both groups. Furthermore clear and practical XR applications should be emphasized to help make the material more engaging and convincing for older adults during workshop. Moreover, content cards were not clear for some older adults that noted in the focus group discussion their preference to have more explanation about these cards. This could be derived from a lack of communication with students at the same table. Furthermore, participants who do not share a common language present an additional challenge

for workshop organization. We had one table composed of an older adult and a student who communicated together in English, while the workshop presentation was delivered in Luxembourgish. One of the facilitators sat near the older adult and translated for him, but this was difficult since he could not translate loudly without distributing the other tables. As a result, the student sitting at same table was unable to benefit from the translation. Therefore, a real time English-speaking translator is necessary so that translations can be provided via headphones for English speaker participants. In the workshop structure, we also recommend providing more hands-on testing time to enhance older adults engagement.

5.4 Co-designing XR application storyboard

Furthermore, four storyboards for a potential XR application aimed at supporting older adults in their daily lives were proposed during the intergenerational workshop. These included: (1) Memory assistance tools for individuals in the early stages of dementia, (2) XR-supported guidance for safely climbing stairs, (3) Augmented Reality (AR) navigation aids for grocery shopping, and (4) AR-enabled emergency assistance and real-time navigation. Each concept addressed specific challenges commonly faced by aging populations and leveraged XR technologies to offer intuitive, engaging, and supportive solutions. Drawing from these storyboards, we identify key areas for future research and development in XR applications tailored to older adults. These areas can be grouped into three overarching domains: (1) Healthcare & Wellbeing, focusing on cognitive support, mental health, and chronic condition management; (2) Accessibility & Mobility, addressing physical limitations, safe navigation, and independence in movement; and (3) Smart Living & Urban Navigation, which includes the integration of XR into smart home environments and public infrastructure to enhance safety, convenience, and autonomy. These domains offer a roadmap for developing inclusive and impactful XR solutions that align with the needs of an aging population. Therefore, we recommend that companies developing XR applications consider older adults during the design process, especially when applications relate to one of three broad areas. For example, applications like [Beat Saber \(2019\)](#) are well-suited for the first area: Healthcare and Well-being. Nevertheless, such applications remain poorly adapted to the needs and abilities of older adults.

5.5 Limitations

An intergenerational workshop can be conducted starting from two persons: an older adult and a younger generation representative. However, to study the benefits and gain insights and findings from the intergenerational workshop, to the best of our knowledge, there is no specific minimum number of participants in intergenerational workshops mentioned in the state of the art, unlike, for example, studies [Lewis \(1994\)](#) and [Robert \(1992\)](#), which have shown that a small number of participants can uncover a large

share of usability issues, with some suggesting that five users may identify up to 80% of problems. However, we consider the sample size in this study ($n = 13$) to be limited and acknowledge that it constrains the generalizability of the findings.

We did not formally assess participants' cognitive or health status to avoid stigmatization and medicalization of the recruitment process. However, this means our sample likely consisted of higher functioning older adults capable of independent living and travel. Therefore, our findings may not generalize to older adults with moderate to severe cognitive impairments or significant functional limitations, and future work should examine intergenerational XR workshop methodology that can accommodate a broader range of cognitive abilities.

Furthermore, future research would benefit from comparing these results with those from non-intergenerational workshops to better contextualize the findings. Hence, it is important to conduct non-intergenerational workshops with older adults to design XR storyboards and others with students, and compare them with the intergenerational workshops proposed in this study, as this would offer valuable context for interpretation.

6 Conclusion

We present a methodology to organize an intergenerational workshop that brings together older adults and students enrolled in a college program focused on game design and programming to co-design a storyboard for XR application to support older adults in their daily lives. This methodology includes a pre-workshop for students and main workshop for both older adults and students. We collected qualitative and quantitative data at the end of the workshop. The quantitative data is grouped into three dimensions: Workshop Impact, Value of Intergenerational Learning, and Future Workshop Demand. The three dimensions are well rated in general by older adults as well as students. Furthermore, older adults highly rated Future Workshop Demand which refers to the necessity of proposing additional workshops while the students emphasized the benefits of intergenerational workshop for students providing higher score for Workshop Impact. Based on both the students and older adults focus groups discussion, we encourage more intergenerational engagement to strengthen knowledge-sharing dynamics and challenge stereotypes. We provide recommendations to improve the organization of intergenerational workshops. These include allowing more hands-on testing time to enhance older adults engagement, ensuring a clear timeline and visible schedules, and offering multilingual support. We also recommend investigating the potential relationship between Personal Innovativeness ([Agarwal and Karahanna, 2000](#)) and the three identified dimensions. Moreover, we suggest providing students with guidance on how to effectively communicate with older adults prior to the workshop. This could include encouraging patience and adapting their communication style to ensure better understanding. Finally, this paper highlights three broad areas as key axes for developing XR applications tailored to older adults: "Healthcare & Wellbeing," "Accessibility & Mobility," and "Smart Living & Urban Navigation."

Data availability statement

The datasets presented in this article are not readily available because we have based our research activity on participants consent, as defined by Article 6(1) of the GDPR. It has been mentioned in the consent that the data acquired during the experimental tests for this study will not be shared with anyone outside of our research institute. Requests to access the datasets should be directed to muhannad.ismael@list.lu.

Ethics statement

The studies involving humans were approved by the Luxembourg Institute of Science and Technology (LIST) Ethics Committee. Affiliation: Luxembourg Institute of Science and Technology (LIST). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

MI: Supervision, Software, Writing – review & editing, Writing – original draft, Conceptualization, Project administration, Methodology, Validation. VM: Methodology, Conceptualization, Validation, Writing – review & editing. MH: Methodology, Conceptualization, Validation, Writing – review & editing. RM: Methodology, Validation, Conceptualization, Writing – review & editing. MH: Writing – review & editing, Software. ET: Writing – review & editing, Validation, Methodology, Conceptualization.

Funding

The author(s) declared that financial support was received for this work and/or its publication. This study is supported

References

- Agarwal, R., and Karahanna, E. (2000). Time flies when you're having fun: cognitive absorption and beliefs about information technology usage. *MIS Quart.* 24:665. doi: 10.2307/3250951
- Amestoy Alonso, B., Donegan, T., Calvis, I., Swidrak, J., Rodriguez, E., Vargas-Revern, C. L., et al. (2024). Focus groups in the metaverse: shared virtual spaces for patients, clinicians, and researchers. *Front. Virt. Real.* 5:1432282. doi: 10.3389/frvir.2024.1432282
- Amouzadeh, E., Dianat, I., Faradmal, J., and Babamiri, M. (2025). Optimizing mobile app design for older adults: systematic review of age-friendly design. *Aging Clin. Exp. Res.* 37, 1–41. doi: 10.1007/s40520-025-03157-7
- Aruanno, B., and Garzotto, F. (2019). Memholo: mixed reality experiences for subjects with Alzheimer's disease. *Multimed. Tools Appl.* 78, 13517–13537. doi: 10.1007/s11042-018-7089-8
- Balcerzak, B., Kopec, W., Nielek, R., Kruk, S., Warpechowski, K., Wasik, M., et al. (2017). "Press F1 for help: participatory design for dealing with on-line and real life security of older adults," in *2017 12th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT)* (Lviv, Ukraine: IEEE), 240–243. doi: 10.1109/STC-CSIT.2017.8098778
- Beat, S. (2019). *Beat saber*. Video game [Oculus Rift, HTC Vive, PlayStation VR].
- Blomqvist, S., Seipel, S., and Engström, M. (2021). Using augmented reality technology for balance training in the older adults: a feasibility pilot study. *BMC Geriatr.* 21, 1–13. doi: 10.1186/s12877-021-02061-9
- Brooke, J. (1996). Sus: a quick and dirty usability scale. *Usability Eval. Ind.* 189, 4–7.
- Chan, S., Liu, R., Ostrowski, A. K., Vaidya, M., Brady, S., Yoquinto, L., et al. (2024). *Co-designing Generative AI Technologies With Older Adults to Support Daily Tasks*. MIT.
- Cucinelli, G., Davidson, A.-L., Romero, M., and Matheson, T. (2018). Intergenerational learning through a participatory video game design workshop. *J. Intergener. Relatsh.* 16, 146–165. doi: 10.1080/15350770.2018.1404855

by the Luxembourg Institute of Science and Technology, GERO- Kompetenzzentrum für den Alter, and the Lycée des Arts et Métiers.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fcomp.2026.1763935/full#supplementary-material>

- Diaz-Orueta, U., Hopper, L., and Konstantinidis, E. (2020). Shaping technologies for older adults with and without dementia: Reflections on ethics and preferences. *Health Inform. J.* 26, 3215–3230. doi: 10.1177/1460458219899590
- Doyle, J., Sassu, A., and McDonagh, T. (2013). “we were all the same age once—experiences of intergenerational app design,” in *27th International BCS Human Computer Interaction Conference (HCI 2013)* (BCS Learning Development). doi: 10.14236/ewic/HCI2013.33
- Erlingsson, C., and Brysiewicz, P. (2017). A hands-on guide to doing content analysis. *African J. Emerg. Med.* 7, 93–99. doi: 10.1016/j.afjem.2017.08.001
- GERO (2024). *Vr-health: Ralit virtuelle dans la maison de retraite*. Available online at: <https://www.gero.lu/infos/vr-health> (Accessed December 1, 2025).
- Gutheil, I. A., Chernesky, R. H., and Sherratt, M. L. (2006). Influencing student attitudes toward older adults: Results of a service-learning collaboration. *Educ. Gerontol.* 32, 771–784. doi: 10.1080/03601270600835470
- Hagen, O., Varga, M., Baxter, R., Bradwell, H., Jones, R., Aly, A., et al. (2024). “Intergenerational technology co-design process: Reflections from underwater telepresence and XR workshops,” in *International Conference on Information and Communication Technologies for Ageing Well and e-Health* (Springer), 102–122. doi: 10.1007/978-3-032-10685-8_7
- Hanusz, Z., Tarasinska, J., and Zielinski, W. (2016). Shapiro-wilk test with known mean. *REVSTAT-Stat. J.* 14, 89–100.
- Hart, S. G., and Staveland, L. E. (1988). “Development of nasa-tlx (task load index): results of empirical and theoretical research,” in *Advances in Psychology* (Elsevier), 139–183. doi: 10.1016/S0166-4115(08)62386-9
- Ienca, M., Schneble, C., Kressig, R. W., and Wangmo, T. (2021). Digital health interventions for healthy ageing: a qualitative user evaluation and ethical assessment. *BMC Geriatr.* 21:412. doi: 10.1186/s12877-021-02338-z
- Jarrott, S. E., Turner, S. G., Naar, J. J., Juckett, L. M., and Scrivano, R. M. (2022). Increasing the power of intergenerational programs: advancing an evaluation tool. *J. Appl. Gerontol.* 41, 763–768. doi: 10.1177/07334648211015459
- Jin, X., Tong, W., Wei, X., Wang, X., Kuang, E., Mo, X., et al. (2024). “Exploring the opportunity of augmented reality (AR) in supporting older adults to explore and learn smartphone applications,” in *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*, 1–18.
- Kalisch, H. R., Coughlin, D. R., Ballard, S. M., and Lamson, A. (2013). Old age is a part of living: student reflections on intergenerational service-learning. *Gerontol. Geriatr. Educ.* 34, 99–113. doi: 10.1080/02701960.2012.753440
- Kanayama, T., Wagner, S., Blake, R., and Haggith, M. (2025). Carnivalized storytelling: a workshop method for intergenerational creativity. *J. Perspect. Appl. Acad. Pract.* 13:48. doi: 10.56433/y4xm9f48
- Kopeć, W., Balcerzak, B., Nielek, R., Kowalik, G., Wierzbicki, A., and Casati, F. (2018). “Older adults and hackathons: a qualitative study,” in *Proceedings of the 40th International Conference on Software Engineering*, 702–703. doi: 10.1145/3180155.3182547
- Lewis, J. R. (1994). Sample sizes for usability studies: additional considerations. *Hum. Factors* 36, 368–378. doi: 10.1177/001872089403600215
- Lindsay, S., Jackson, D., Schofield, G., and Olivier, P. (2012). “Engaging older people using participatory design,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1199–1208. doi: 10.1145/2207676.2208570
- Mannheim, I., Schwartz, E., Xi, W., Buttigieg, S. C., McDonnell-Naughton, M., Wouters, E. J., et al. (2019). Inclusion of older adults in the research and design of digital technology. *Int. J. Environ. Res. Public Health* 16:3718. doi: 10.3390/ijerph16193718
- Mannheim, I., Wouters, E. J., Köttl, H., Van Boekel, L. C., Brankaert, R., and Van Zaal, Y. (2023). Ageism in the discourse and practice of designing digital technology for older persons: a scoping review. *Gerontologist* 63, 1188–1200. doi: 10.1093/geront/gnac144
- Margrett, J. A., Ouwerson, K. M., Gilbert, S. B., Phillips, L. A., and Charness, N. (2022). Older adults’ use of extended reality: a systematic review. *Front. Virt. Reality* 2:760064. doi: 10.3389/frvir.2021.760064
- McDonough, C. (2016). The effect of ageism on the digital divide among older adults. *Gerontol. Geriatr. Med.* 2, 1–7. doi: 10.24966/GGM-8662/100008
- Mehrabi, S., Mu noz, J. E., Basharat, A., Boger, J., Cao, S., Barnett-Cowan, M., et al. (2022). Immersive virtual reality exergames to promote the well-being of community-dwelling older adults: protocol for a mixed methods pilot study. *JMIR Res. Protoc.* 11:e32955. doi: 10.2196/32955
- Ng, P., Zhu, S., Li, Y., and Van Amejide, J. (2025). Intergenerational cooperation and co-creation in public space design assisted by Virtual Reality (VR) environments. *Architect. Intell.* 4:1. doi: 10.1007/s44223-024-00080-1
- Otjacques, B., Krier, M., Feltz, F., Ferring, D., and Hoffmann, M. (2009). “Helping older people to manage their social activities at the retirement home,” in *People and Computers XXIII Celebrating People and Technology. BCS Learning and Development*. doi: 10.14236/ewic/HCI2009.46
- Penick, J. M., Fallshore, M., and Spencer, A. M. (2014). Using intergenerational service learning to promote positive perceptions about older adults and community service in college students. *J. Intergerener. Relatsh.* 12, 25–39. doi: 10.1080/15350770.2014.870456
- Pradhan, A., Jelen, B., Siek, K. A., Chan, J., and Lazar, A. (2020). “Understanding older adults’ participation in design workshops,” in *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 1–15. doi: 10.1145/3313831.3376299
- Reis, L., Mercer, K., and Boger, J. (2021). Technologies for fostering intergenerational connectivity and relationships: scoping review and emergent concepts. *Technol. Soc.* 64:101494. doi: 10.1016/j.techsoc.2020.101494
- Robert, A. V. (1992). Refining the test phase of usability evaluation: How many subjects is enough? *Hum. Factors* 34, 457–468. doi: 10.1177/001872089203400407
- Rogers, Y., Paay, J., Brereton, M., Vaisutis, K. L., Marsden, G., and Vetere, F. (2014). “Never too old: engaging retired people inventing the future with makey makey,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 3913–3922. doi: 10.1145/2556288.2557184
- Rohrbach, N., Gulde, P., Armstrong, A. R., Hartig, L., Abdelrazeq, A., Schröder, S., et al. (2019). An augmented reality approach for ADL support in Alzheimer’s disease: a crossover trial. *J. Neuroeng. Rehabil.* 16, 1–11. doi: 10.1186/s12984-019-0530-z
- Student (1908). The probable error of a mean. *Biometrika* 6, 1–25. doi: 10.1093/biomet/6.2-3.302
- Turner, S. G., Hooker, K., Jarrott, S. E., and John Geldhof, G. (2025). Development of a new measure of intergenerational contact. *J. Adult Dev.* 2025, 1–14. doi: 10.1007/s10804-025-09525-x
- Ullal, A., Tauseef, M., Watkins, A., Juckett, L., Maxwell, C. A., Tate, J., et al. (2024). “An iterative participatory design approach to develop collaborative augmented reality activities for older adults in long-term care facilities,” in *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*, 1–21. doi: 10.1145/3613904.3642595
- United, G., and Jarrott, S. (2019). *Intergenerational evaluation toolkit*. Technical report, Generations United/The Eisner Foundation. Toolkit includes outcome-measurement tools for intergenerational programs.
- US Census Bureau (2016). *An aging world: 2015*. Technical Report P95–16–1, United States Census Bureau.
- Varella, A., Antoniou, P. E., Pickering, J. D., Chatzimalis, C., and Bamidis, P. D. (2022). “Evaluating co-creative XR resource design and development; observations from the field,” in *2022 8th International Conference of the Immersive Learning Research Network (ILRN)* (IEEE), 1–5.
- Wang, G., Kasraian, D., Lu, Y., Hurst, W., Jambroes, M., and Van Wesemael, P. (2024). “The intangible outcomes of an intergenerational hackathon for active aging: a case study,” in *Proceedings of the Participatory Design Conference 2024: Full Papers*, 208–220. doi: 10.1145/3666094.3666114
- Wang, G., Kasraian, D., Valk, C., Kersten, A., Hurst, W., Lu, Y., et al. (2025). Interdisciplinary hackathons for community-based co-design with older adults: a case study. *CoDesign* 21, 136–151. doi: 10.1080/15710882.2024.2378933
- Wang, Y., and Zhang, Y. (2024). “Enhancing cognitive recall in dementia patients: integrating generative AI with virtual reality for behavioral and memory rehabilitation,” in *Proceedings of the 2024 6th International Conference on Big-Data Service and Intelligent Computation, BDSIC '24* (New York, NY, USA: Association for Computing Machinery), 86–91. doi: 10.1145/3686540.3686552
- Wei, X., Gu, Y., Kuang, E., Wang, X., Cao, B., Jin, X., et al. (2023). “Bridging the generational gap: exploring how virtual reality supports remote communication between grandparents and grandchildren,” in *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, 1–15. doi: 10.1145/3544548.3581405
- Wilson, P. (2024). “An updated wilcoxon–mann–whitney test,” in *Developments in Statistical Modelling*, eds. J. Einbeck, H. Maeng, E. Ogundimu, and K. Perrakis (Cham: Springer Nature Switzerland), 159–165. doi: 10.1007/978-3-031-65723-8_25
- Yang, Q., Zhang, L., Chang, F., Yang, H., Chen, B., and Liu, Z. (2025). Virtual reality interventions for older adults with mild cognitive impairment: Systematic review and meta-analysis of randomized controlled trials. *J. Med. Internet Res.* 27:e59195. doi: 10.2196/59195
- Zhao, W., Kelly, R. M., Rogerson, M. J., and Waycott, J. (2024). “Older adults imagining future technologies in participatory design workshops: supporting continuity in the pursuit of meaningful activities,” in *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*, 1–18. doi: 10.1145/3613904.3641887
- Zou, R., Yin, S., Song, T., Qin, P., and Lee, Y.-C. (2024). Mitigating ageism through virtual reality: intergenerational collaborative escape room design. *arXiv:2403.03742*.