How Older Adults Integrate Smart and Robotic Technologies into the Daily Lives

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Abstract. This paper explores the integration of smart and robotic technologies into the daily lives of older adults, alongside an examination of digital technologies. We conducted a study involving first-year students from the University of Udine, who interviewed 344 older adults, including their grandparents, great-uncles, neighbors, or family friends. The interviews addressed the ownership of these technologies, patterns of usage, and whether they contribute to alleviating loneliness and simplifying the lives of older adults. Additionally, we explored their preferences regarding technology they would like to possess, cannot do without, and wish to learn to use. Finally, we examined how they perceive their relationship with these technologies and their level of comfort in using them. Our research questions were as follows: Do these respondents exhibit similar attitudes toward smart and robotic technologies as older individuals did toward digital technologies? Do different age groups within the older population (young-old, ages 65–74; old-old, 75–84; and oldest-old, 85–99) experience specific relationships with these technologies? Do older women lag behind men in adopting smart and robotic technologies, as they did with digital technologies? Our findings reveal that: (1) Older adults generally express a dissonance towards smart and robotic technologies similar to what they felt and continue to feel towards digital technologies; (2) Young-old respondents (65–74) are quite engaged with these technologies, while the oldest-old interact significantly less with them compared to their younger counterparts. The old-old stand in balance between the two, in some cases being no different from the young-old and in others no different from the oldest-old; (3) Older women experience significantly more difficulties with these technologies compared to men.

Keywords: Digital Technology · Smart Technology · Robotic Technology · Young-old · Old-old · Oldest-old

1 Introduction

This paper explores how older adults navigate the landscape of smart and robotic technologies in their daily lives. In contrast to many studies focusing solely on social robotics among older adults, we have opted to investigate a broader technological spectrum by

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including digital devices. Our aim was to encompass all household technologies except domestic appliances. Why? Because, as Edwards et al. (2024) argued, there exists a continuum between digital, smart, and robotic technologies, with the latter two evolving from the foundation laid by digital technologies. For instance, virtual assistants like Siri and Cortana originated within mobile phones and computers before evolving into standalone entities. Therefore, to comprehensively study the adoption of robotic products in households, it is imperative to take a holistic approach and explore the entire network of domestic technologies. Existing discussions on the relationship between older adults and robotics often highlight older adults' limited technological literacy. However, it is essential to recognize that this deficiency isn't solely attributable to robotic products but rather extends to a broader lack of literacy concerning the digital technologies that preceded them.

We decided to take advantage of the accumulated knowledge from scholars who have previously studied information and communication technologies from a user's perspective. Drawing on Edwards et al. (2024), we built our conceptual framework starting from the family of theories on users, including Bourdieu's theory on the practices of use (1977), the social shaping of technology (MacKenzie and Wajcman 1985), the co-construction of technology (Oudshoorns and Pinch 2003), and domestication theories (Silverstone and Haddon 1996). We chose to adopt these theories because they have proven effective in centering users in scientific research, deeply capturing their attitudes and behaviors toward technologies. Users as an independent variable of technology diffusion and adoption have represented the reading of a more dynamic relationship between society, culture, and technology (Fortunati 2014). These theories, which developed primarily in the fields of communication and sociology in the early 1990s, have challenged the prevalent conception of users as merely dependent variables of technology diffusion and adoption. Bourdieu's theory on the relations of power in digital technologies has inspired us to investigate how power dynamics between devices and users shape our specific case: do older people empower themselves through smart and robotic technologies, or do they feel disempowered by them? From this theoretical perspective, we aim to offer a fresh insight into the rich debate on robotics and aging (e.g., Pederson et al. 2018; Pu et al. 2019; Søraa et al. 2023).

The recent introduction of robotic devices into households has sparked a renewed interest among tech companies in domestic innovations, ending a prolonged period of stagnation in new appliance development for the home environment (Fortunati and Edwards, 2024). Robotic technologies such as Roomba vacuum cleaners (Forlizzi and DiSalvo 2006), Bimby kitchen machine (aka Thermomix) (Ascione 2013; Truninger 2016), robotic lawnmowers (Bogue 2017) and home automation systems or smart technologies (Strengers et al. 2019) and Alexa (Fortunati et al. 2022a, b; Edwards et al. 2024) are beginning to gain popularity even among older adults.

In this paper, we introduce the new concept of structural dissonance, which aims to describe the mismatch between the design of contemporary digital technologies and the everyday realities of older individuals. This concept also extends to smart and robotic products. Digital technologies, originating in the 1990s within communities largely dominated by young, hyper-masculine ICT designers (Lingel and Crawford 2020), were primarily tailored for a specific demographic—enthusiastic, knowledge-hungry young

users with a penchant for novelty and adaptability. Conversely, older individuals often lacked expertise in digital technologies from their youth and adulthood. Moreover, at this life stage, continuous learning is not a priority and may be perceived as a burden. However, they had little choice but to accept or reject digital technology as it was presented to them.

During this initial phase, older adults were often blamed for their slow adoption of technology, leaving them feeling guilty about their perceived inadequacy and under pressure to integrate into the information society (Ling 2008). Unfortunately, scholars studying this early stage of older adults' engagement with these technologies have provided limited insights into the real conditions of older adults' lives. Therefore, our first research question is: Do our respondents internalize this feeling of guilt and inadequacy towards smart and robotic technologies as well?

As time has progressed, individuals who gained experience with digital technologies during their adult lives, both in professional settings and at home, have aged, leading to a diversification of the older population. This diversification has affected various aspects of older population's lives, including health, family dynamics, travel opportunities, and exploration of the world, as well as attitudes toward technology. As a consequence of this diversification, technology access and usage among older people today are highly varied, rather than static. Even when the oldest-old are adequately represented in research and data (a rarity), we argue that, with some exceptions, the genuine conditions of their lives are not fully captured in current literature and discussions on aging and technology.

As long as digital, smart, and robotic technology is viewed solely as a lens for observing the lives of older adults, we will continue to overlook their experiences and fail to engage in a meaningful comprehension of what it truly means to grow older. Despite this diversification, the careful management of personal resources, which often diminishes in later life, remains consistent compared to previous generations of older adults. Thus, older adults frequently encounter a reduced willingness or outright refusal to invest time in learning how to use these technologies, even if they have the potential to enhance their quality of life.

Moreover, according to ISTAT (2022, p. 8), the population over sixty-five in Italy year after year grows, totaling 14 million 177 thousand individuals at the beginning of 2023, constitutes 24.1% of the total population, compared to 23.8% the previous year. Additionally, in the case of oldest individuals, who are more affected by excess mortality, namely those over eighty, there is still an increase, bringing their number to 4 million 530 thousand and representing 7.7% of the total population, compared to 7.6% the previous year. Vincent (2023) argued that social research rarely takes into account the present demographic structuring of the third age, which, according to the definitions officially adopted to date (see, for example, Cohen-Mansfield et al. 2013), is far from being monolithic and is now divided into three groups: young- old (65–74), old-old (75–84), and the oldest-old (85–99). Therefore, our second research question is: Do these three age groups experience a specific relationship with digital, smart, and robotic technologies?

Finally, an often-overlooked fact is that 60% of old individuals over the age of 75, constituting the majority, are women. According to ISTAT (2020), over 4 million and 300 thousand women (4,330,074) have reached and surpassed 80 years of age,

with 774.5 thousand (774,528) reaching 90 years. The prevalence among the female population, who tend to live longer than males, increases by 10 percentage points between octogenarians and nonagenarians, rising from 63% to 73% respectively. Fortunati and Edwards (2022) demonstrated that the emergence of digital technologies has represented a specific challenge for women, as they have lagged behind men in various indices related to mediated communication, particularly computer-mediated communication. Building upon this, we were interested in investigating how this more problematic relationship with digital technologies also manifests with smart and robotic technologies among older women. Therefore, our third research question is: Do women lag behind men in their later years with respect to these new technologies as well?

To gain deeper insight into Italian older adults' attitudes towards digital, smart, and robotic technologies, a study was conducted involving first-year students from the University of Udine, Italy. A total of 344 older individuals were interviewed, and the interviews explored ownership, frequency of use, respondents' opinions, needs, desires, and evaluations regarding these technologies. Insights from this research shed light on fundamental dynamics characterizing the relationship between older individuals and digital, smart, and robotic technologies. Their answers offer a compelling window into the everyday realities experienced by older adults, providing a nuanced glimpse into their daily lives.

2 Methodology

2.1 Participants and Procedure

In 2021, we developed a questionnaire for this study based on insights gained from two previous research projects conducted in 2012 with 23 students and in 2016 with 76 students enrolled in the same undergraduate technical course at the University of Udine. These students were tasked with serving as key informants, providing their experiences and observations on older people's use of digital technologies through written essays (Fortunati 2018). Eight years later, in the same university, a class of undergraduate students was tasked with administering a questionnaire on digital, smart, and robotic technologies to their grandparents, great-uncles, neighbors, or family friends. In total, 344 valid questionnaires were collected.

The questionnaire, which took an average of 30 min to complete, presented questions always given in the same order. In terms of the overall convenience sample, we examined various socio-demographic variables, including gender, age, education, marital status, place of residence, and the types of jobs respondents held before retirement. While existing discussions on the relationship between older adults and technologies often emphasize the importance of two key socio-demographic variables—gender and education—we chose to include additional variables to determine if any of them have gained significance over time.

2.2 Measures and Data Analysis

For the current study, we included a question specifically related to ownership, with a yes/no answer format. Respondents were presented with a list of devices encompassing

both old and new technologies such as radio, television, tablet, fixed telephone, mobile phone, laptop, and the internet, and including smart (home automation system) and robotic technologies (vocal assistant such as Alexa, robot vacuum cleaner like Roomba, multifunction kitchen robot such as Bimby, and robot lawn mower). Additionally, we inquired about the frequency of use of these technologies using a 5-point scale (where 1 correspond to never, 2 rarely, 3 sometimes, 4 often and 5 always).[1]

We also examined respondents' opinions on two specific issues through yes/no answers: (1) Do you believe new communication technologies can reduce loneliness? (2) Do you think new technologies can be useful in simplifying the life of an elderly person?

Following this, we explored respondents' desires and needs with three questions utilizing yes/no answers: (1) What other technology would you like to have at home? (Multiple answers were allowed); (2) What technology could you never give up?; (3) What technology would you like to learn to use?

At this stage, we delved into respondents' evaluations of their relationship with these technologies through two questions: (1) On a 5-point scale, how do you rate your relationship with technology? (1 = completely negative, 5 = completely positive); (2) On a 5-point scale, how comfortable do you feel using the following technologies? (1 = Not at all, 2 = A little, 3 = Quite a bit, 4 = A lot, 5 = Completely).

The open-ended questions were: Why do you believe new communication technologies can reduce loneliness?

Why do you think new technologies can be useful in simplifying the life of an elderly person? Why did you judge your relationship with technology positively or negatively?

Responses to open-ended questions were subjected to open coding and thematic analysis, which is a qualitative technique within the content analysis family. This method emphasizes identifying, analyzing, and interpreting patterns of meaning or themes within textual data (Clarke and Braun 2021). An inductive procedure was applied to identify relevant thematic categories representing participants' opinions and experiences. Textual data were organized according to these categories. Three independent coders analyzed each theme, and the categories were cross-referenced with socio-demographic variables.

Qualitative findings will be presented using a narrative approach with macro-categories and excerpts. For quantitative analyses, SPSS 21 was employed to conduct χ^2 tests with standardized residuals, t-tests, and ANOVA. For parsimony, only significant results of the statistical analyses will be reported, highlighting differences between socio-demographic groups.

[1] We adopted this scale to investigate the frequency of use of digital, smart and robotic technologies because this required less cognitive burden to our older respondents rather than the scale "never, a few times a week, once a week, several days a week, daily", which is usually used with younger samples.

3 Results

3.1 Our Sample

The age range of respondents varies from 65 to 95, with an average age of 76.3 (SD = 6.771). We categorized respondents into three commonly used age groups (Fornara et al. 2001): Young-old (65–74) accounted for 128 respondents (35.9%), Old- old (75–84) comprised 147 respondents (41.2%), and the group of Oldest-old (85–99) consisted of 49 respondents (13.7%). For verifying if these three groups were balanced, we crossed them with the other socio-demographic variables and we found out that there were no significant differences among the groups concerning gender ($\chi^2 = 1.38$, df = 2, p = n.s.) or place of residence (urban or rural) ($\chi^2 = .86$, df = 2, p = n.s.). By contrast, as to education, not unexpectedly older adults 75–84 and 85–99 were more numerous among those with elementary school diploma or no qualifications ($\chi^2 = 28.20$, df = 6, p < .00001, Stand. Res. 2.8 and 3.0), while older adults 65–74 were more present among those with lower secondary school diploma or higher (Stand. Res. 2.7 and 2.3).

In terms of gender distribution, there were more women than men in the sample (n = 185, 53.6% vs. n = 159, 46.1%). Regarding education levels, among our interviewees, there were still 12 old individuals who lacked formal educational qualifications or were illiterate (3.4%), 118 (33.1%) who had completed primary school, 101 (28.3%) who had obtained a lower middle school degree, 81 (22.7%) with a high school diploma, and 31 (8.7%) with a university degree or higher. When considering education, numerous studies on digital technologies emphasize the significance of this variable in explaining differences in users' relationships with these technologies (e.g., van Deursen and van Dijk 2016; Fau and Moreau 2018). It remains to be seen whether education holds the same weight concerning smart and robotic technologies. Additionally, only 39 respondents, equivalent to 11.3% of the sample, reported having attended a computer literacy course (with no significant differences among the various socio-demographic groups).

Another variable we aimed to explore was the place of residence, as previous research has shown contrasting effects between this variable and the adoption and use of digital technologies (e.g., Fortunati and Taipale 2013). In our sample, a small portion of respondents (13, 3.8%) lived abroad in countries such as the United States, Canada, Netherlands, Slovenia, and Romania. The majority of interviewees (249, or 69.7%) lived in rural or semi-rural environments, while 95 respondents (26.6%) resided in urban areas.

Regarding marital status, 201 respondents (56.3%) were married or cohabiting, 87 (24.4%) were widowed, and 28 (7.8%) were single or divorced/separated. Finally, in terms of the occupations they held before retiring, our respondents display a wide and diverse range of occupations, including: 68 craftspeople (19.7%), 54 workers (15.7%), 54 personal service professionals (15.7%), 44 employees (12.8%), 33 housewives (9.6%), 26 professionals in commercial activities (7.5%), 15 freelancers (4.3%), 12 entrepreneurs/senior managers (3.5%), 9 armed forces (2.6%), and 7 farmers (2.0%) (with 22 respondents indicating other or not providing an answer, accounting for 6.4% of the total).

3.2 Technological Ownership and Usage Patterns Among Older Adults

Figures 1 and 2 illustrate the technologies owned by the respondents, along with the frequency of their use.

These older adults, on average, possess nearly five technologies each. Examining whether sociodemographic variables affect the ownership of these technologies, we observe no differences in ownership of radio and television, except for the fact that individuals with an inferior middle school degree and married individuals possess the radio more than others ($\chi^2 = 11.98$, df = 4, $p < .05$, Stand. Res. 2.8; $\chi^2 = 10.68$, df = 3, $p < .05$, Stand. Res. 3.0).

Regarding tablets, various differences emerge: young-old individuals own significantly more tablets than old-old ($\chi^2 = 9.49$, df = 2, $p < .01$, Stand. Res. 2.7), while there is no gender difference. However, differences are observed in terms of education and marital status: the highest percentage of tablet owners have a high school degree, followed by graduates ($\chi^2 = 24.98$, df = 4, $p < .00001$, Stand. Res. 3.5 and 2.7), and widowers own fewer tablets than married, divorced, and single individuals ($\chi^2 = 10.68$, df = 3, $p < .05$, Stand. Res. 2.6).

Regarding landline telephones, the only difference that emerges pertains to the residence of the respondents. Those living in urban environments are significantly more likely to have a landline telephone compared to those living in rural areas ($\chi^2 = 3.93$, df = 1, $p < .05$, Stand. Res. 2.0).

As for mobile phones, differences are more varied: young-old individuals own significantly more mobile phones than old-old ($\chi^2 = 23.22$, df = 2, $p < .0001$, Stand. Res. 3.8). Additionally, 98.8% of individuals with a high school degree (the highest percentage among those with other qualifications) own a mobile phone ($\chi^2 = 23.90$, df = 4, $p < .0001$, Stand. Res. 2.9). Lastly, individuals living in rural areas own more mobile phones than those living in urban areas ($\chi^2 = 5.81$, df = 1, $p < .05$, Stand. Res. 2.4).

The desktop computer shows no differences between age groups, but significant differences emerge regarding gender, favoring men ($\chi^2 = 9.43$, df = 1, $p < .01$, Stand. Res. 3.1). Additionally, education and marital status reveal differences: 54.8% of graduates (the highest percentage) own a desktop computer, followed by those with a high school degree ($\chi^2 = 41.31$, df = 4, $p < .0001$, Stand. Res. 4.3 and 3.6); regarding marital status, 39.3% of single individuals own a desktop computer, representing the highest percentage ($\chi^2 = 11.01$, df = 3, $p < .05$, Stand. Res. 2.0).

For laptops, significant differences emerge: young-old individuals own significantly more laptops than old-old ($\chi^2 = 15.85$, df = 2, $p < .01$, Stand. Res. 3.4), and older men own more than women; 46.4% of single and divorced individuals own a laptop ($\chi^2 = 11.00$, df = 3, $p < .05$, Stand. Res. 2.2 and 2.2), as do 48.1% of those with a high school degree and 64.5% of graduates ($\chi^2 = 58.64$, df = 4, $p < .00001$, Stand. Res. 4.6 and 4.7).

Regarding Internet access, significant differences are observed both by age and gender: young-old individuals have significantly more access to the Internet than both the old-old and the oldest-old ($\chi^2 = 45.08$, df = 2, $p < .0001$, Stand. Res. 6.4), and older men have more access than women ($\chi^2 = 6.64$, df = 1, $p < .05$, Stand. Res. 2.6). Education also reveals significant differences: 19.5% of respondents with Internet access have a

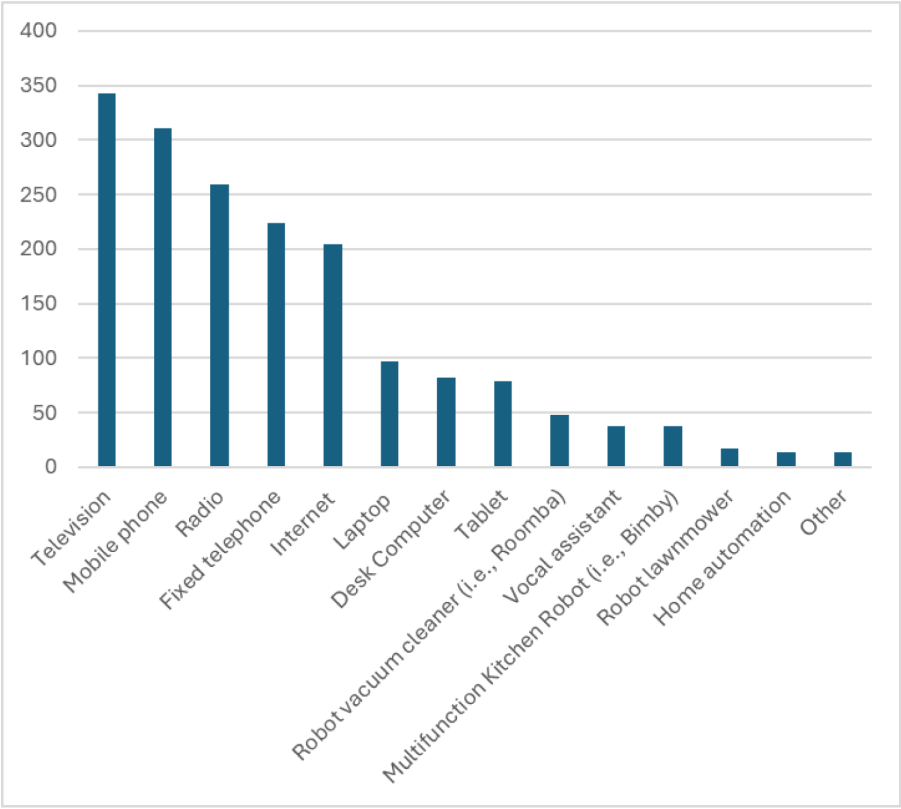

Fig. 1. The technologies owned by the respondents presented in absolute numbers.

high school diploma, followed by 7.9% of graduates ($\chi^2 = 59.39$, df = 4, $p < .0001$, Stand. Res. 4.9 and 3.3).

Regarding the availability of a multifunction kitchen robot, home automation system, voice assistant, robot vacuum cleaner, and robot lawnmower, only three differences emerge:

1. The ownership of a multifunction kitchen robot is significantly more widespread among young-old people than among the other two age groups ($\chi^2 = 7.53$, df = 2, $p < .05$, Stand. Res. 2.6).
2. 17.9% of unmarried individuals own a home automation system, which is the highest percentage compared to married, separated/divorced, and widowed individuals ($\chi^2 = 18.18$, df = 3, $p < .0001$, Stand. Res. 3.9).
3. Alexa is proportionally more owned by those with a high school degree (n = 15), followed by graduates (n = 7) ($\chi^2 = 14.55$, df = 4, $p < .01$, Stand. Res. 2.4 and 2.1).

Regarding the frequency of use among our respondents—a variable essential for understanding the relevance and familiarity of these technologies in their lives—as

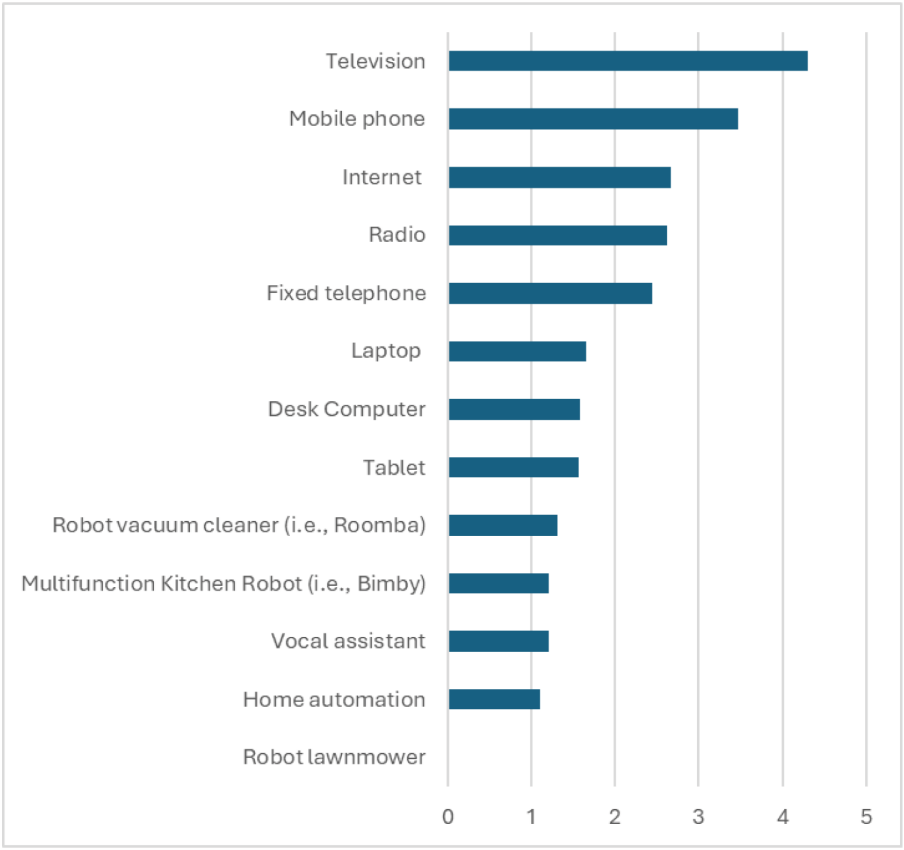

Fig. 2. The frequency of use of the technologies owned by the respondents, measured on a 5-point scale.

expected, television ranks as the most frequently used technology among older respondents, with daily use being predominant (Fig. 2). It is followed by mobile phones, which are used somewhere between occasionally and frequently. Internet, radio, and fixed telephones are utilized from infrequently to frequently. The realm of information technology, in its various forms, appears to present a challenge and seems intimidating to our respondents, as they report rare usage of laptops, computers, and tablets. Naturally, smart and robotic technologies, being the most recently acquired, seem to still be in the early stages of adoption, with reported usage ranging from never to rarely.

Regarding gender, the *t*-test highlights that the only significant differences between men and women in the frequency of use of these technologies (all in favor of men) concern the computer ($M = 1.78$ vs $M = 1.41$) ($t_{342} = 2.91$, $p < .01$), laptop ($M = 1.90$ vs $M = 1.44$) ($t_{342} = 3.68$, $p < .0001$), and internet access ($M = 2.98$ vs $M = 2.41$) ($t_{342} = 3.22$, $p < .01$).

Finally, as to education, this variable generates significant differences among the groups with various levels of education for the frequency of use of all the technologies, except for radio, home automation system, and the lawn mower.[2]

3.3 Older Adults' Opinions on Digital, Smart and Robotic Technologies

We investigated the opinions of older adults regarding the social significance of modern technologies, posing two questions. Firstly, we inquired whether they believe that new communication technologies can alleviate loneliness. The majority of our respondents, 228 (66.3%), expressed conviction that these advanced technologies indeed reduce feelings of loneliness. Notably, women exhibit a significantly higher level of conviction compared to men (59.2% vs. 20.8%) ($\chi^2 = 8.02$, df = 1, p. < .01, Stand. Res. 2.8), and young-old individuals hold this belief more strongly compared to both old-old and the oldest-old (44.6% vs. 39.9% and 15.5%) ($\chi^2 = 8.23$, df = 2, p. < .05, Stand. Res. 2.6). Other socio-demographic variables did not yield significant differences.

To gain a deeper understanding of the opinions of this demographic, we invited them to elucidate the rationale behind their responses. We collected 444 open-ended answers, revealing two distinct perspectives on the matter. The prevalent viewpoint starts by recognizing the current deficiency in familial and social relationships, resulting in heightened loneliness among older adults, which is attributable to a series of intertwined socio-economic variables. These respondents view new technologies as vital tools to mitigate this loneliness to some extent, finding solace in the modest offerings of technology compared to nothing at all. For instance, Augusto, an 83-year-old retired Telecom Italia employee, remarked, "Because in the case of lonely older adults, they can keep in touch with their friends/family and feel less alone."

The life experiences of these older adults highlight two additional factors that have rendered these technologies even more invaluable in combating loneliness: the COVID-19 pandemic and the disabilities often associated with old age. Teresa, an 80-year-old ex-employee, attests, "During the pandemic period, new technologies have been very useful for keeping in touch with friends and relatives." Similarly, Enzo, an 84-year-old former ice cream maker, reflects, "After the pandemic, I shifted my perspective. I used my mobile phone to video call my daughter in Germany, and I felt closer to her. I hadn't seen her for a long time." Additionally, Giovanna, an 85-year-old retired factory worker, asserts, "For me, living alone and facing mobility challenges, communication technologies have alleviated loneliness, a sentiment echoed by friends in similar circumstances."

The contrasting perspective, albeit less common, views technology's offerings as minimal and acknowledges its dual effect: while it serves as a communication and sociality palliative, it also has the potential to exacerbate isolation. Angela, an 81-year-old former cook, succinctly expresses, "The only thing that can alleviate my loneliness is meeting people I know." Severino, an 87-year-old ex-farmer, observes, "I see my grandchildren spending a lot of time with their cell phones, isolating themselves from

[2] Television ($F_{3,339} = 3.48$, $p < .05$), Tablet ($F_{3,339} = 9.27$, $p < .0001$), Fixed telephone ($F_{3,339} = 3.18$, $p < .05$), Mobile phone ($F_{3,339} = 14.57$, $p < .0001$), Computer ($F_{3,339} = 15.76$, $p < .0001$), Laptop ($F_{3,339} = 23.44$, $p < .0001$), Internet ($F_{3,339} = 21.49$, $p < .0001$), Vocal Assistant ($F_{3,339} = 6.13$, $p < .0001$), Multifunction kitchen robot ($F_{3,339} = 4.52$, $p < .01$).

their surroundings." Francesco, an 85-year-old retired financier, reflects, "Ultimately, you may be surrounded by others, but still feel alone." Roberto, a 74-year-old electrician, adds, "I believe the only loneliness that diminishes is the one that arises with the normalization of new technologies."

Regarding the second question on whether these technologies can simplify the lives of older individuals, once again, the majority of our respondents (210, 64.8%) answered affirmatively. While neither gender nor age showed significant differences, education did, with 75.3% of those with a high school degree viewing these technologies as facilitators (the highest percentage) $\chi^2 = 15.38$, df = 6, p. < .05, Stand. Res. 2.1). We also gathered 344 open-ended responses explaining the rationale behind their answers.

Tiziano, a 71-year-old commercial agent, emphasizes, "If used competently, they allow for greater autonomy." Valeria, a 70-year-old former head of the municipality's education and youth policy office, adds, "Sometimes they can simplify life, for instance, by avoiding queues at health facilities, banks, and public offices."Paola, a 67-year-old retired cook, illustrates, "For example, a robot lawnmower would relieve me from constantly relying on my brother-in-law for help." Maria Antonietta, a 77-year-old former member of an agricultural consortium, suggests that for these technologies to truly simplify older adults' lives, they "should be specifically tailored to their needs and cultural backgrounds."

However, many respondents express frustration that although these technologies could potentially simplify their lives, they struggle with using them effectively. Marcela, a 69-year-old, remarks, "It depends on whether you are proficient in using them; they could also complicate things." Armando, an 85-year-old retired manager, observes, "Instead of fostering autonomy, these technologies often lead to increased dependence on their children and relatives."

3.4 Desires and Needs of Older Adults Towards Digital, Smart and Robotic Technologies

We have delved into the exploration of our respondents' attitudes towards digital, smart, and robotic technologies through two specific inquiries: What additional technology would you like to have at home? and What technology could you never do without?

Figure 3 presents the technologies desired by older adults to own, along with the technologies they consider indispensable (Fig. 4).

In terms of desires, Fig. 3 reveals preferences of course for technologies not currently possessed by these older adults. The top desired item among respondents is a robot vacuum cleaner, followed by a robot lawn mower, home automation and a multifunctional kitchen robot. Interestingly, the voice-based assistant ranks similarly to the desktop computer in terms of desire. Concerning the digital realm, respondents primarily mention tablets, laptops, desktop computers, and internet access, although the percentages are relatively low. These responses suggest that older adults prioritize smart and robotic technologies that alleviate household chores over new communication facilitators like Alexa, with the mobile phone likely deemed sufficient for communication needs.

Examining responses to the question "What technology could you never do without?" reveals that mobile phones and televisions are considered indispensable by older adults.

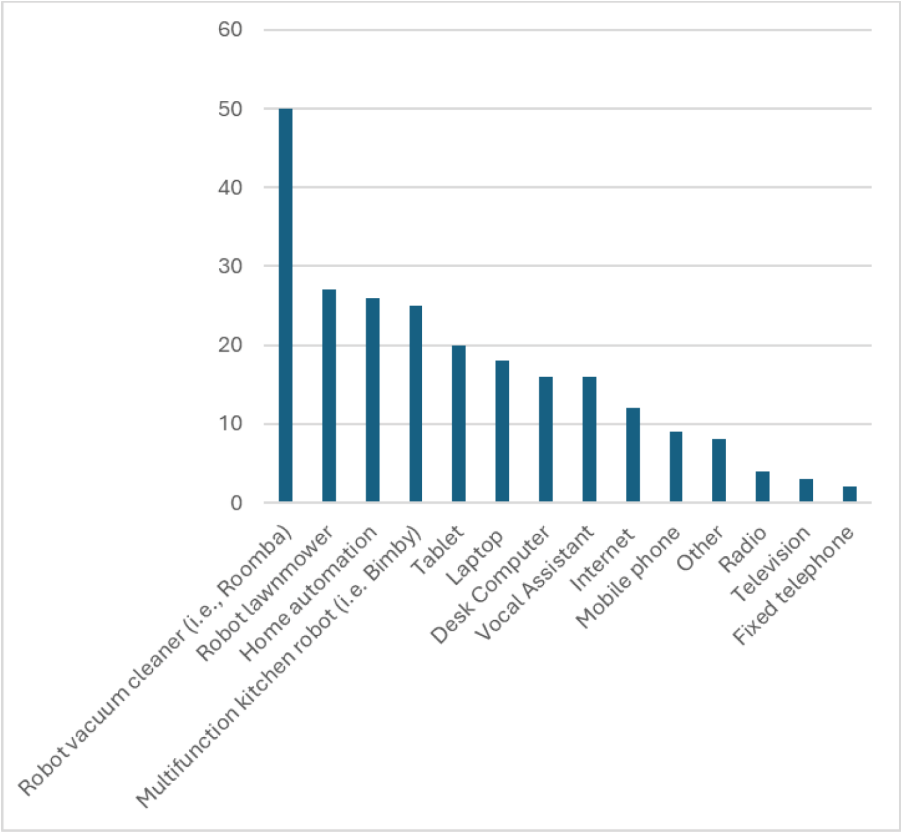

Fig. 3. The technologies older adults would desire to own.

Specifically, more than third of the interviewees (38.1%) cited the mobile phone, while slightly less the television (37.6%).

To gain further insight into the attitudes of these respondents towards these technologies, we inquired: "What technology would you like to learn to use?" The response garnering the highest percentage of answers is "none" (156, 45.2%), confirming what we said before, that is that older adults are in a phase of life where learning new skills is not a priority. Other responses to this question generally show relatively low percentages, typically under 10% (with the exception of the mobile phone), suggesting that only a small minority of respondents are open to learning new technologies.

Regarding the specific technologies respondents expressed an interest in learning, the responses are fairly distributed among the options provided. The highest concentration of interest is observed for the mobile phone (41, 11.5%), followed by the laptop (30, 8.7%), desktop computer (22, 6.4%), and tablet (19, 5.5%). Additionally, some interest is also notable for home automation systems (18, 5.2%), voice-activated assistants (14, 4.1%), multifunction kitchen robots (11, 3.2%), robot vacuum cleaners (8, 2.3%), and robot lawnmowers (4, 1.2%).

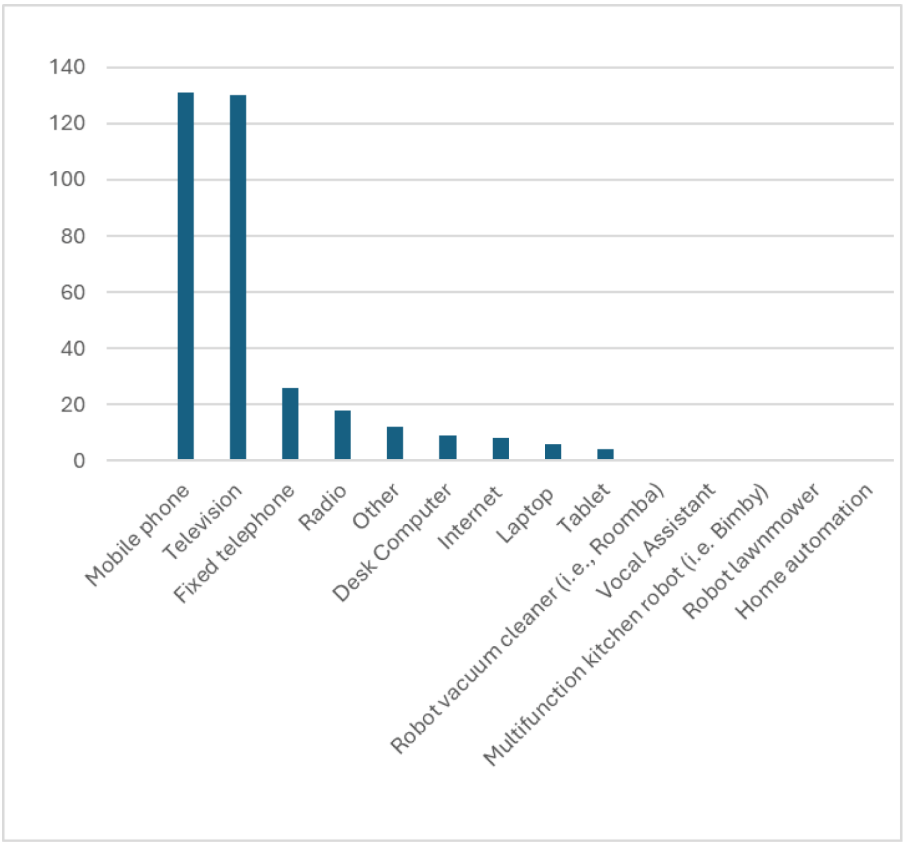

Fig. 4. The technologies to which older adults would never give up.

3.5 Evaluations of the Relationship with Technology and How Comfortable Respondents Are in Using Them

To conclude our exploration of the relationship older adults have with digital, smart, and robotic technologies, we posed the question: "How do you judge your relationship with technology?" (on a 5-point scale, where 1 corresponds to completely negative and 5 to completely positive). The average judgment stands at $M = 2.74$ ($SD = 1.185$), indicating a lukewarm assessment. Notably, 41.9% of the judgments lean towards the negative end, while only 25.9% express positivity. This finding is not surprising, because these technologies, as we already mentioned before, initially tailored for younger demographics, make them less suitable for older adults. Consequently, older adults, along with adults in general and women, find themselves outside the primary commercial target and have had to adapt to technologies designed with different user characteristics.

Interestingly, men provide only a slightly more positive evaluation of their relationship with technology compared to women ($M = 2.88$ vs $M = 2.62$, $t_{342} = 2.129$, $p < .05$). Furthermore, when examining various age groups through ANOVA, a significant difference in opinion emerges ($F_{2,321} = 20.47$, $p < .0001$). However, the Bonferroni test

indicates that this significant difference is primarily between the old-old and the oldest-old ($p < .0001$), implying that up to the age of 84, the perception of the relationship with technology remains relatively consistent.

We delved deeper into the reasons behind these judgments by asking respondents to elaborate on their evaluations. From the 332 open-ended answers collected, we categorized them into six main clusters:

1. Positive judgments (111, 32.2%): Responses expressing favorable views towards technology;
2. Problems in comprehension, difficulty in the understanding and use of digital technologies, and feeling insecurity (91, 26.4%);
3. Hostile emotions—Responses indicating rejection or resistance towards technology (28, 8.1%);
4. Lack of interest or motivation to learn or update (42, 12.2%);
5. Limitations related to age and past experience ("Blaming words") (24, 7.0%);
6. Negative opinion on technologies (36, 10.4%).

These categories provide insights into the diverse reasons behind older adults' judgments regarding their relationship with digital, smart, and robotic technologies.

We present also quantitative findings from content analysis. It emerged that men give significantly more positive judgments than women (39.5% vs 28.3%), whereas women express feeling inadequate more frequently than their male counterparts (34.4% vs 21.1%) ($\chi^2 = 9.01$, $df = 3$, $p < .05$, Stand. Res. 2.1 and 2.7).

Regarding age, respondents aged 64 to 84 predominantly display positivity. The majority of old-old respondents, at 46.7% (the highest percentage), express significantly more positive judgments than other age groups ($\chi^2 = 21.05$, $df = 6$, $p < .001$, Stand. Res. 4.4).: " I'm quite independent in using it" (Anna, 75, ex seamstress); "I recognize its usefulness in keeping in touch with family and friends who live far away from me" (Mariagrazia, 81); " I like to use some digital technologies" (Maria Teresa, 78, ex-nurse); Luciana, 84, also shares, "They provide me with companionship and keep me informed."

Concerning education, respondents with graduate and high school degrees are more inclined to judge their relationship with digital technologies positively, while those with lower educational levels express greater difficulty understanding and using them ($\chi^2 = 39.99$, $df = 9$, $p < .0001$, Stand. Res. 4.1, 3.5, 2.2).

Respondents with lower levels of education, particularly those aged 85 and older, often highlight economic difficulties, memory challenges, a lack of learning opportunities, and an overall perception of technology as too complex and difficult. In some cases, outright hostility towards technology is expressed, as exemplified by Rosa, aged 95, who described technology as "an illness."

Oldest-old respondents are particularly vulnerable to challenges with technology because many did not have the opportunity to develop digital literacy or social learning skills in their formative years. As Vanda, aged 85, expressed, "No one has ever explained to me how it works." Similarly, Maria, aged 88, stated, "I have no technological knowledge," and Vittorio, aged 87, mentioned, "I have trouble understanding some things." Carmela, also 87, admitted, "I don't understand anything about it, but I think it has a more or less positive effect on the world." These sentences confirm the results of many other studies, which show that the use of technology during childhood and adolescence

is a strong predictor for the foundation of later personal experience with technology (e.g., Mitzner et al. 2019). However, there are exceptions, such as Vittorio, aged 87, who expressed a lifelong passion for technology.

These difficulties in embracing technology, leading to limited or absent use, stem from a lack of early exposure and learning opportunities in dealing with these advancements.

These difficulties are linked also to other factors, such as the fact that only 11.7% of our respondents have taken a computer course, the life stage of older adults where, as we said before, often they perceive continuous learning as burdensome, compounded by the demands of digital, smart, and robotic technologies, which necessitate ongoing updates. "Because, given my age, I don't want to start learning new things," says Dina, 82 years old, a housewife. Armando, 85, an ex-carpenter, adds, "I don't have much time to learn new things." Several interviewees emphasize that, instead of learning new things, the remaining time should be devoted to reflecting on one's past experiences and life.

This attitude among older adults who struggle to adapt to digital technologies is frequently interpreted as a form of self-marginalization from the information society. Their perceived inability to keep up with technological advancements has often been portrayed in the media and discussed in scientific circles as a deficiency or gap in the capabilities of older individuals.

This misrepresentation has contributed to the societal devaluation of older adults, leading to their humiliation and internalization of feelings of inadequacy. "I don't feel comfortable at all using completely new devices, and I'm constantly afraid of making mistakes due to my lack of experience," expresses Michele, a retired mason 74 years old. "I feel unsafe using them," shares Ivo, 78, a former department head. Silvana, 76, a former FIAT employee, adds, "Older people are afraid of making mistakes with devices." Laura, 77, a former secretary, elaborates, "Some devices are 'easy' to use once you learn how, while others inspire fear of making mistakes and causing trouble."

The responsibility for technology that may not be suitable for older adults is often wrongly attributed to them, further reinforcing their feelings of inadequacy. "I've always been bad at the subject," explains Lorenzina, 72, a retired cook. Silvana, 72, a former nurse, concurs, stating, "I am primitive in the use and understanding of technology."

However, older adults often push back against attempts to devalue them and instead launch a counterattack by expressing negative judgments towards these technologies. For instance, our respondents argue that these technologies are too difficult to learn and use, lack intuitive interfaces, are overly complicated, require excessive time investment, lack essential functionality, offer limited or superficial knowledge, restrict human relationships, and foster addictive behaviors. Overall, these technologies are perceived as detrimental to individuals, as Francesca, 75, a housewife, articulates, "Because I feel like it's something that takes away the emotions from what you do."

It is noteworthy that older adults exhibit a specific attitude towards mobile phones. This sentiment is evident in statements such as: "The only technology that gives me some satisfaction is my cell phone, with which I can watch news, text, take photos, etc. However, sometimes I press too many buttons and the phone jams, so I am forced to ask my children for help," reveals Maria Laura, 73, a retired bartender. Similarly, Antonietta, 83, a former trader, expresses, "I do not consider myself capable of using

any technological device apart from the smartphone, with which I am able to perform all basic functions." Finally, Elio, 71, a retired male nurse, states, "It's only been a few years since I bought a smartphone. Before that, I didn't feel the need for it; I only used phone calls to communicate with my family. Now that I have a smartphone, I use WhatsApp, which is more convenient, but my technological knowledge is limited to that."

We conducted further exploration into the respondents' perceptions of their relationship with digital, smart, and robotic technologies by asking them about their comfort level in using these technologies (on a five point-scale: not at all, a little, quite a lot, very much at all). The greatest comfort is felt by these respondents towards old technologies (television M = 4.01, SD.972; radio M = 3.54, SD.1.361; landline telephone M = 3.15, SD 1.569), followed closely, however, by mobile phones (M = 3.04, SD 1.273). On the contrary, the IT world creates discomfort to varying degrees (Internet M = 2.24, SD1.352; laptop M = 1.79, SD 1.246, tablet M = 1.72, SD 1.259 and desktop computer M = 1.71, SD 1.214). Even more discomfort is created by smart and robotic technologies (robot vacuum cleaner M = 1.40, SD 1.031; multifunction kitchen robot M = 1.35, SD .961; voice assistant M = 1.30, SD .822; robot lawn-mover robot M = 1.23, SD .846). The results of this inquiry are summarized in Fig. 5.

In terms of feeling comfortable using these technologies, men generally exhibit significantly higher comfort levels across various devices. However, notable disparities favoring men were observed only for the radio (M = 3.81 vs M = 3.31, $t_{342} = 3.47$, $p < .01$), television (M = 4.14 vs M = 3.89, $t_{342} = 2.48$, $p < .05$), computer (M = 1.99 vs M = 1.46, $t_{342} = 4.17$, $p < .0001$), laptop (M = 2.11 vs M = 1.52, $t_{342} = 4.44$, $p < .0001$), and lawn mower (M = 1.37 vs M = 1.11, $t_{342} = 2.85$, $p < .01$).

Regarding age, differences were also limited, primarily impacting perceptions of the tablet ($F_{2,321} = 6.29$, $p < .01$), mobile phone ($F_{2,321} = 18.38$, $p < .00001$), laptop ($F_{2,321} = 10.80$, $p < .00001$), internet access ($F_{2,321} = 20.43$, $p < .00001$), and multifunctional food processor ($F_{2,321} = 6.03$, $p < .01$). Bonferroni tests revealed significant differences between the 75–84 age group and the 85–99 age group, in favor of the first, for the tablet ($p < .05$), laptop ($p < .01$), internet ($p < .0001$), and multifunctional food processor ($p < .05$). Conversely, evaluations of feeling comfortable with the mobile phone differed significantly across all age groups, decreasing with age.

Education level significantly influenced respondents' evaluations of most technologies,[3] except for the television and lawn mower. Higher education levels correlated with more positive evaluations across the sample.

[3] Radio ($F_{3,339} = 10.44$, $p < .0001$), Tablet ($F_{3,339} = 12.10$, $p < .0001$), Mobile phone ($F_{3,339} = 23.45$, $p < .0001$), Computer ($F_{3,339} = 29.80$, $p < .0001$), Laptop ($F_{3,339} = 80.36$, $p < .0001$), Internet ($F_{3,339} = 25.17$, $p < .0001$), Vocal Assistant ($F_{3,339} = 8.74$, $p < .0001$), Home automation system ($F_{3,339} = 6.06$, $p < .0001$), Robot vacuum cleaner ($F_{3,339} = 4.48$, $p < .01$), Multifunction kitchen robot ($F_{3,339} = 7.22$, $p < .0001$).

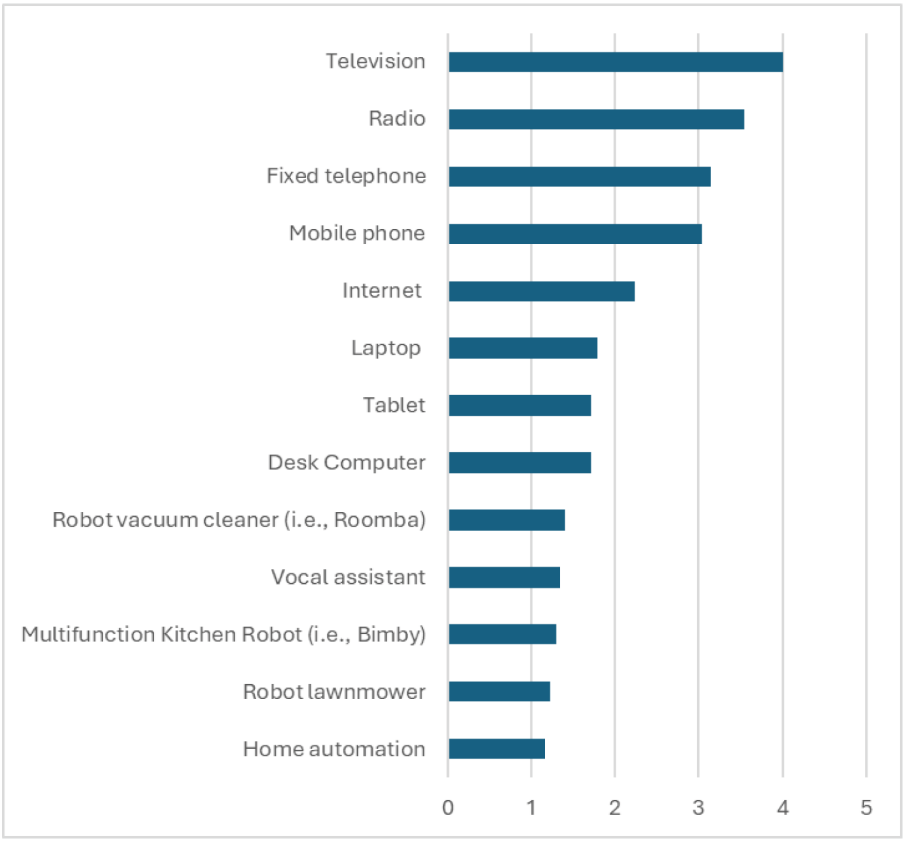

Fig. 5. How comfortable older adults are in using digital technologies.

4 Discussion and Final Remarks

The findings of this research are significant for several reasons and convey at least three novelties compared to the current literature. First, they explore in detail the main range of domestic technologies, excluding domestic appliances. For example, while Offerman et al. (2023) investigated a broad range of clusters of domestic technologies (from health technologies to exercise technologies) without detailed specification, we are the first to restrict the range of technologies investigated and explore the main technologies within three specific clusters: digital, smart, and robotic technologies. By encompassing the entire spectrum of digital technologies in studying the relationship between older adults and smart and robotic technologies, we were able to demonstrate that the concept of the technological continuum is a fundamental key to understanding how smart and digital technologies are positioned within the domestic technological ecology of older adults. At the same time, we have gained a deeper understanding of the implications that interaction with digital technologies has on the robotic realm. For instance, it has emerged that if older generations lack digital literacy or have an incomplete understanding of it, this

deficiency inevitably affects their relationship with humanoid social robots, which often incorporate tablet interfaces.

Even the guilt and inadequacy felt by older adults, as reported in many research studies on the adoption and use of ICTs, re-emerge with smart and robotic technologies. The free responses we collected strongly suggest that the inherent limitations of these technologies persistently impose a sense of inadequacy on older adults as they struggle to comprehend and effectively utilize them. The dissonance between older adults and the digital realm, particularly the world of computing, is evident in these findings. This discord extends to smart and robotic technologies and is compounded by the widespread lack of literacy among our respondents. The importance of these findings extends to both researchers, designers, and policymakers. Researchers should recognize that smart and robotic research is part of a lineage of technology stemming from digital technologies. Thus, the unresolved issues associated with digital technologies also impact the adoption and use of robotic technologies.

The second novelty is that this study did not consider the older population as an internally undifferentiated social group, as it is still common in the literature on older adults and smart and robotic technologies and even in studies on digital technologies (Vincent 2023) or in studies that compare older adults with cohorts of youth and adults, as was done by Offerman et al. (2023). In contrast, we approached older adults as comprising three fundamental components or sub-groups, as now recognized by sociologists and demographers for their specific characteristics in terms of demographics, health, social attitudes and behavior, wellbeing, and lifestyles. From another perspective, we can view these three sub-groups as three different generations of older adults experiencing aging in distinct ways.

We were interested to see if the differences that emerge among the various generations of older adults also extend to their attitudes towards and use of technologies, including smart and robotic technologies. These findings demonstrate that young-old respondents manage a more meaningful relationship with digital, smart, and robotic technologies, while old-old and oldest-old individuals overall exhibit a less positive attitude towards these technologies and show significantly lower levels of engagement with them.

Designing adequate robotic tools for active and assisted living requires taking into account the dissonance between digital technologies and older adults and avoiding the repetition of the same mistakes. For instance, if tablets are integrated within robots, the interface needs to be revisited to ensure simplicity; continuous updating of software, interfaces, and applications should be avoided. Moreover, researchers and designers should acknowledge that the older population is internally structured into three sub-groups. When inventing new robotic tools, it's essential to decide which sub-group to address.

Policy makers also play a crucial role. They should consider the dissonance between digital technologies and older adults to prevent their marginalization from public administration (PA) and public services. A significant portion of these respondents struggle to effectively use information systems. Thus, basing continuous innovation in public administration on informatization might lead to the social exclusion of older adults, particularly the old-old and oldest-old. Policy makers need to diversify public policies on

aging in light of these findings and allocate funds for research on robotics capable of addressing these issues.

Regarding the role of the other socio-demographic variables in this research, in addition to age, gender and education reaffirm themselves as crucial factors that differentiate the relationship between various groups of older adults and smart and robotic technologies. In particular, our findings consistently demonstrate that older women experience significantly greater challenges than men in their interactions with these technologies. Another socio-demographic factor that notably influences the ownership of smart and robotic technologies is marital status, while the place of residence significantly impacts only ownership of fixed and mobile telephones. We recommend researchers to control the marital status of respondents in their research, as this variable has proven to be relevant in determining the likelihood of acquiring robotic products. Especially when they remain alone, older adults need help in doing housework and smart and robotic tools can become strategic for allowing them to live in an active and assisted living environment.

4.1 Limitations and Future Research

It is worth to report at least three limitations of this study, which require discussion. First, the participants in the current study were part of a convenience sample, which may limit the generalizability of the findings. We plan to conduct future studies with a representative sample of the older adult population in Italy to better generalize the results. Second, this study relied on self-report data. While this method is suitable for understanding ownership, frequency of use, desires, needs, opinions, and perceptions among older adults, despite its known limitations such as memory bias, social desirability bias, response bias and self-selection bias and possible measurement error), future studies should incorporate also experiments and expand the use of qualitative tools. Third, utilizing students as administrators of the questionnaire may have introduced some reliability issues with the data (e.g., potential errors in recording responses), despite their thorough training before administration and continuous monitoring throughout the data collection process.

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