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# Robotic Versus Human Coaches for Active Aging: An Automated Social Presence Perspective

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**Abstract** This empirical study compares elderly people's social perception of human versus robotic coaches in the context of an active and healthy ageing program. In evaluating hedonic and utilitarian value perceptions of exergames (i.e., video games integrating physical activity), we consider elderly people's judgments of warmth and competence (i.e., social cognition) of their assigned coach (human vs. robot). Our field experiments involve 58 elderly participants in the real-life context. Leveraging a mixed-method approach, combining quantitative and qualitative data, we show that i) socially assistive robots activate feelings of (automated) social presence in the elderly; ii) human coaches score higher on perceived warmth and competence relative to robotic coaches; iii) social cognition impacts elderly people's experience (i.e., emotional and cognitive reactions and behavioral intent) with respect to the exergames. With these findings, we inform future development and design of social robots and systems for their smoother inclusion in the elderly people's social networks. In particular, we advocate for socially assistive robots to take complementary roles (e.g., motivational coach) in assisting human caregivers in improving elderly people's physical and psychosocial wellbeing.

**Keywords** Automated social presence · Social cognition · Socially assistive robots · Exergames · Elderly care · User experience

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## 1 Introduction

Many societies across the world face challenges of ageing populations at risk of reduced physical activity [45]. Meanwhile, an active lifestyle continuously proves its health-related benefits for ageing adults [3]. As the sedentary lifestyle becomes their routine [5], falls among the elderly develop into an alarming problem, often causing hospitalization and reduced physical autonomy [66]. Evidence suggests decreased motivation for physical activity being linked to advanced age [57], and urges healthcare systems to develop effective solutions to ensure the physical wellbeing of elderly. *Exergames* have emerged as an innovative way for seniors to avoid a sedentary lifestyle and combat the degenerative effects of ageing. The easy-to-follow steps and gamified nature of exergames motivates seniors to be physically active through playful interactions. The application of exergames in the healthcare has yielded positive outcomes for both physical and cognitive wellbeing [9, 65]. Recent studies in the use of exergames in rehabilitation [61, 14] suggest comparable or slightly better results (e.g., in balance and gait) than the conventional fitness programs.

**Fig. 1** Vizzy interacting with an elderly lady

According to a study which investigates the usability of exergame platforms [60], elderly persons' cognitive deficiencies act as a hindrance in establishing engagement with the exergame. In our study, we propose that a social agent is supportive in guiding and motivating the elderly throughout the gaming process. Professionals in care institutions do their best to keep elderly physically and mentally active, but the unprecedented relative growth of the elderly population is creating a gap between supply and demand of care services [37]. As an aid to professional caregivers, several gaming platforms use virtual agents for guidance and motivational roles, seeking to automate social presence of caregivers. However, the presence of a physical entity enhances the interaction with an autonomous agent when compared with a virtual or real entity presented on a screen [48, 59, 40]. Such findings motivate researchers to turn their attention to Socially Assistive Robots (SAR), like Vizzy [42], MBOT [64], and GrowMu [47]. These are robots that understand social cues through facial and voice recognition technology, are capable of engaging in quasi-social interactions, and hence could make their users feel like they are in a company of a social entity [62].

The extent to which current SARs are capable of making people enjoy and perceive exergames as useful is a crucial research topic. The adoption of a user-centered design perspective, with continuous benchmarks and comparisons between SARs and care professionals, leads to technological improvements that better suit professionals and elderly patients. In this study, we focus on the perspective of the elderly and we address the following research question: *How does automated (i.e., of Socially Assistive Robots) vs. human presence affect elderly peoples experience with the exergames for improvement of physical activity?* We use the Vizzy robot (Fig. 1) and the Portable Exergames Platform for Elderly (PEPE) [60] for this purpose. By means of an experimental design carried out at four elderly care locations, we investigate user experience while playing exergame in the company of either a human or robotic coach. We evaluate elderly peoples' experiences through a questionnaire augmented with a set of probing questions. Our contributions and practical implications include:

- An empirical test of the new concept of automated social presence and how it influences exergame experience for seniors.
- Quantitative and qualitative comparison of social perceptions elderly people form about human and robotic coaches.
- Evaluations of elderly peoples' experiences (i.e., emotional and cognitive reaction and behavioral intent) with the exergame depending on the company.

The remainder of this paper is organized as follows. In Section 2 we discuss several works regarding similar end-user studies with SARs in motivational and conversational roles. We then present the conceptual background in Section 3 that grounds our conceptual model. Our hypotheses are presented in Section 4. Afterwards, we present Vizzy and PEPE and describe research setup, experimental design, and data collection procedures in Section 5. Finally, we present results in Section 6 and discuss contributions and implications of our study in Section 7.

## 2 Related work

### 2.1 Social robots for older adults

Applications of SARs in elderly care are a trending research topic. Several studies with older adults have tested SAR's acceptability and possible applications in a wide range of areas. In [36] two robots were used by seniors as shopping partners. Findings suggest that robot's social skills (e.g., conversation) improve the intention to use a robot. [41] presents an exploratory study at an elderly care facility to investigate user engagement and compliance during meal-time interactions with a robot. Participants were engaged and compliant with the robot's instructions, and perceived the robot as enjoyable.

Other studies investigated the evolution of seniors' perceptions about SARs over a longer period of time. These include [30], which examined which factors play a role in long-term user acceptance of social robots. It was observed that hedonic factors gained most attention but utilitarian factors are a fundamental base before engaging in long-term interactions (the robot must have a clear purpose). A more recent example [39] investigated older adults with dementia at residential aged care facilities over four years. After each trial the services of the robot were improved with staff and residents' feedback. Results showed statistically significant improvements in terms of engagement and robot acceptability.

### 2.2 Robotic Coaches

Robotic coaches are platforms that engage, monitor and support physical exercise activities, through verbal and non-verbal communication, demonstration of exercises and real-time corrective or motivational feedback. An early study [22] explored the enjoyment of interaction and perceived utility of two different approaches. The first implemented by a relational robot that praises, addresses user by name, has humor, and shows empathy. The second uses a non-relational robot that just informs scores and provides help as needed. The users perceive a relational robot as a better companion and exercise coach than a non-relational one. Robotic coaches should provide motivational support to users while performing an exercise. With such a role, the majority of people perceived the relational robot as more intelligent as well as more helpful. A more recent study [21] describes feasibility tests of a robot coach architecture with older adults and also reports promising acceptability results. This architecture has a rule based decision process, but is able to learn user preferences, estimate their "affective state", and recall past interactions with the user. Users' perceptions about the interaction with the robot improved over their initial expectations. Paper [56] studies motivational differences between a robot that solely instructs users (Robot Instructor role) and a robot that exercises alongside the user (Robot Companion role). The study concludes that people are more motivated by the robot companion role. A recent user-study in a robot coaching scenario for the elderly [29] evaluated people's engagement and enjoyment while exercising. It also reports several difficulties including hearing the instructions, focusing on the physical aspects of the robot while ignoring verbal instructions and confusion while performing sequences of gestures.

These studies are important to measure SARs' acceptance, improve their human-robot interaction (HRI) capabilities, and gradually integrate SARs in real life environments. However, they do not compare older adults' perceptions about exergames when being coached by a human or a robot. To our knowledge, there are no studies that address such a problem, which led us to prepare this work. The following section explains why such a study is wanted.

## 3 Conceptual background

Nowadays, social interactions are not exclusively reserved to humans. With technologies mimicking humans, in their appearance and behaviors (e.g., social robotics; [11]), there is a rising number of quasi-social interactions in diverse types of service settings. Think for example of robotic waiters, robotic bank tellers, or robotic receptionist. These are all artificially intelligent social actors capable of engaging in quasi-social interactions [6]. Robots are not social by nature, but rather programmed to act as conversational partners and socially interactive peers [28]. Yet, it has been argued that when engaging in quasi-social interactions, humans equate robotic systems to social beings [32] [50]. This phenomenon is closely linked to the concept of social presence, broadly defined as the sense of being with others (e.g., in virtual reality; [34]) or the feeling of having the access to others' minds (i.e., their cognitive, affective and intentional states; [7]). According to [6] social presence is a property of humans - not technologies; therefore current theories may benefit from using social presence as a lens to compare interactions between human and non-human actors. Recently, [62] introduced the concept of *automated social presence* to service literature, defined as "the extent to which machines (e.g., robots) make consumers feel that they are in the company of another social entity" (p. 44). Hence, if robots are capable of interacting with people in human-like ways through listening, conversations, or reading of emotional cues, then people might start automatically responding socially to them [50]. In particular, this study argues that people will activate their social cognition and will judge the non-human social actor on warmth and competence dimensions (i.e., universal dimensions of social cognition).

### 3.1 Social cognition

According to Fiske et al. [27], when interacting with members of the same species, humans need to determine whether the other is 'friend or foe' (i.e., warmth dimension), and whether the other is capable to act on good or ill intentions (i.e., competence dimension). Despite the fact that robots are not members of the same species, their anthropomorphism [44] and increasing social dexterity makes them resemble humans in many as-

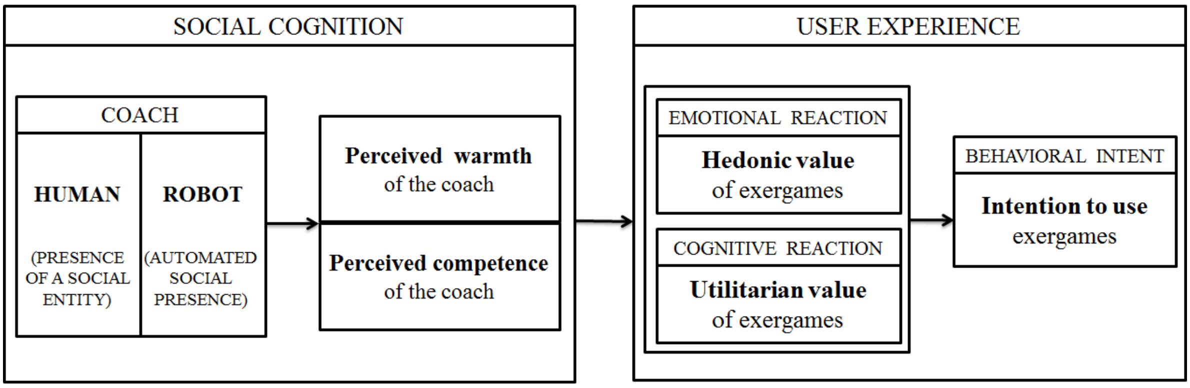



**Fig. 2** Conceptual model

pects. This study in particular focuses on SARs, which offer assistance through social interactions in a human-like manner [23]. In a healthcare context, SARs are autonomous, understand social cues through facial and voice recognition, and can provide both child (e.g., autism therapy; [55]) and elderly (e.g., medication reminders, [12]) care. In an elderly care context, SARs offer services such as health monitoring and safety, encouragement to engage in rehabilitation or general health-promoting exercises, social mediation, interactions, and companionship [24]. As they perform more socially engaging tasks, these robots take the roles of companions, collaborators, partners, pets, or friends [18] [28]. Hence, this study builds on the idea that humans judge their social interactor (even if it is a non-human actor) on warmth (i.e., friendliness, kindness, caring) and competence (i.e., efficacy, skill, confidence) dimensions which will further affect their emotional, cognitive, and behavioral reactions. In this way, it addresses recent calls for further research on the effects of automated social presence on perceived enjoyment and usefulness of service interactions and the acceptance of new technologies [32] [62]. Fig. 2 depicts our conceptual model.

## 4 Hypotheses development

We test our empirical model through field experiments with the elderly. The aim of the study is to investigate the differences between human vs. robotic company in motivating the elderly persons for physical activity. We introduce the hypotheses in the following order: i) hypothesis concerning robotic coaches only (H1), ii) hypotheses comparing human and robotic coaches (H2 and H3), iii) hypotheses concerning user experience with the exergame (H4 and H5).

Following the argument that humans tend to treat non-human actors/system as social beings [50] [32] and the definition of automated social presence [62], this study investigates whether SARs, using human-like social behavior and communicative skills [10], do evoke feelings of social presence in humans. Furthermore, this study extends previous research [26, 38] by involving socially dexterous robots (i.e., capable of engaging in a dialog, gazing, responding to social cues). Thus, we hypothesize:

**H1**: The robotic coach is perceived to have automated social presence (i.e., makes people feel that they are in a company of a social entity).

Furthermore, if people feel like they are in a company of a social entity, they might evaluate robots through the same mechanisms of social cognition (i.e., warmth and competence) as they do with human company [62]. This study warrants further investigation on human social cognitive mechanisms by extending previous research [26] through comparisons of human and robotic coaches. We therefore postulate:

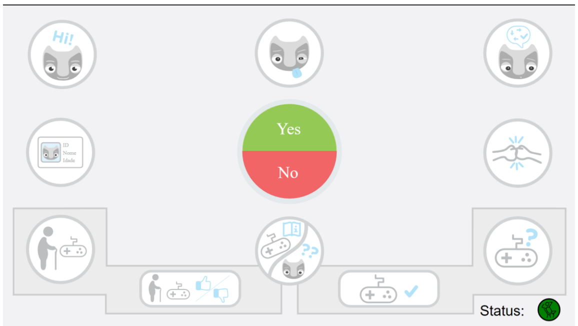
**H2**: There is a difference in the a) perceived warmth and b) perceived competence between human and robotic coaches.

Moreover, in line with calls from [31, 33], we explore the effects of automated social presence vs. presence of human coaches on users' emotional and cognitive reactions, influencing their acceptance of technologies [63]. We expect that being in the company of a human vs. a robot influences whether the elderly participants find playing the exergame enjoyable and effective. We therefore postulate:

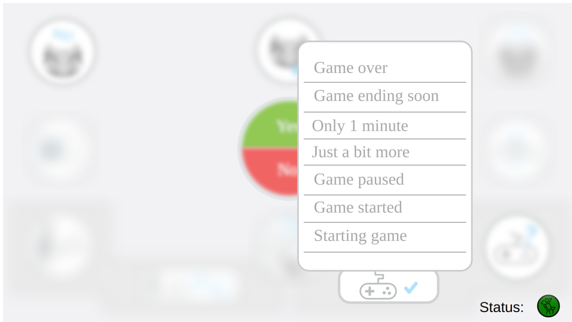
**H3**: There is a difference in the a) hedonic and b) utilitarian value perceptions of the exergame depending on whether the coach is human vs. robot.

Finally, if both human and robotic entities are evaluated through the universal dimensions of social cognition, we can further investigate how the differences in peoples' social cognition of human vs. robot affect their

**Fig. 3** The Vizzy robot




(a)




(b)

**Fig. 4** The dialogue control GUI. (a) shows the default view with several buttons grouping verbal intentions. On (b) one of button has been pressed, showing several options.

emotional and cognitive responses, and ultimately, their intention to use. Therefore:

> **H4**: **a)** Perceived warmth and **b)** perceived competence of the coach has an impact on users' i) hedonic and ii) utilitarian value perceptions of the exergame experience.
> **H5**: **a)** Hedonic and **b)** utilitarian value perceptions have an impact on users' intention to use the exergame.

## 5 Methods and Materials

### 5.1 Robot description

The robotic platform used in these experiments is the Vizzy robot [42], developed by the Institute for Systems and Robotics (ISR-Lisboa/ISR). Vizzy is a 1.75 m tall wheeled robot with a humanoid upper torso and a friendly marsupial-like design (Fig. 3). It has a total of 30 mechanical degrees of freedom (DOF). The two DOF's of the differential drive base allow it to easily navigate on planar surfaces and plan its trajectories using well-established algorithms [49] [54]. The head can perform pan and tilt movements, and its eyes can do tilt, vergence and version movements, totaling 5 DOFs. Vizzy's arms and torso have 23 DOFs which allow it to perform human-like motions.

Two laser scanners at the bottom of the mobile base allow the capture of planar point-clouds of the environment, providing valuable information for the robot to safely navigate. Each of Vizzy's eyes contains a camera, used for object/people detection and tracking. A depth camera is mounted on Vizzy's chest further enhancing the robot's sensing capabilities for human movement analysis.

Other components include a loudspeaker and a microphone useful for HRI scenarios, as well as twelve tactile sensors [46] on each hand, mounted on the finger phalanges.

Vizzy's actuators and controllers allow it to navigate, grasp objects, perform gestures and gaze in a biologically inspired way [53] [1]. The robot also has software that enables it to detect and follow people in the environment using an implementation of the Aggregate Channel Features Detector [19] with appearance-based tracking using color features [25]. A set of RVIZ plug-ins allow the remote control of the robot in Wizard-Of-Oz (WoZ) experiments, namely the head and the base in a gaming-like way while visualizing the obstacles gathered by both laser and the people detected by the cameras. A web interface (see Fig. 4) allows a "wizard" to quickly select utterances for the robot to speak while hearing through the robot's microphone. This approach allows faster reply and interaction than explicitly typing the utterances in a keyboard, at the cost of speech flexibility.

## 5.2 Gaming platform description

To perform the exergames with seniors, we used the Portable Exergames Platform for Elderly (PEPE) [60], an augmented reality platform that projects exergames on the floor, while a Kinect sensor captures the person's movements to control the game elements. Hence, users can play using PEPE without any kind of wearable sensor or controller, thus minimizing the burden and complexity for older adults. Two touchscreens on the top of the platform show additional information to staff. For now, the games need to be initiated and terminated by a person, but in the future, the social robot will be able to perform the control of the game-flow. The chosen game for our experiments is ExerPong [14]. In this game, the player controls the green paddle (see Fig. 5) with body movements. The objective is to hit the yellow ball with the green paddle, making sure it does not leave the game area. Colored boxes populate the gaming area. When touched by the yellow ball, the colored boxes are destroyed and yield points to the player. After destroying all the boxes, the player completes the level. Every time the player fails to hit the yellow ball, and it leaves the playing area, a box reappears. During the game, audiovisual stimuli give performance information to the player in the form of a red visual feedback and success and failure sounds. The players can either control the paddle by walking sideways or with horizontal arm movements. In this way ExerPong can be played by people with different degrees of mobility.

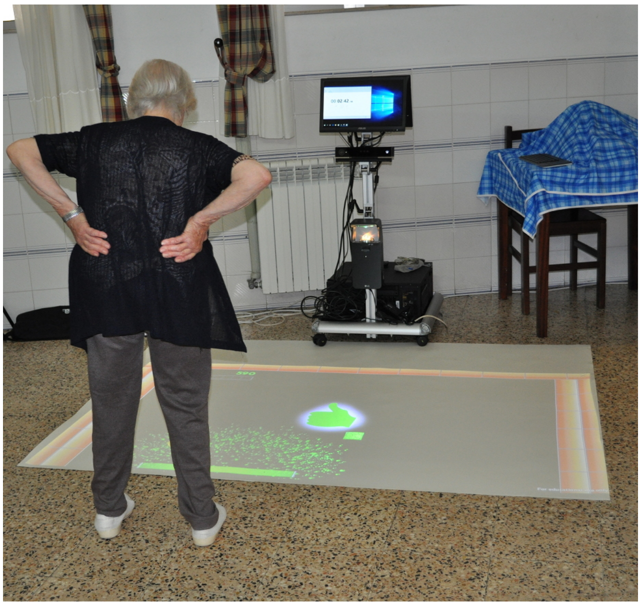


**Fig. 5** The Exergames platform PEPE: Portable Exergames Platform for Elderly during an ongoing ExerPong game

## 5.3 Participants

In total, 58 elderly persons (42 female, 16 male) participated in the study. Elderly persons suffering from severe physical (e.g., full physical immobility) or mental (e.g., dementia) health problems were not considered, as well those incapable of giving their consent. The target population comprised elderly persons living autonomously (e.g., in their own home) or in a nursing home, where they accept services from the care institution. In particular, all participants were clients of care centers which offer a wide range of senior tailored activities (e.g., card games, fitness, or handcrafts). The total sample was further randomly divided into two experimental groups: i) 22 participants in the *human coach group* (16 female, 6 male; with a mean age of 76) and ii) 36 participants in the *robotic coach group* (26 female, 10 male; with a mean age of 81).

## 5.4 Experimental Setup

Data was collected in collaboration with four elderly care institutions during July to September 2017. Each participating elderly care institution provided: i) spacious activity area, ii) adjoining room for surveys/ interviews, iii) in-house psychologist. Spacious activity area was essential because we needed to fit the gaming platform and secure enough space for the robot to navigate throughout the area. We requested an additional room to assure informant's privacy during survey/interview data collection. Finally, the role of the in-house psychologist was to help screening the elderly clients to evaluate their fit for the experiment (exclusion criteria: severe physical or mental health problems). The visits were scheduled during regular activities time of each care center.

## 5.5 Experimental Procedure

As a part of the study, the exergame platform was installed in the main 'activities' room of each care institution. During the regular activities time, seniors were approached either by a human or the robot, depending on the experimental group they were assigned to. To keep both experimental scenarios as constant as possible, we developed a standardized set of steps each of the actors (i.e., human/robot) needed to follow: 1) Human/Robot approaches an elderly person who satisfies the inclusion criteria, 2) Human/Robot introduces the new activity at the center (i.e., exergames) and invites the elderly person to join the game, 3) If the elderly person accepts the invitation, human/robot escorts the elderly to the gaming area, 4) Human/Robot gives the instructions on how to play the game, 5) During the game, human/robot motivates the elderly person by words of encouragement and feedback on the game progression, 6) Human/Robot asks the elderly person whether to continue or terminate the game. The communication was also standardized, so that both human and robot actors used the same sentence to introduce exergames, to give instructions, and motivate players. On average, the time spent playing the exergame was 10:08 min. After the game, a member of the research team escorted the elderly participants to the room/area where they were further surveyed and interviewed.

## 5.6 Data collection

To test whether a robot (i.e., an automated social presence) can be comparable to humans in motivating the elderly for physical activity, we chose a mixed-method approach, combining quantitative and qualitative data. The main instrument was a questionnaire, augmented with probing questions to elicit more in-depth qualitative data.

### *5.6.1 Quantitative data collection*

Each of 58 elderly participants was asked to allocate 10 to 15 minutes of their time and join the first author to discuss their overall experience with the activity. For that purpose, a questionnaire was constructed to guide the discussion. With the decrease of their cognitive functioning, elderly people often struggle with the question and rating scales comprehension [58]. We hence decided to conduct guided survey questionnaires. In particular, the researcher would read out the question to the elderly person and explain the rating scale (e.g., totally disagree to totally agree) and then ask the elderly person to indicate their response.

To measure elderly participant's experience with playing exergames (i.e., emotional and cognitive reaction), we adopted two bipolar scales developed by [43] and [15]. Specifically, we employed a five-item measure ($\alpha = .85$) to assess their hedonic value perceptions (i.e., users' enjoyment in physical activity using the exergame platform). We assessed utilitarian value perceptions (i.e., users' perceptions of effectiveness of physical activity using the exergame platform) with a three-item measure ($\alpha = .85$). Participants responded to a seven-point bipolar scale. To add to the emotional and cognitive reaction a component of behavioral intent, we measured elderly participants' future intention to play exergames by a two-item measure ($\alpha = .91$).

Furthermore, we assessed elderly participants' evaluations whether the human/robotic coach was good or ill-intended (i.e., warmth) and competent to perform the task. In line with the conceptualizations of social cognition by [17], we adopted a three-item measure for perceived warmth ($\alpha = .76$) and three-item measure for perceived competence ($\alpha = .88$). Participants responded to all items on five-point Likert scales ("totally disagree" = 1 to "totally agree" = 5).

Finally, to evaluate the experience of sensing a social entity when interacting with the robot, we developed a four-item measure ($\alpha = .7$) to assess the automated social presence based on [2] and [33]. Again, all items were measured on a five-point Likert scale. Tables 1 and 2 show all constructs and items used in the questionnaire.

### *5.6.2 Qualitative data collection*

We chose to employ a convergent parallel mixed methods design [16] in which we collected both quantitative and qualitative data at the same time, with an aim to analyze whether the findings from both types of data will support each other. During the surveying process, the researcher would further probe on particular items from the questionnaire either through 'tell me more' probes [4] or laddering technique [51]. For example, after elderly participants would indicate their enjoyment level on a bipolar scale from "I hated it" = 1 to "I enjoyed it" = 7, the researcher would further ask what in particular they found enjoyable or not. Or, after they would indicate their intention to use the exergame platform in the future on a scale from 1 to 5, the researcher would ask 'why' - with the intention to uncover core values guiding their behavioral intentions.

All collected narratives were digitally audio-recorded and then later transcribed, translated, and reviewed. The analysis was conducted in the following order. First, the authors read the transcripts independently to form their own understanding of each participant's narratives [52]. Second, four co-authors met for a joint analysis session to share emerging codes and develop a more focused coding scheme. Finally, the first two authors coded the remaining narratives based on the coding scheme. Due to the exploratory nature of the study, codes and thematic descriptions emerged from the data rather than from preconceived categories or theories [35].

**Table 1** Items related to the exergame

| **Hedonic Value** ($\alpha = .85$) | | | **Utilitarian Value** ($\alpha = .85$) | | |
|---|---|---|---|---|---|
| 1: I hated it (1) | ... | I enjoyed it (7) | 1: I find it harmful for my physical health (1) | ... | I find it useful for my physical health (7) |
| 2: I felt bored (1) | ... | I felt interested (7) | 2: I find exergames ineffective (1) | ... | I find exergames effective (7) |
| 3: I disliked it (1) | ... | I liked it (7) | 3: I feel like it cannot improve my physical health (1) | ... | I feel like it can improve my physical health (7) |
| 4: I found it unpleasurable (1) | ... | I found it pleasurable (7) | **Intention to use** (1 - 5 Likert scale, $\alpha = .91$) | | |
| 5: It was not fun at all (1) | ... | It was a lot of fun (7) | 1: I think I will play exergames during the next few days. | | |
| | | | 2: I will use the exergame platform in the future. | | |

**Table 2** Items related to the human/robotic coach

| **Perceived Warmth** (1-5 Likert scale, $\alpha = .76$) | **Automated Social Presence** (1-5 Likert scale, $\alpha = .70$) |
|---|---|
| 1: I feel the human/robotic coach understands me. | 1: I can image the robot to be a living creature. |
| 2: I think the human/robotic coach is well-intentioned. | 2: When interacting with the robot I felt I'm talking with a real person. |
| 3: I think the human/robotic coach is friendly. | 3: Sometimes the robot seems to have real feelings. |
| **Perceived competence** (1-5 Likert scale, $\alpha = .88$) | |
| 1: I think the human/robotic coach is competent. | 4: I felt like the robot was actually looking at me throughout the interaction. |
| 2: I think the human/robotic coach is reliable. | |
| 3: I think the human/robotic coach is an expert/knowledgeable. | |

## 6 Results

### 6.1 Automated social presence

To investigate H1, we ran a one sample t test to determine whether the mean value of automated social presence is statistically different from a neutral value, in our case from a mid-point (=3) on a 5-point Likert scale. We found support for H1, with the mean score of 3.5 ($SD = .97$) which is significantly different from 3, $t(35) = 2.97$, $p = .005$ (Fig. 6).

Hence, there is evidence that the elderly people do experience some sort of automated social presence when interacting with the robot. Furthermore, if we augment quantitative findings with the collected qualitative data, we can see the emergence of a thematic paradox we label as: "We know it's a machine, but it feels like a human". From the narratives shared by the elderly participants, it is observable that they experience a conflict of thoughts, as captured in the following quotes:

> *It's almost the same thing [as talking with a real person].* (Female, 80)

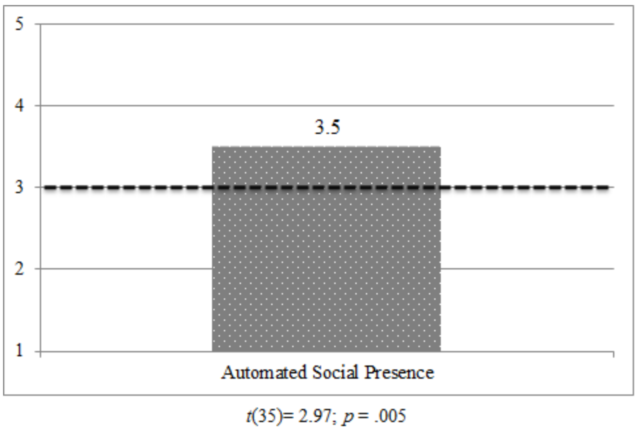



**Fig. 6** Automated social presence

> *No, I mean... we can see that it's a robot, right? But we can see that it's something intelligent... but it's not a person... but it's as if it is a person.* (Female, 89)
> *It's a robot but ...I imagined it as a person there talking to me.* (Female, 94)

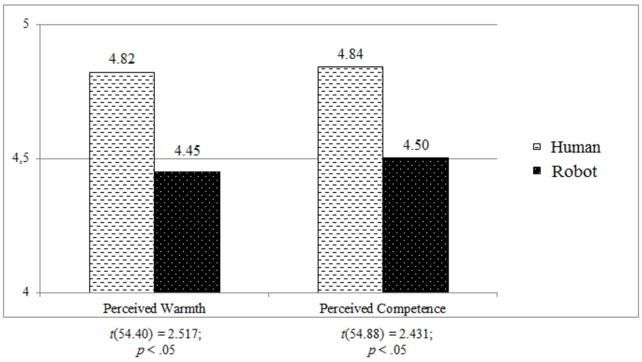



**Fig. 7** Perceptions of warmth and competence

*It felt like talking to an adult person. It's like the grown-ups.* (Male, 71)

Indeed, the comparison of quantitative and qualitative data shows similarities, with findings supporting H1.

### 6.2 Social cognition

To test H2, we ran an independent samples t test, to determine whether the means of two groups (human vs. robot) differ statistically. We found a significant difference in the mean scores for perceived warmth when the coach is a human ($M = 4.82$, $SD = .37$) and when the coach is a robot ($M = 4.45$, $SD = .73$), $t(54.40) = 2.517$, $p < .05$. Similar follows for the perceived competence of the coach: human $M = 4.84$, $SD = .47$) and robot ($M = 4.50$, $SD = .67$), $t(54.88) = 2.431$, $p < .05$ (Fig. 7).

These results support H2, the difference for both perceived warmth and perceived competence is statistically significant. The elderly people perceive the robot to be quite friendly, well-intentioned, and understanding of their needs, but to a lesser extent than the human coach. Perceiving the robot as high on the warmth dimension is in itself an important finding. It is also further supported with the qualitative data. After we coded all the narratives, another broader theme emerged, which we label as: "It's a machine, but it's kind and gentle". As emphasized by the elderly participants:

*The robot spoke very politely to us [laughs]. He is really friendly.* (Female, 86)
*The robot seems gentle to me.* (Female, 64)
*If he has revealed all of his intentions... they are good.* (Male, 72)
*I was very loyal to the robot and it became my friend.* (Male, 90)

Similarly, the elderly people perceive the robot as competent, reliable, and a knowledgeable expert for the particular task at hand. They evaluate it on average with 4.5 on a 5-point scale, slightly lower than the human coach. Again, an interesting finding in itself. Our qualitative data yields similar results, offering further empirical evidence for the high perceived competence of the robotic coach, as shown by the following quotes:

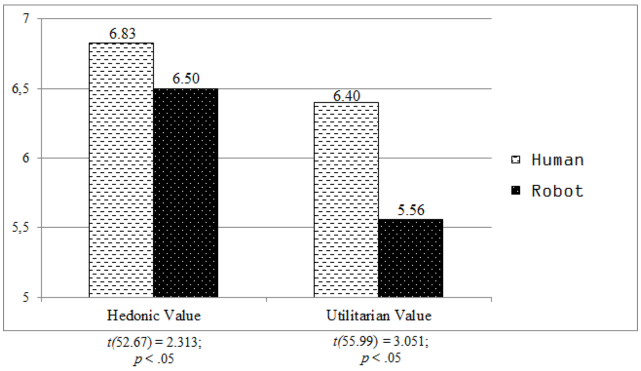



**Fig. 8** Hedonic and utilitarian value perceptions of exergames

*For what he is programmed, he is competent. He seemed smart to me. He did not say that much. If he had spoken about football...[laughs]* (Male, 72)
*Wasn't it intelligent? It is more intelligent than I am.* (Female, 84)
*It is well-informed. If it wasn't well informed it wouldn't come here.* (Female, 80)
*It's smart to the max!* (Male, 81)

### 6.3 Hedonic and utilitarian value

These results support H3, but do not explain why these differences exist. When we combine quantitative findings with the qualitative data, we observe that the elderly people had fun and enjoyed the experience with the exergames while in the company of a robot:

*I loved it. I found it very interesting...and believe me, I don't participate if I don't enjoy the activity...I had the maximum score. It was very funny. And the robot was a good lad.* (Male, 72)
*I liked it a lot, lot, lot, lot, lot! The robot was always saying: 'Excellent, excellent'. That motivated me.* (Female, 84)

Still, the elderly enjoyed the experience slightly less than with a human coach, as they express in their narratives:

*I was a bit shy and anxious, right? Without knowing what to say, or what to do... the movements I should do.* (Female, 89)

*I found it funny [enjoyable]. But I almost can't hear, so I couldn't understand most things that the robot said.*(Female, 91)

Similarly, when asked to share their narratives of whether they find the exergames effective (i.e., utilitarian value perceptions) for the improvement of their physical condition, some of the participants shared the following concerns:

*Robot's explanations were not enough! I was there doing something that I didn't know if it was right or wrong. And if I really was... as the robot was saying "Excellent", but those are the words it has inside and we cannot trust that very much.* (Female, 81)
*Let's see... if the robot only does that exercise, that isn't much more than moving left and right, I think it's insufficient. So it should have more, more advantages...*(Female, 81)

### 6.4 Regressions

To test hypotheses 4 and 5 we estimate a system of five regressions using the seemingly unrelated regressions (SUR) procedure in STATA. The significant Breusch-Pagan-Lagrange multiplier test for error independence ($\chi^2(10) = 28.306$, $p < .01$) indicates correlated errors in the five equations, and the R-square for each individual equation is statistically significant at $p < .01$ (see Table 4). Therefore, using SUR is appropriate [13, 20]. The first two equations have perceived warmth and perceived competence as dependent variables and the type of coach as independent variable. These two equations serve to control for the influence of the coach on social cognition. The third equation has hedonic value as the dependent variable and perceived warmth and competence as independent variables while the fourth equation has utilitarian value as the dependent variable and perceived warmth and competence as independent variables. These two equations test hypothesis 4. Finally, the fifth equation has intention to use as the dependent variable and hedonic and utilitarian value as the independent variables, thus testing hypothesis 5. Table 3 contains an overview of the descriptive statistics and correlations.

The unstandardized coefficients and their standard errors, obtained with the SUR estimator (*sureg* command) in STATA 14.2, are in Table 5. Perceived warmth of the coach has a positive, significant coefficient on hedonic value (.29; $p < .05$) supporting H4a.i, while its impact on utilitarian value does not have a significant coefficient (.23; $p > .05$), hence we cannot find support for H4a.ii). Perceived competence of the coach has a positive, significant coefficient on both hedonic (.46; $p < .01$) and utilitarian values (1.08; $p < .01$), thus supporting H4b. Finally, hedonic value has a positive, significant coefficient on intention to use (.52; $p < .01$), as well as utilitarian value on intention to use (.22; $p < .05$). Therefore, we find support for H5a and H5b.

## 7 Discussion

This research evaluates the application of robots (i.e., SARs) in social contexts, formerly exclusively reserved to human agents. Motivated by the importance of physical activity for healthy ageing, and urged by the shortages of elderly care staff [45], our aim is to examine if SARs can take a coaching role in motivating the elderly for physical activity, and hence expand the elderly person's social networks. In particular, we test whether SARs, that are not inherently social entities, but rather programmed to exhibit social behaviors, can give rise to social perceptions in elderly people and affect them in similar ways as human agents [32]. Furthermore, if SARs equipped with social capabilities can be comparable to human agents, then we are interested to investigate their efficiency in motivating the elderly for a new kind of physical activity (i.e., exergames) and to compare their impact with that of human coaches.

### 7.1 Automated social presence and social cognition

Our findings suggest that the elderly people do feel like they are in a company of social entities when they interact with SARs [62]. Our mixed-method empirical tests show that the elderly struggle to place the robot into the "machine" box, because of its expressiveness, friendly voice, politeness, and considerateness. Throughout their narratives, we can detect that they see the robot as a "metal box", but due to the robot's social dexterity, they humanize the machine in their imagination. In this way we show that, in the future, SARs could potentially extend elderly people's social networks, and support human caregivers not only in mechanical tasks, but also tasks of a social nature (e.g., motivational coaches, playing games, conversational partners).

Our research further suggests that, in quasi-social interactions, elderly people perceive SARs as social entities, they might evaluate SARs through the same mechanisms of social cognition as they do with humans. Our experiments hence shed light on social perceptions of automated agents [50]. We found that elderly people do activate warmth and competence judgments when interacting with SARs. However, comparing humans and a robot in performing the same (coaching) task,

**Table 3** Descriptive statistics and correlations

| Correlations | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1. Coach (Human vs. Robot) | 1 | | | | | |
| 2. Perceived warmth | -.28* | 1 | | | | |
| 3. Perceived competence | -.29* | .61** | 1 | | | |
| 4. Hedonic value | -.25 | .56** | .63** | 1 | | |
| 5. Utilitarian value | -.34** | .42** | .59** | .54** | 1 | |
| 6. Intention to use | -.13 | .43** | .55** | .56** | .53** | 1 |
| **Descriptive statistics** | | | | | | |
| Minimum | 0 | 3 | 3 | 4 | 2 | 1 |
| Maximum | 1 | 5 | 5 | 7 | 7 | 5 |
| Mean | .62 | 4.59 | 4.64 | 6.62 | 5.87 | 4.52 |
| Std. Deviation | .49 | .64 | .62 | .63 | 1.20 | .85 |

**Table 4** Overview of Seemingly Unrelated Regressions (SUR) Equations

| Equation | Hypothesis | Independent variable | Dependent variable | RMSE | R-sq | $\chi^2$ | p |
|---|---|---|---|---|---|---|---|
| (1) | NA | Coach (Human vs. Robot) | Perceived warmth | .61 | .08 | 5.64 | .02 |
| (2) | NA | Coach (Human vs. Robot) | Perceived competence | .59 | .08 | 6.21 | .01 |
| (3) | H4.i | Perceived warmth<br>Perceived competence | Hedonic Value | .47 | .44 | 48.11 | .00 |
| (4) | H4.ii | Perceived warmth<br>Perceived competence | Utilitarian Value | .96 | .35 | 37.09 | .00 |
| (5) | H5 | Hedonic Value<br>Utilitarian Value | Intention to use | .66 | .39 | 36.16 | .00 |

Notes: Sample size = 58; NA = Not applicable

**Table 5** Overview of Seemingly Unrelated Regressions (SUR) Results

| | (1) Perceived warmth | | (2) Perceived competence | |
|---|---|---|---|---|
| | Coefficient | Standard error | Coefficient | Standard error |
| Intercept | 4.83** | .13 | 4.89** | .12 |
| Coach (Human vs. Robot) | −.39* | .16 | −.39* | .16 |
| | **(3) Hedonic value** | | **(4) Utilitarian value** | |
| | Coefficient | Standard error | Coefficient | Standard error |
| Intercept | 3.15** | .51 | −.20 | 1.04 |
| Perceived warmth | .29* | .12 | .23 | .25 |
| Perceived competence | .46** | .12 | 1.08** | .26 |
| | **(5) Intention to use** | | | |
| | Coefficient | Standard error | | |
| Intercept | −.19 | .91 | | |
| Hedonic value | .52** | .16 | | |
| Utilitarian value | .22* | .08 | | |

Notes: Sample size: 58; Breusch-Pagan-Lagrange: $\chi^2(10) = 28.306$, $p < .01$.
Number in parentheses above each dependent variable refer to the equations in Table 4
$*p < .05$; $**p < .01$

they evaluate humans superior to the robot. We explain this slight difference by looking into our qualitative data. What humans are more successful at is responding to the elderly persons' individual needs. While finding Vizzy cute and funny, some elderly participants complained that they could barely hear what the robot had to say because of their hearing problems. Unlike Vizzy, who always had the same pace and pitch of the voice, humans could adjust their voice to the needs of the hearing impaired elderly. We believe this affected both warmth and competence judgments of the elderly.

### 7.2 Hedonic and utilitarian values

We conducted the experiments in a real-life context, where we tested whether the elderly will enjoy and appreciate a new type of gamified workout, depending on their coaching partner (human vs. robot). We demonstrate that seniors' hedonic and utilitarian value perceptions of exergames are driven by the social cognition they develop of their coaches. We show that the elderly, both enjoy more and find the exergame more effective if they are instructed and motivated by a human, in comparison to a robot. The reason for this difference we find in the slightly higher levels of anxiety (expressed through the narratives) the elderly experienced while interacting with the robot. Indeed, for our elderly participants that was the first time to see and engage with an automated agent. Some shared that they experienced nervousness when the robot first approached them ("Initially, I wasn't very relaxed, but I ended up being more relaxed as we continued", Male, 86). Some seniors lacked some information to fully enjoy playing exergames ("I did not quite understand the purpose of the game, because I could not hear well what the robot was saying", Female, 87).These quotes give us insights into elderly persons' psychological states and physical (e.g., hearing) impairments which hinder them from full enjoyment while playing exergames. These are also important inputs for the technology developers and service designers on how to better design the robotic platform for improved experience of the senior population.

Our analysis further demonstrates that the perceived competence has a positive impact on both hedonic and utilitarian value perceptions. The effect of competence on utilitarian value is even stronger than that of perceived warmth. We explain the effect by taking the context of exercising into account. Since the activity seniors were evaluating involved physical exercise, they were particularly interested in the reliability and competence of the coach. Furthermore, in the case of the robotic coach, they were exposed to a new and unfamiliar agent, which further increased the need to trust in its abilities before being able to enjoy in the activity. Here again, humans performed better than the robot. We argue that the reason for this better performance is human capability to, if necessary, demonstrate the movement. Some seniors had difficulty understanding the requirements of the exergame. In such cases, the robot could only repeat the instructions, in hope that the elderly will understand what is expected of them. In addition, humans could augment their voice instructions with movement demonstration, hence getting better evaluations for their competence.

### 7.3 Contributions and implications

With our findings, we primarily contribute to the theory of social presence and further explain cognitive mechanisms activated when interacting with artificial minds [8]. We advance current knowledge on the ways SARs, through their social resemblance to humans, make people interacting with them feel like they are in a presence of social entities [62].

By showing how elderly people feel social presence when interacting with SARs and develop social perceptions about them, we inform further developments and design of social robotics and systems. We suggest that by including robots in the social network of the elderly as exercise coaches, we could improve both, their physical and psychosocial wellbeing. We however acknowledge that in contexts which require high social engagement, humans perform better than SARs. This is where social robots still need to improve the empathy and spontaneity to adjust their behavior to the heterogeneity of human needs.

Thus, we argue that SARs can be used to enhance elderly people's experience, to augment human caregivers for certain tasks. Yet, assisted living facility managers need to make a knowledgeable decision on which tasks should be automatized and which should remain in human hands. Reflecting on our coaching tasks, SARs can be used to motivate seniors to be more active, while human caregivers should make sure the elderly perform the exercises correctly and assist them if necessary.

### 7.4 Limitations and further research

While this study provides an interesting and necessary perspective on ways in which SARs can support human caregivers in motivating the elderly for physical activity, it also contains some limitations. First, each elderly care institution we collaborate with does not patron as many physically active clients as we needed for our experiments. Therefore, we had to conduct this study at several locations. Second, involved care institutions, although in the same region of the country, have not only heterogeneous elderly populations, but also varying conditions for conducting field experiments. Hence, future research might consider not only expanding the sample, but also minimizing the differences between elderly populations and care institutions.

Third, the short-term nature of the study (i.e., only one trial) introduces the novelty factor, both with regard to the robot and exergames. One way to rule out the effect of novelty, future research could set up a longitudinal study and then measure the same constructs in different phases of the experiment. This would also enable the researchers to track not only the behavioral intent, but also the actual behavior (i.e., whether the elderly indeed play the exergames in the future). Finally, robot's speech abilities were controlled with the WoZ, which limits the spontaneity of dialogs between the elderly and the robot. Future research should allow for more flexibility - not to use the pre-set utterances, but allow for more natural social interactions (e.g., typing responses that exactly address the questions/statements raised by the elderly participants). Until, of course, the human network giving the agency to the robot can be eliminated and the robot can interact completely autonomously.

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**Compliance with Ethical Standards**

**Conflict of interest** No conflict of interest declared.

**Informed consent** All the elderly participants agreed to take part in this study and signed the informed consent.

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