Comparing Middle-Aged and Seniors' Preferences Toward Virtual Agents and Android Robots: Is There a Generational Shift in Assistive Technologies' Preferences?

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Abstract. The present research aims at investigating effects of participants' age (middle-aged and seniors) and type of assistive device (female virtual agents vs female android robots) on users' acceptance. The study involved 4 groups of two middle-aged and two seniors (for a total of 181) participants asked to express their potential acceptance to be assisted in their daily routines by two female android robots/virtual agents. Acceptance was assessed in terms of scores assigned by participants to their willingness to interact with the female agents/robots and pragmatic (PQ), hedonic - identity (HQI), hedonic - feeling (HQF) and attractiveness (ATT) qualities. Video clips of the proposed agents or robots were randomly presented, and after each presentation, participants scored the proposed assistive device by filling either the VAAQ (Virtual Agent Acceptance) or the RAQ (Robot Acceptance) questionnaire. Repeated measures ANOVA were utilized to statistically assess participants' preferences. Seniors were significantly more open to interact with virtual agents rather than robots, while middle-aged participants were showed slightly more open to interact with robots rather than agents. Participants' gender significantly affected the evaluation of robots rather than agents' one, and the appearance of the proposed de- vices (younger toward mature agents, or haired toward hairless robots), strongly affected users' acceptance.

Keywords: Seniors · Middle-aged · Assistive technologies · Virtual agents · Android robots · Users' acceptance

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1 Introduction

Ambient Assisted Living (AAL) technologies aim at supporting seniors, promoting active aging, their independence, and healthy living [1]. Virtual agents and social assistive robots (SARs) represent two typologies of technological devices which could be exploited within the field of AAL, to support elderly users in their daily activities, providing assistance and companionship [2, 3]. Hence the need to focus on elders' acceptance and perceptions toward these potential assistants, identifying features which may favor and facilitate seniors' usage of the above-mentioned devices. Concerning elders' perception of virtual agents, which are defined as "*…computer- generated animated characters that combine facial expression, body stance, hand gestures, and speech to provide a more human-like and more engaging interaction*" [4], studies highlighted that elders prefer to interact with humanoid agents (rather than with robotic or animal appearing agents), displaying positive personalities (i.e. joyful and practical) and consider female agents able to interact using voices more useful and pleasant than their male counterparts [5–8].

On the other hand, studies exploring elders' acceptance of social robots produced conflicting findings. Some studies had shown that seniors prefer to interact with humanoid (with human-like appearance) rather than android (mimicking realistically human appearance) robots [9–12]. Others had shown that elders felt more positively engaged by female android rather than female humanoid robots [13, 14]. These studies differed among them for the type of robots used (from animal-like to human-like appearing robots), methods of investigations (showing pictures or movies of the robots and/or exploiting only questionnaires from different sources) and robots' appearances (varying degree of human like appearance). In addition, some current studies [13, 14] reported that seniors largely preferred androids vs. humanoid robots. Since the main aim of this paper was to investigate seniors' differences in preferences toward virtual agents and robots, only android robots were chosen since their appearance was very human-like and close to the appearance of the selected virtual agents. In additions since it was reported that female virtual agents [5–8] were largely preferred to male ones, we selected only female agents and robots. The current investigation aims to compare users' preferences toward virtual agents and android robots in order to:

1. Investigate which technological device (virtual agents vs android robots) is more accepted by the proposed users (seniors and middle-aged adults).
2. Investigate differences in preferences according to differences in participants' gender and age.
3. Investigate whether there can be specific agents or robotics' features (such as boldness or long hairs) affecting users' preferences.

2 Material and Method

To achieve the abovementioned goals an experiment assessing users' degree of acceptance toward female either virtual or robotics agents was carried out. Acceptance was investigated in terms of participants' willingness to interact with the agents/robots and scores attributed to their pragmatic, hedonic, and attractive qualities (details are on Sect. 2.3).

2.1 Participants

A total of 181 participants joined the experiment. Participants were partitioned into four groups. Group 1 composed of 45 middle-aged (21 males, mean age = 50.42, SD = ±4.12), and group 2 composed of 46 older adults (22 males, mean age = 71.59, SD = ±6.32) were administered video clips showing two female virtual agents. Group 3 composed of 45 middle-aged (23 males, mean age = 47.67, SD = ±4.72) and group 4 composed of 45 older adults (22 males, mean age = 73.04, SD = ±7.03) were administered video clips showing two female android robots. To be included in the study, participants had to declare that they were in a good health with no (or corrected) vision and/or hearing problems, and belong to the age groups of interest, i.e., middle- aged between 40–55 years and seniors 65+ years old. Participants were recruited in the Campania region (south of Italy). They joined the study on a voluntary basis and signed an informed consent formulated according to the current Italian and European laws about privacy and data protection (D. Lgs. 196/2003). The research was approved, with the protocol number 25/2017, by the ethical committee of the Università degli Studi della Campania "Luigi Vanvitelli", Department of Psychology.

2.2 Stimuli

From the website BOTLIBRE (www.botlibre.com), which provides a wide set of agents with different visual semblances and enables users to create a customer version, two female virtual agents were selected. (See Fig. 1). The two agents were named Clara and Giulia (Victoria2 and Julie3 on BOTLIBRE).

The selected female android robots (see Fig. 2) were Sophia developed by the Hanson Robotics (https://www.hansonrobotics.com/) and Erica (developed by Ishiguro at the University of Osaka, Japan, http://www.geminoid.jp/en/robots.html). Four video clips were defined, showing the two female virtual and robotic agents, half torso, in a frontal position while uttering the Italian sentence "Ciao sono Clara/Giulia/Sophia/Erica. Se vuoi posso aiutarti nelle tue attività quotidiane" (Hi, my name is Clara/Giulia/Sophia/Erica. If you allow me, I can assist you in your daily activities).

The Italian female synthetic voices were generated through the Natural Reader synthesizer (www.naturalreaders.com), recorded with the free audio software Audacity (www.audacityteam.org), and inserted in the video clips by using the Windows 10 application "Videomomenti". Each video clip lasted between 4 and 7 seconds, to avoid interferences in the assessment of both robots and virtual agents the quality of synthetic voices was kept the same both robots and virtual agents. Indeed, the appearance of the two virtual agents and robots was different to assess the weight of their appearances inside the same class of assistive devices.

2.3 Tools

Participants' preferences toward the proposed agents/robots were assessed by administering the Virtual Agent Acceptance Questionnaire (VAAQ), and Robot Acceptance Questionnaire (RAQ) for the agents and robots, respectively. VAAQ and RAQ have been

Fig. 1. The proposed virtual agents Clara (on the left) and Giulia (on the right)

Fig. 2. The android robots Sophia (on the left) and Erica (on the right)

developed by Esposito and colleagues [7, 8, 13, 14] at Università degli Studi della Campania, "Luigi Vanvitelli", Department of Psychology. The two question- naires are structured in sections of which Sect. 1 consists of 7 items investigating participants' degree of experience and familiarity with technological devices such as smartphones, tablets, and laptops. Section 2 consists of a single item assessing partic- ipants' willingness to be involved in a potential long-lasting interaction with the pro- posed agents/robots. Sections 3, 4, 5 and 6 (each composed of ten items) assessing the Pragmatic, Hedonic and Attractive qualities an interactive system should be endowed with in order to be widely accepted by their potential users. Specifically, the investi- gated qualities (inspired by Hassenzahl's theoretical model [15, 16]) were:

- Pragmatic Qualities (PQ) associated to the usefulness, practical and easiness of use perception of the proposed agent/robot.
- Hedonic Qualities-Identity (HQI) associated to originality, creativity, and aesthetical pleasantness attributed by users to the proposed agents/robots.
- Hedonic Qualities- Feeling (HQF) devoted to assign to the proposed agents/robots the ability to arouse either positive or negative emotions.
- Attractiveness (ATT) devoted to check whether proposed agents/robots engage their users in an increasing usage.

Except for Sect. 1, questionnaires' items are scored on a 5-point Likert scale (1 = strongly agree, 2 = agree, 3 = I do not know, 4 = disagree, 5 = strongly disagree), and involve both positive and negative statements. Negative statements were corrected in a reverse way, and therefore, low scores summon to more positive, and high scores to more negative evaluations of the proposed agents/robots. Middle-aged and seniors who saw the female agents, were administered the paper version of the VAAQ, while those who saw the female android robots, were administered respectively the paper and a digitalized version of the Robot Acceptance Questionnaire (RAQ). The RAQ digitalized version was developed by using a Java script enabling to automatically randomize the presentation order of the questionnaire's sections for each participant.

2.4 Procedures

Participants were briefed on the aims of the study, subsequently signed an informed consent, and then they were randomly assigned to one of the experimental conditions (assessing virtual or robotic agents). Then, they completed the socio-demographic section (section 1 of the questionnaire). Subsequently, they watched either video clips depicting agents or robots presented to them in a random order, and after each presentation they filled the remaining sections of questionnaires.

3 Data Analysis

Separate ANOVA repeated measures analyses were carried out on the questionnaire's scores to assess participants' (middle-aged and seniors) preferences toward either virtual agents (A) or robots (B). The questionnaire's scores obtained by virtual agents and robots were compared (C) as to investigate participants' preferences toward these two different typologies of assistive devices. In a first analysis (A) preferences ex- pressed by middle-aged and seniors toward the two proposed female virtual agents (Clara and Giulia) were investigated. Participants' gender and their age group (middle-aged and seniors) were considered as between subjects' factors and VAAQ scores obtained in terms of willingness to interact, pragmatic (PQ), hedonic -identity (HQI) and feeling (HQF)- and attractiveness (ATT) as within subjects' factors. The significance was set at $\alpha < .05$ and differences among means were assessed through Bonferroni's post hoc tests. Due to the reverse correction of negative items, low scores summon to more positive whereas high scores to more negative agents' evaluations. In a further analysis (B) preference expressed by middle-aged and seniors toward the female android robots Sophia and Erica were considered. Participants' gender and their age (middle-aged and seniors) were considered as between subjects' factors and RAQ scores obtained in terms of willingness to interact, pragmatic (PQ), hedonic- identity (HQI), hedonic-feeling (HQF) and attractiveness (ATT) qualities as within subjects' factors. The significance was set at $\alpha < .05$ and differences among means were assessed through Bonferroni's post hoc tests. Due to the reverse correction of negative items, low scores summon to more positive and high scores to more negative robots' evaluations. The third and last data analysis compares preferences expressed by middle-aged and senior participants toward female virtual agents and android robots. To this aim, PQ, HQI, HQF and ATT scores obtained

by the agents Clara and Giulia and the robots Erica and Sophia were respectively added together. Repeated measures ANOVA analyses were performed considering participants' gender and age (middle-aged and seniors) and stimulus' type (virtual agents and android robots) as between subjects' variables. PQ, HQI, HQF, and ATT scores were considered as within subjects' variables. The significance was set at $\alpha < .05$ and differences among means were assessed through Bonferroni's post hoc tests. Due to the reverse correction of negative items, low scores summon to more positive and high scores to more negative evaluations of either the proposed agents or robots.

4 Descriptive Statistics

Before describing results obtained through the statistical analysis, in the present section will be portrayed some information concerning participants' educational level and their degree of experience with technological devices. As shown in Figs. 3 and 4, seniors which were administered robot, reported lower educational levels and lower degree of technological expertise compared to the groups of middle-aged participants, both the ones who saw robots and virtual agents.

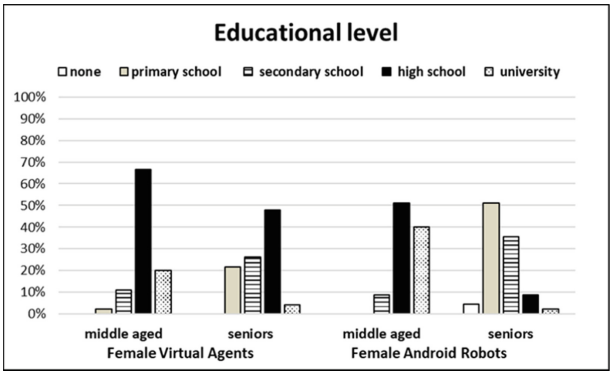

Fig. 3. Descriptive statistics: educational level of the four group of participants

5 Results-Virtual Agents' Assessment (A)

Separate ANOVA repeated measures analyses were carried out on the VAAQ questionnaire's scores to assess participants' preferences toward the two virtual agents. Participants' gender and their age group (middle-aged = Group 1 and seniors = Groups 2) were considered as between subjects and VAAQ scores as within subjects' factors. For sections 2 (willingness to interact), 3 (PQ), 4 (HQI), 5 (HQF) and 6 (ATT) due to the reverse correction of negative items, low scores summon to positive agents' assessments whereas high scores to negative ones. In all the analyses, the significance level was set at $\alpha < .05$ and differences among means were assessed through Bonferroni's post hoc tests.

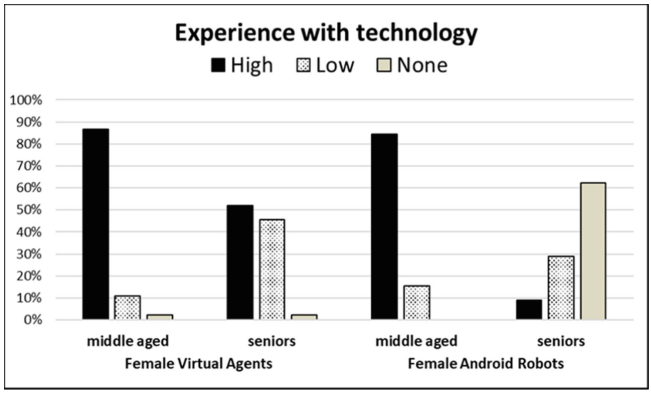

Fig. 4. Descriptive statistics: participants' technological expertise

Willingness to Interact
Significant differences emerged between age' groups ($F(1,87) = 24.607$, $p << .01$): seniors' (mean = 1.634) were significantly more prone than middle-aged (mean = 2.333, $p << .01$) participants to interact with the agents. Significant differences emerged in participants' willingness to interact ($F(1,87) = 12.045$, $p = .001$) with the proposed agents, both seniors and middle-aged participants were significantly more willing to interact with Giulia (mean = 1.789, $p = .001$) rather than with Clara (mean = 2.179).

Pragmatic Qualities (PQ)
Significant differences emerged between PQ scores attributed to the agents by seniors and middle-aged participants ($F(1,87) = 26.948$, $p << .01$): agents were considered significantly more useful by seniors (mean= 20.624) compared to middle-aged participants (mean = 26.948, $p << .01$). The two proposed agents differed significantly in the PQ scores attributed to them ($F(1,87) = 6.751$, $p = .011$), Giulia (mean = 22.638) was considered significantly more useful than Clara (mean = 24.934, $p = .011$) by both seniors and middle-aged participants.

Hedonic Qualities-Identity (HQI)
Significant differences emerged between HQI scores attributed to the agents by seniors and middle-aged participants ($F(1,87) = 14.184$, $p << .01$), agents were considered significantly more pleasant by seniors (mean= 22.252) compared to middle-aged participants (mean = 27.485, $p << .01$). The two female agents differed significantly in the HQI scores attributed to them ($F(1,87) = 10.748$, $p = .002$): Giulia (mean = 23.287) was considered significantly more pleasant than Clara (mean = 26.450, $p = .002$) by both seniors and middle-aged participants.

Hedonic Qualities-Feeling (HQF)
Significant differences emerged between HQF scores attributed to the agents by seniors and middle-aged participants ($F(1,87) = 19.526$, $p << .01$), agents were considered significantly more able to arouse positive feelings by seniors (mean = 21.616) com- pared to middle-aged participants (mean = 27.878, $p << .01$). The two proposed female agents significantly differed in the HQF scores attributed to them ($F(1,87) = 5.124$, $p = .026$),

Giulia (mean = 23.728) was considered more able to arouse positive feelings than Clara (mean = 25.767, p = .026) by both seniors and middle-aged participants. A significant interaction emerged between participants' age group and HQF scores (F (1,87) = 5.335, p = .023). Bonferroni's post hoc tests were performed for each single factor (participants' age and Clara and Giulia HQF scores). Tests revealed that: concerning participants' age, Clara (mean = 23.676) and Giulia (mean = 19.557) were significantly more able to elicit positive feeling in seniors rather than middle-aged participants (Clara: mean = 27.857, p = .017; Giulia: mean = 27.899, p << .01). Concerning the HQF scores, seniors attributed to Giulia (mean = 19.557) HQF scores significantly more positive than those attributed to Clara (mean = 23.676, p = .002).

Attractiveness (ATT)
Significant differences emerged between age' groups (F (1,87) = 20.311, p << .01). Seniors (mean = 20.939) considered the two proposed agents significantly more attractive than middle-aged participants (mean = 27.119, p << .01). Clara and Giulia scored slightly differently in terms of attractiveness (F (1,87) = 4.263, p = .042). Giulia (mean = 23.097) was considered slightly more attractive than Clara (mean = 24.962, p = .042). Fig. 5 summarizes the above discussed results.

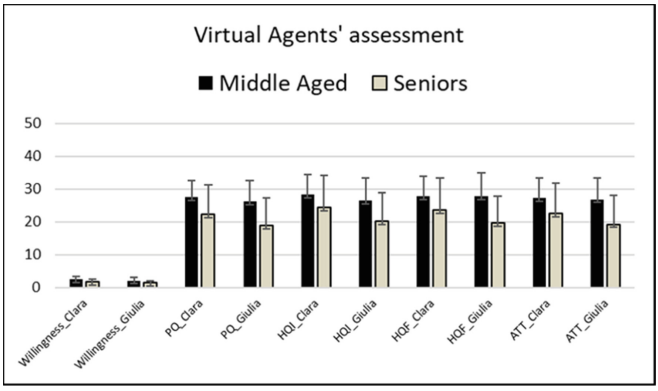

Fig. 5. Middle-aged and seniors' assessment of the two proposed virtual agents Clara and Giulia on willingness to interact, PQ, HQI, HQF, and ATT scores

6 Results-Robots' Assessment (B)

Separate ANOVA repeated measures analyses were carried out on the RAQ questionnaire's scores to assess participants' preferences toward the two android robots. Participants' gender and their age group (middle-aged = Group 3 and seniors = Groups 4) were considered as between subjects and RAQ scores as within subjects' factors. For sections 2 (willingness to interact), 3 (PQ), 4 (HQI), 5 (HQF) and 6 (ATT) due to the reverse correction of negative items, low scores summon to positive robots' assessments whereas high scores to negative ones. In all the analyses, the significance level was set at $\alpha < .05$ and differences among means were assessed through Bonferroni's post hoc tests.

Willingness to Interact

Significant effects of participants' gender ($F(1,86) = 7.355$, $p = .008$) were observed in terms of willingness to interact with the proposed female robots. Male participants (mean = 2.252) were significantly more willing to interact than female participants (mean = 2.869, $p = .008$) with the proposed robots. Significant differences emerged between age' groups ($F(1,86) = 11.644$, $p = .001$), middle-aged (mean = 2.173) were significantly more prone than seniors (mean = 2.948, $p = .001$) to interact with the proposed robots. Willingness to interact scores differed significantly between the pro- posed female robots ($F(1,86) = 15.226$, $p << .01$): participants were significantly more willing to interact with Erica (mean= 2.323) rather than with Sophia (mean = 2.798, $p << .01$). A significant interaction emerged between age' groups and willingness to interact scores ($F(1,86) = 13.988$, $p << .01$). Bonferroni's post hoc tests were per- formed for each single factor (participants' age and Erica and Sophia willingness to interact scores). Tests revealed that concerning participants' age, seniors (mean = 3.482) were significantly less willing than middle- aged participants (mean = 2.183, $p << .01$) to interact with Sophia. Concerning robots, seniors' willingness to interact scores attributed to Sophia (mean = 3.482) were significantly worse than those attributed to Erica (mean = 2.482, $p << .01$).

Pragmatic Qualities (PQ)

Robots' pragmatic qualities were significantly affected by participants' gender ($F(1,86) = 6.216$, $p = .015$). Male participants (mean = 26.665) considered the proposed robots significantly more useful than female participants (mean = 29.718, $p = .015$). PQ scores differed significantly between the two robots ($F(1,86) = 12.449$, $p = .001$). Erica (mean = 27.366) was considered significantly more useful than Sophia (mean = 29.017, $p = .001$). A significant interaction emerged between participants' age and PQ scores ($F(1,86) = 7.698$, $p = .007$). Bonferroni's post hoc tests were performed for each single factor (participants' age and robots – Erica and Sophia PQ scores). Concerning participants' age, seniors (mean = 30.715) considered Sophia significantly less useful than middle-aged participants (mean = 27.318, $p = .012$). Concerning the two robots, PQ scores attributed by seniors to Sophia (mean = 30.715) were significantly worse than those attributed to Erica (mean = 27.766, $p << .01$).

Hedonic Qualities-Identity (HQI)

HQI scores were significantly affected by participants' gender ($F(1,86) = 6.941$, $p = .010$). Male participants (mean = 25.603) considered the robots significantly more pleasant than female participants (mean = 28.875, $p = .010$). Significant differences emerged between age' groups ($F(1,86) = 4.982$, $p = .028$). Middle-aged participants (mean = 25.853) considered the robots significantly more pleasant than seniors (mean = 28.625, $p = .028$). HQI scores significantly differed between the two proposed robots ($F(1,86) = 29.198$, $p << .01$). Erica (mean = 25.555) was considered significantly more pleasant than Sophia (mean = 28.922, $p << .01$). A significant interaction emerged between participants' age and HQI scores ($F(1,86) = 11.256$, $p = .001$). Bonferroni's post hoc tests were performed for each single factor (participants' age and robots – Erica and Sophia HQI scores). Concerning participants' age, seniors (mean = 31.354) considered Sophia significantly less pleasant than middle-aged participants (mean = 26.491, $p = .002$). Concerning the robots, seniors' HQI scores attributed by seniors to

Sophia (mean = 31.354) were significantly worse than those attributed to Erica (mean = 25.895, p << .01).

Hedonic Qualities-Feeling (HQF)
HQF scores were significantly affected by participants' gender (F (1,86) = 6.548, p = .012). Male participants (mean = 24.780) considered the proposed robots significantly more able to arouse positive feelings than female participants (mean = 28.203, p = .012). HQF scores significantly differed between the two robots (F (1,86) = 5.914, p = .017). Erica (mean = 25.799) was considered significantly more able to arouse positive feelings than Sophia (mean = 27.184, p = .017). A significant interaction emerged between participants' age and HQF scores (F (1,86) = 13.196, p << .01). Bonferroni's post hoc tests were performed for each single factor (participants' age and robots – Erica and Sophia HQF scores). Concerning participants' age, HQF scores attributed to the proposed robots do not differed significantly among seniors and middle-aged participants. Concerning the robots, HQF scores attributed by seniors to Sophia (mean = 28.213) were significantly worse than those attributed to Erica (mean = 24.760, p << .01).

Attractiveness (ATT)
ATT scores were significantly affected by participants' gender (F (1,86) = 9.303, p = .003). Male participants (mean = 24.978) considered the proposed robots significantly more attractive than female participants (mean = 28.490, p =.003). Participants' age significantly affected ATT scores (F (1,86) = 9.063, p = .003). Middle-aged participants' (mean = 25.001) considered the robots significantly more attractive than seniors (mean = 28.467, p = .003). ATT scores significantly differed between the two robots (F (1,86) = 5.147, p = .026). Erica (mean = 26.109) was considered significantly more attractive than Sophia (mean = 27.359, p = .026). A significant interaction emerged between participants' age and ATT scores (F (1,86) = 17.989, p << .01). Bonferroni's post hoc tests were performed for each single factor (participants' age and robots– Erica and Sophia ATT scores). Concerning participants' age, seniors (mean = 30.261) considered Sophia significantly less attractive than middle-aged participants (mean = 24.458, p << .01). Concerning the robots, ATT scores attributed by seniors to Sophia (mean = 30.261) were significantly worse than those attributed to Erica (mean = 26.674, p << .01). Figure 6 summarized these results.

7 Results-Comparing Virtual Agents and Robots (C)

Scores at participants' Willingness to Interact (second section of the VAAQ and RAQ questionnaires, respectively) composed of a single item were analyzed through arithmetical means. Conversely, PQ, HQI, HQF and ATT scores obtained by the agents Clara and Giulia and the robots Erica and Sophia were respectively added together. Repeated measures ANOVA analyses were carried out considering participants' gen- der and age (middle-aged and seniors) and stimulus' type (virtual agents and android robots) as between subjects' variables. PQ, HQI, HQF, and ATT scores were considered as within subjects' variables. The significance was set at $\alpha < .05$ and differences among means

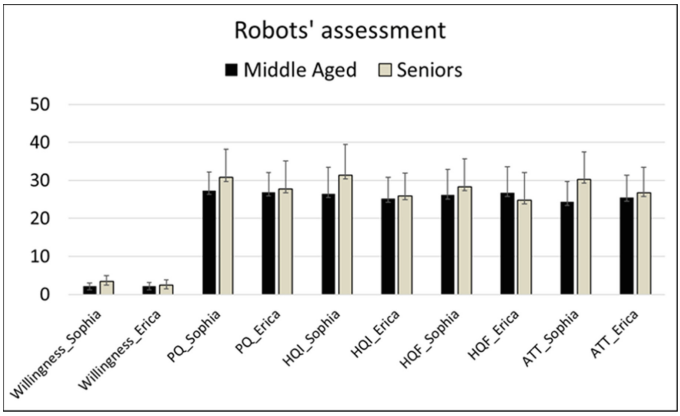

Fig. 6. Middle-aged and seniors' assessment of the female android robots Sophia and Erica on willingness to interact, pragmatic (PQ), hedonic-identity (HQI), hedonic- feeling (HQF), and attractiveness (ATT) scores.

were assessed through Bonferroni's post hoc tests. Please note, due to the reverse correction of negative items, low scores summon to more positive and high scores to more negative evaluations of either the proposed agents or robots.

Willingness to Interact

Participants' willingness to be involved in a potential long-lasting interaction with the proposed agents or robots is reported in Table 1. The data suggest that seniors are more willing than middle-aged participants to interact with virtual agents rather than robots. This is not the case with middle-aged participants who did not show preferences towards either agents or robots.

Table 1. Virtual Agents and Robots' scores in terms of participants' willingness to interact with them.

Virtual Agents			Robots	
	Mean	SD	Mean	SD
Middle- aged	4.644	1.583	4.333	1.610
Seniors	3.261	1,084	5.911	2.695

Comparing Agents and Robots' PQ, HQI, HQF, and ATT Scores

Significant effects of participants' age emerged ($F(1,173) = 4.968$, $p = .027$). PQ, HQI, HQF, and ATT scores attributed by seniors (mean = 49.563) either to the robots or agents were significantly more positive than those attributed by middle-aged participants (mean = 53.480, $p = .027$). Significant differences emerged among agents and robots ($F(1,173) = 10.195$, $p = .002$), PQ, HQI, HQF, and ATT scores attributed to the agents (mean = 48.715) were significantly more positive than those attributed to robots (mean = 54.328,

p = .002). A significant interaction (F (1,173) = 7.348, p = .007) emerged between participants' gender and the type of assistive device (agents vs robots). Bonferroni's post hoc tests were performed for each single factor (participants' gender and type of assistive device). Concerning the gender, a significant preference of female participants toward virtual agents (mean = 47.266) rather than android robots (mean = 57.643, p << .01) was observed. Concerning the assistive devices, robots were evaluated significantly more positively by males (mean = 51.013) rather than female participants (mean = 57.643, p = .009), while virtual agents received similar scores by both male (mean = 50.165) and female (mean = 47.266, p = .244) participants. A significant interaction (F (1,173) = 21.139, p << .01) emerged between participants' age and the type of assistive device (agents vs robots). Bonferroni's post hoc tests were performed for each single factor (participants' age and type of assistive device). Concerning participants' age, seniors scored the agents (mean = 42.716) significantly better than robots (mean = 56.410, p << .01). Concerning the type of assistive device, seniors (mean = 42.716) significantly differed from middle-aged participants (mean = 54.715, p << .01) in attributing significantly more positive scores to the agents rather than robots.

Significant differences emerged among PQ, HQI, HQF, and ATT scores (F (3,519) = 3.831, p = .010): both agents and robots were evaluated significantly more positively on ATT scores (means = 50.763) rather than PQ (mean = 51.977, p = .028) and HQI (mean = 52.107, p = .044) scores.

A significant interaction emerged between participants' age and PQ, HQI, HQF, and ATT scores (F (3,519) = 7.313, p << .01). Bonferroni's post hoc tests were performed for each single factor (participants' age and PQ, HQI, HQF, and ATT scores). Concerning participants' age, middle-aged participants scored agents and robots as more attractive (ATT mean = 52.120) rather than useful (PQ mean = 54.090, p = .007) and able to arouse positive feelings (HQF mean = 54.374, p = .001). Instead, seniors scored agents and robots as more able to arouse positive feelings (HQF mean = 48.103) rather than being useful (PQ mean = 49.865, p = .036) and pleasant (HQI mean = 50,876, p << .01).

A significant interaction emerged between type of assistive device (agents vs robots) and PQ, HQI, HQF, and ATT scores (F (3,519) = 12.349, p << .01). Bonferroni's post hoc tests, performed for each single factor (type of assistive device and PQ, HQI, HQF, and ATT scores) revealed that, concerning the type of assistive devices, agents' usefulness (PQ mean = 47.572) was considered more valuable than agents' pleasantness (HQI mean = 49.737, p = .016) and agents' ability to arouse positive feelings (HQF mean = 49.494, p = .017). Indeed, robots' ability to arouse positive feelings (HQF mean = 52.983, p << .01) and attractiveness (ATT mean = 53.468, p << .01) were considered more valuable than robots' usefulness (PQ mean = 56.382). Concerning PQ, HQI, HQF, and ATT scores, PQ (mean = 47.572), HQI (mean = 49.737) and ATT (mean = 48.058) scores attributed to the agents were significantly more positive than PQ (mean = 56.382, p << .01), HQI (mean = 54.477, p = .012) and ATT (mean = 53.468, p = .003) scores attributed to robots.

A significant interaction emerged among the type of assistive device (agents vs robots), participants' age and PQ, HQI, HQF, and ATT scores (F (3,519) = 4.702, p = .003). Bonferroni's post hoc tests were performed only for type of assistive device,

and participants' age, while PQ, HQI, HQF, and ATT scores were not compared among them since already discussed at the beginning of this section. Concerning participants' age seniors' PQ (mean = 41.248), HQI (mean = 44.504), HQF (mean = 43.233), and ATT (mean = 41.879) scores significantly differed from middle-aged PQ (mean = 53.896, p <<.01), HQI (mean = 54.970, p << .01), HQF (mea n= 55.756, p << .01) and ATT (mean = 54.238, p << .01) scores. Concerning the assistive devices, HQI (mean = 57.249) and ATT (mean = 56.935) scores attributed to robots by seniors were significantly different from HQI (mean = 51.706, p = .037) and ATT (mean = 50.002, p = .007) scores attributed to robots by middle-aged participants. Instead, seniors' PQ (mean = 41.248), HQI (mean = 44.504), HQF (mean = 43.233), and ATT (mean = 41.879) scores attributed to the agents differed significantly from seniors' PQ (mean = 58.481, p << .01), HQI (mean = 57.249, p << .01), HQF (mean = 52.973, p = .001) and ATT (mean = 56.935, p << .01) scores attributed to robots. These results are summarized in Fig. 7.

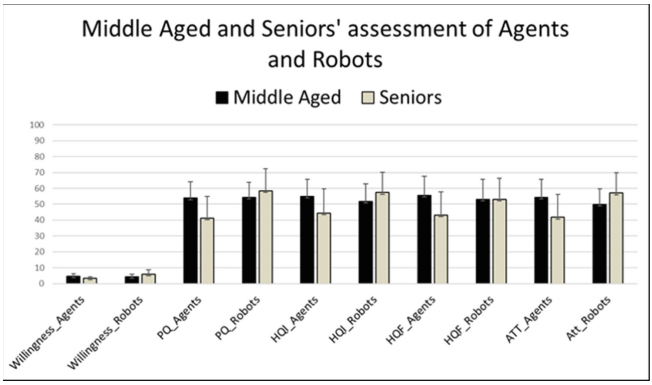

Fig. 7. Middle-aged and seniors' assessment of virtual agents and android robots on willingness to interact, pragmatic (PQ), hedonic-identity (HQI), hedonic-feeling (HQF) and attractiveness (ATT) scores.

Figures 8 and 9 reports separately the scores attributed by seniors (Fig. 6) and middle-aged participants (Fig. 7) to the proposed agents and robots.

8 Discussion and Conclusions

The proposed study was devoted at investigating whether middle-aged and seniors' users may differ in their preferences to interact with virtual agents (Clara and Giulia) or android robots (Sophia and Erica) or both. The agents and robots' investigated qualities were participants' willingness to interact with them and scores attributed to their pragmatic (PQ), hedonic- identity (HQI), hedonic- feeling HQF) and attractive (ATT) qualities.

When only agents are considered, results show that seniors are significantly more willing than middle-aged participants to interact with the agents, and judged them as more useful, easy to use, more pleasant and attractive than middle- aged participants. In

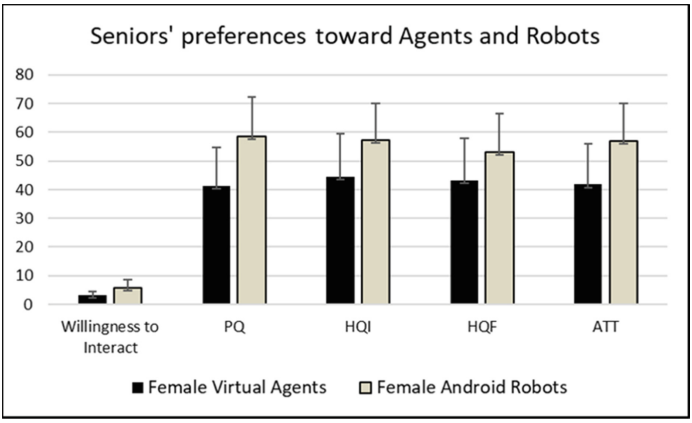

Fig. 8. Seniors' evaluations of agents and robots

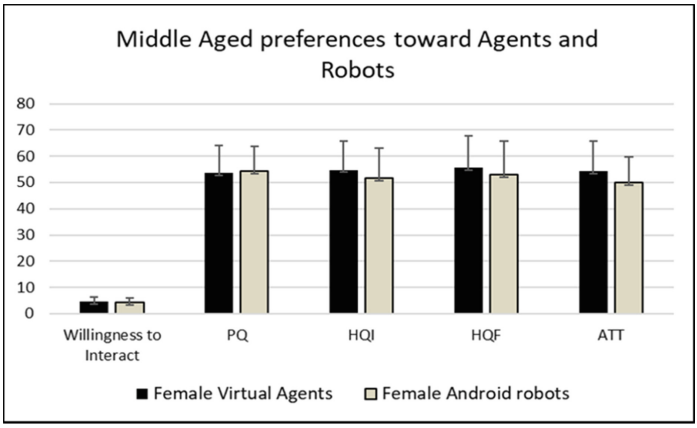

Fig. 9. Middle-aged participants' evaluations of agents and robots

addition, between the two proposed agents, both middle-aged and seniors ex- pressed a clear preference toward the female agent Giulia rather than Clara, suggesting that also agents' appearance plays a role in users' preferences. It is likely that this choice was motivated by the fact that Clara, was perceived younger than Giulia and therefore appeared more naïve and unprofessional and less capable than Giulia to arouse positive feelings (see details in [8, 14]).

On the other hand, when only robots are considered, it appears that middle-aged participants are significantly more willing than seniors to interact with robots rather than the agents, and judged them as more useful, easier to use, more pleasant and attractive than seniors. In addition, between the two proposed robots, both middle-aged and seniors expressed a clear preference toward the female robot Erica rather than Sophia, suggesting that also robots' appearance plays a role in determining users' preferences. It is likely that, the fact that Sophia is hairless may have elicited a sense of social discomfort, since

hairless females are socially unusual in everyday interactional ex- changes, and this feature may have guided participants' preferences in favor of Erica. Moreover, the fact that we have chosen a hairless robot excluding hairless virtual agents could represent an element which could have affected results and also limited the research, in particular when comparing the two types of assistive devices. This effect was strongly biased by seniors' rather than middle-aged participants' scores, the latter did not show significant differences in the scores attributed to the two robots. Finally, when robots and agents were compared together, it clearly appears that seniors' preferences are strongly toward virtual agents rather than android robots, while middle-aged participants preferences are slightly toward robots rather than virtual agents. This effect seems to suggest a generational change, with middle- aged participants less prejudiced and more used to accept the physical presence of such assistive devices. Other studies [17–19] highlighted younger participants' more positive attitude toward robots compared to elders, which instead seem to be more engaged by humanoid agents with a less robotic appearance.

In general, when PQ, HQI, HQF, and ATT scores are compared together for robots and agents, it clearly appears that seniors scored agents significantly more reliable, practical, engaging, and attractive than robots, while middle-aged participants even less enthusiast than seniors seemed to prefer robots rather than agents. In addition, significant differences among participants' gender were observed only for robots, and not for virtual agents, with male more favorable than female participants in initiating a long-lasting interaction with the robots. An element worth to be investigated is if this effect shows-up in a reverse form when android male robots are considered, as to test a possible cross-gender effect, or in other words male participants preference toward female robots and female participants better evaluation of male robots [20, 21]. Otherwise, it can be deducted that female are less available than male participants to be assisted by robots, as already showed by studies highlighting that females have more negative attitudes toward interaction with robots than males [22–24].

Conclusively, the present study highlighted that both types of assistive devices and the age of their users play a fundamental role in the design and implementation of ambient assisted living technologies. It also suggests that preferences may be generational, as for the datum that seniors showed a clear preference toward virtual agents rather than robots, while middle-aged preferences were in the opposite direction. In addition, this study showed that depending on the type of assistive device, the gender attributed to the device plays a role on its acceptance. Female robots are more accepted by male rather than female users. Finally, the appearance of the device plays a role on users' acceptance. Mature virtual assistants are preferred to younger ones, haired robots are preferred to hairless.

These results may also be attributed to a cultural generational gap existing between seniors and middle-aged participants either in their educational level or their experience with the technology or both. It is evident that the two groups of seniors and particularly seniors which were administered the robots' stimuli, reported lower educational levels and lower degrees of technological expertise with respect to the two groups of middle-aged participants. These differences may support the hypothesis of a generational gap. More investigations are however needed to assess these data and the proposed work posits the bases for future research.

Future works should also consider comparisons between male virtual agents and robots, and then male and female virtual agents and robots, as well as involve differently aged groups of participants, among those adolescents and young adults.

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