Companionship Is Not a Function: The Effect of a Novel Robotic Object on Healthy Older Adults' Feelings of "Being-Seen"

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ABSTRACT
One of the challenges faced by healthy older adults is experiencing feelings of not "being-seen". Companion robots, commonly designed with zoomorphic or humanoid appearance show success among clinical older adults, but healthy older adults find them degrading. We present the design and implementation of a novel non-humanoid robot. The robot's primary function is a cognitive word game. Social interaction is conveyed as a secondary function, using non-verbal gestures, inspired by dancers' movement. In a lab study, 39 healthy older adults interacted with the prototype in 3 conditions: Companion-Function; Game-Function; and No-Function. Results show the non-verbal gestures were associated with feelings of "being-seen", and willingness to accept the robot into their home was influenced by its function, with game significantly higher than companion. We conclude that robot designers should further explore the potential of non-humanoid robots as a new class of companion robots, with a primary function that is not companionship.

Author Keywords
older adults; successful aging; tangible interaction; loneliness; acceptance; social-interaction; non-humanoid robot.

CCS Concepts
•General and reference → Design; •Human-centered computing → Human computer interaction (HCI);

INTRODUCTION
Being an older adult is becoming a significant stage of life that lasts several decades. Technology should play a key role in achieving successful aging. This stage of life comes with both negative and positive changes. Aging commonly involves

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Figure 1. A novel robotic object for healthy older adults, designed as a cognitive game, aimed to provide feelings of "being-seen" through non-verbal gestures.

cognitive, sensory, and physical decline [1, 42]. On the other hand, aging is also associated with higher self-acceptance and positive affect [40, 56]. A growing population of older adults maintain relatively high levels of physical and cognitive functioning [73, 74] and have the potential to experience feelings of happiness and satisfaction [36]. For this reason, successful aging has become a worldwide goal [86]. Older adults face several challenges that may limit their opportunities to experience successful aging [73, 74]. One common emotional challenge reported by many healthy older adults, living with or without a partner, is the subjective feeling of loneliness [24, 33]. While loneliness can be experienced in different intensities [35], healthy older adults are commonly concerned by feeling invisible, set aside, and unacknowledged by others [16, 28, 31, 33]. These feelings are commonly described as being unseeable [85]. This involuntary state of "not being-seen" can take on various forms, including experiencing emptiness and feeling unwanted [19, 33, 63]. These feelings are considered highly negative, [33] and as a result, the feeling of "not being-seen" is one of the main challenges when striving for successful aging [62].

When older adults experience interactions in which they are "being-seen", they feel cared for, and report less feelings of loneliness, regardless of the number of actual social relationships in their life [19, 64, 72, 88]. In other words, the feeling of "being-seen" can be enhanced even without changing the number of social interactions. In recent years, companion robots have been suggested as a potential solution for increasing social experiences amongst older adults [53, 54, 75]. These robots are designed to evoke feelings of warmth and safety that are believed to reduce feelings of loneliness [47, 57]. Existing companion robots commonly take on a humanoid or zoomorphic appearance (e.g. seal, cat, dog) and are typically presented as a friend who will provide companionship [41]. Such companion robots were shown to be successful in reducing feelings of loneliness with clinical populations, including older adults who suffer from mild cognitive impairment or dementia [43, 65, 83]. However, healthy older adults who have the potential to experience successful aging, reject the idea of interacting with companion robots [78].

Healthy older adults have different needs and preferences than those of clinical populations. Prior studies that mapped these preferences reveal that the robots' *function* and *appearance* are key factors contributing to the robot's acceptance [37, 84]. Healthy older adults favor robots with a *function* that is relevant for their daily routine, as robots that assist in specific tasks [20], and view the function as the robot's most important aspect [30, 78]. However, not all functions are accepted by healthy older adults. They reject functions that make them feel degraded, specifically companion robots that "pretend to be a friend" [22, 29, 41]. Interviews with older adults indicated that they do not reject social interaction when it is presented as a secondary function, following a primary function that is perceived as valid and appropriate for healthy older adults [22]. Older adults were also concerned with the robot's *appearance*, especially when it framed aging in a negative or stereotypical manner [48], or when it made them feel "different" [69]. In some cases, older adults expressed a strong objection to humanoid or zoomorphic designs (i.e. human-like or animal-like), describing the design as not authentic and artificial [22]. This negative attitude was associated with their view that the robot's design should reflect its function [89].

A recent study performed qualitative interviews, mapping healthy older adults' attitudes and preferences towards robots, and presented guidelines for designing robotic companions for healthy older adults [22]:

1. Valid primary function: robots should be designed with a primary function that is significant for healthy older adults' well-being. This function cannot be companionship.
2. Authentic appearance: the robot's appearance should reflect the object's function, and should not pretend to be something it is not.
3. Social cues as a secondary function: social interaction cannot be implemented as the primary function. It can be integrated as a secondary function.

In this context, non-humanoid robots can be relevant candidates for increasing the feeling of "being-seen". Their appearance is authentic (unlike humanoid robots), they can be designed to perform a valid function, and they can generate physical gestures as non-verbal social communication. The main challenge with non-humanoid robots is their limited communication modalities and limited movement capabilities, making it infeasible to design human-like gestures [13, 39, 50]. However, previous studies indicate that non-humanoid non-verbal gestures can be consistently interpreted as social cues [4, 11, 38], an interpretation that in some cases may even be automatic [25]. Yet, prior work has not demonstrated that it is possible to design non-humanoid robotic gestures that can be associated with feelings of "being-seen".

We present the design process and technical implementation of a novel non-humanoid robotic object. The robot was designed with two goals in mind: (1) to increase feelings of "being-seen" among healthy older adults, using non-verbal gestures (see Figure 1); and (2) to overcome healthy older adult's rejection of companion robots, by implementing a primary function which is a cognitive game and not companionship. We additionally report on a lab study with 39 healthy older adults who interacted with the robotic object in three conditions, with a different function in each condition. The goals of the lab study were to validate whether: (1) minimal gestures of a non-humanoid robotic object are associated with the feeling of "being-seen"; (2) the robot's function influences participants' willingness to accept such a robot into their home. Our lab study is a first step towards an in-situ study at older adults' homes.

RELATED WORK

Prior work includes tangible and robotic technologies designed for older adults in the context of loneliness, as well as non-humanoid robots designed for social interaction.

Tangibles for human-human social interaction

Increasing opportunities for human-human social interactions was typically addressed by tangible user interfaces (TUI) designed for remote digital communication between older adults and younger family members or friends [6, 66]. Using digital communication enables older adults to expand their social networks and the quantity of social interactions [5, 7, 21]. Example projects include a tangible window [5], a physical book [7], and a tangible photo frame [67]. The interface and system operation are designed specifically for older adults [67], and some employ an asymmetric design for older adults and younger family members, increasing the different age groups' engagement [7, 67, 81, 90]. Examples of such technologies include Blossom, a prototype consisting of two vases with flowers and family photos, allowing the transmission of voice messages. The shape of the flowers indicates that a message was sent [90]; A Messaging Kettle designed to enhance and increase distance communication by the addition of a messaging function to an object used on a daily basis by all family members [80]; and the Common Petanque Bag designed to send a notice to older adults in the community, indicating that a game has begun when sensing that balls are being taken out of the bag [61]. While these technologies were designed in collaboration with older adults, their influence on social interaction was not consistently evaluated, nor was their influence on feeling of loneliness or feelings related to "being-seen".

Companion robots

Companion robots are designed to provide companionship in an effort to reduce the negative influences of loneliness [70]. Most companion robots are designed to resemble pets or animal-like toys. Leading examples are Paro, a soft seal-like robot; Huggable, a teddy-bear like robot; and Aibo, a dog-like robot [17, 45, 82]. Studies with clinical populations (i.e. older adults who suffer from dementia, mild cognitive impairment, and depression) showed positive influences with animal-like companion robots. The interaction with the robot led to consistent success in reducing feelings of loneliness, improving mood, reducing stress, increasing well-being, and reducing depression symptoms [3, 43, 87]. Similar effects were found when using companion robots with older adults in nursing homes [8] and hospitals [71]. The robots improved residents' and patients' physical state (reduced blood pressure, reduced stress hormones, heartbeat regulated) and decreased feelings of loneliness [12, 17, 49, 71, 76]. However, these positive effects of companion robots were not shown with the healthy older adults population. On the contrary, several studies indicated that healthy older adults reject companion robots and do not consider companionship as a valid function for a robot they are expected to use [20, 29, 78]. Healthy older adults perceive companion robots as unacceptable for interaction and define them as "unproductive entities" [26] and in some cases also reject their humanoid or zoomorphic form [22].

Non-humanoid robots designed for social interaction

Robotic objects do not take a humanoid or zoomorphic form. These robots cannot provide social interaction by mimicking human behavior (e.g. facial expressions or waving a hand). However, previous studies have already indicated that it is possible to evoke a social experience using non-verbal gestures. An automatic door designed to offer different levels of approachability was perceived as welcoming and inviting when it opened at a specific speed and trajectory [44]; another example is a robotic footstool, named 'The Mechanical Ottoman' was perceived as indicating willingness for interaction [77]. Abstract robotic objects were also perceived in social context, even when performing minimal movements [4]. This social association could not be avoided, indicating that the social interpretation of the gestures is an automatic cognitive process [25]. Participants also associate emotions to gestures of robotic objects. A robot designed as a stick [34] and a robotic speaker [15] performed gestures that were interpreted as communicating the emotional state of the object (happiness, sadness, fear, and interest). Collectively, these studies show that movement of robotic objects can be interpreted as a social cue and even convey emotion.

One strategy to address older adults' rejection of human-like and animal-like companion robots is to design a non-humanoid robot. In the design & implementation section we present design sketches, gesture elicitation study with dancers, animation studies, physical implementation using custom mechanisms, fine motor-control using a custom robotics prototyping platform, and multi-material fabrication.

DESIGN AND IMPLEMENTATION

We present the design process and technical implementation of a robotic object for healthy older adults (see Figure 1). The robot was designed with two goals in mind: increasing the feeling of "being-seen" through non-verbal gestures, and increasing willingness to accept among healthy older adults, using a primary function that is not companionship. The chosen function was a cognitive game, purposely designed as a very simple game, to prevent it from indirectly influencing willingness to accept. We followed the three design guidelines recommended by prior literature, and continuously tested our design with relevant users throughout the process. The design team included a psychologist with expertise in older adults, an industrial designer with expertise in mechanical movement, an animator, dancers, an HRI researcher, a TUI researcher, robotic engineers, and user study experts. Below we present our design process arranged according to the three guidelines.

Companionship is not a function

The first design guideline was to choose a primary function that is not companionship, and is perceived as valid by healthy older adults. To determine what is valid for this unique population, we conducted interviews with 10 healthy older adults between the ages of 69 and 85 ($M = 72.21$, $SD = 3.47$). Among other topics, we discussed their daily routine and preferred leisure activities. The interviews were analyzed using the Thematic Coding method [14]. Common themes were identified, and preferred leisure activities were selected. Top leisure activities were: watching the news, playing card games (e.g. bridge), and playing word games (e.g. crosswords, scrabble, etc.). Coupling these insights with research mapping the top concerns among healthy older adults [51, 58], we decided to focus on a word game aimed to preserve cognitive abilities. We defined an anagram-style word game using 4-letters, and defined a motivating target goal: to form as many 2, 3, or 4-letter words as possible during a fixed time frame. We tested the concept of the anagram game by comparing it to closely-related games. 10 healthy older adults played three different pen & paper games ($M \sim 80.17$, $SD \sim 5.88$): the anagram game, a trivia game, and a word search game. Participants favored the anagram game, with positive comments including

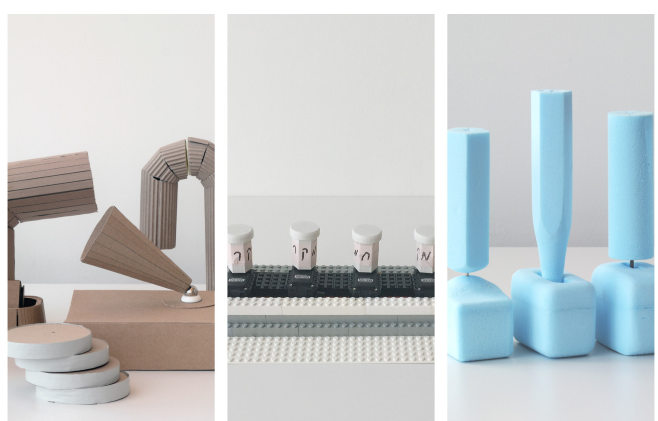

Figure 2. Low-fidelity prototypes made of cardboard, Lego and blue foam used during the design process to validate the form factor with our target users.

"highly enjoyable", "mentally stimulating", and "for people like me". Following the definition of the primary function as a 4-letter anagram game to help preserve cognitive abilities, we progressed to design the object's form, mechanics, and appearance.

Authentic appearance

The second guideline was to design the robot's appearance in a way that reflects the device's function in an authentic way, and does not resemble a human or animal in any way, as these representations reflect a function of companionship. It was critical to design a form that will be appropriate for the target population, will not be perceived as childish, and will be appropriate in size for an older adult's home. We chose to focus on an abstract form, inspired by geometric forms, to prevent associations with human-like or animal-like forms. We wanted the design to convey the primary function, the simple cognitive game, and hoped to leverage natural affordances for two hand manipulation. The chosen game was a 4-letter anagram game, which led our design to the following form: a base with four pillars, each pillar representing a small set of letters, placed close to one another to be perceived as a whole word. From a tangible interaction perspective, the 4 pillars afford tangible manipulation of the game letters by grabbing and rotating each of the pillars to form a 2, 3, or 4-letter word.

A 12-week long design process started with sketches and progressed to low-fidelity prototypes (see Figure 2) using cardboard. After a few informal user testing sessions, the form of a base with 4 pentagon-shaped pillars was set. A basic Lego bricks functional model was built, and the form finding process continued with a series of low-fidelity 3D printed shapes which were tested with a representative user. Based on the input we received, we constructed a medium-fidelity prototype using 3D-printed parts and motors mounted inside a base. We tested the prototype with 5 users to assess the metaphor, affordances, and interaction. The analysis involved the identification of repeating patterns in participant's comments. Specifically, we observed if the older adults were able to identify the letters, grab and rotate the pillars, and perceive the 4 letters as one word. Based on these observations we created foam prototypes to refine the form (see Figure 2), and adjusted some of the design factors (height of the pillars, diameter of the pentagon pillars, and contrast between letters and background). We also performed various technical tests with different motor setups (see Figure 5), observing the movement of each individual pillar and especially the movement of the four pillars together. To finalize the prototype, we improved the robustness by restructuring the base to four smaller single-pillar modules with a more stable inner mechanism printed in SLA (see Figure 5). We also simplified the letter placement mechanism using magnets that can be pulled-off and put-on easily.

Social Cues as a Secondary Function

The third guideline was to leverage non-verbal communication cues to form a social experience. Non-verbal communication cues, and specifically "Gaze" and "Lean" gestures play an instrumental role in human-human interaction [52]. Such non-verbal gestures can increase feelings of friendliness and interest in an interaction [46], as well as empathy and rapport [2]. In our prototype, each of the four pillars was controlled by two motors, making it possible to perform a "Lean" and "Gaze" gestures. The "Lean" gesture resembled a "Bow" movement of the pillar leaning towards or away from the user. The "Gaze" movement is a rotation along the pillar's own axis. Since there are four independent pillars, each controlled by separate motors, all of the pillars can move independently, forming a new experience of "collective movement" that can be either uniform or different in pace or length of movement. With this non-human-like movement capability, we started the gesture design process, in an effort to design gestures that evoke a social experience of "being-seen".

Gesture Design

The gesture design process had three steps: Mechanism-focused animation tests; Gesture elicitation with dancers; and Mapping of the human movement into the robot morphology.

Step 1: Mechanism-focused animation tests

The animator created various movements using a 3D model of the robotic object that includes the exact morphology and mechanism limitations. She explored animations that in her view represent behaviors such as welcoming or following, and emotions such as excited or bored. This animation stage enabled us to explore movement richness, from minimal and

Figure 3. Gesture elicitation study with dancers, performing social gestures representing situations such as "welcoming" and "following".

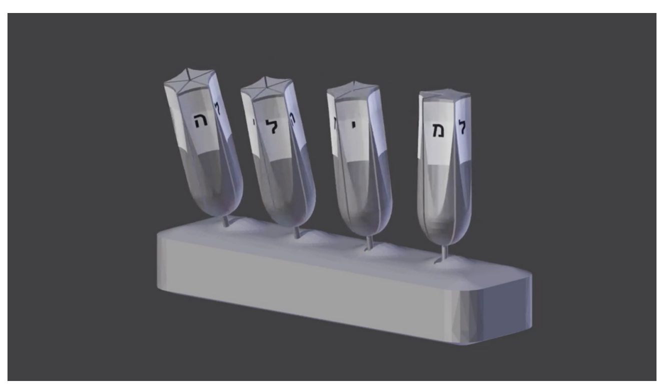

Figure 4. Dancers' movement simulated in an animation software, before mapping into the limited robot morphology.

simple movement to a more expressive and complex movement.

Previous work with robotic objects showed it is possible to create a social experience with minimal movement using 2 Degrees of Freedom (DoF) [4]. Striving for simplicity and minimalism, we were intrigued to explore if an even more limited mechanism can generate movement that will be perceived as an expressive social experience. Therefore, we applied a 1.5 DoF mechanism to each pillar, enabling a subtle and fluent movement, but a very restricted one, with a mechanism enabling only straight lean-forward or lean-backward movement, with no angle of movement to the bottom-left or bottom-right, only straight bottom-middle movement. When testing the animations, we found that the movement of a single pillar with the 1.5 DoF mechanism is not expressive, and seems mechanical and non-inspiring. However, when testing animations of the 4 pillars moving together, as a collective movement, the result was very expressive and inspiring. The most expressive gestures involved the four pillars moving in a phase shift. Our conclusion from the animation tests was that 1.5 DoF mechanism is appropriate, and the 4 pillars should create a "rhythm" of movement.

Step 2: Gesture elicitation study with professional dancers

To better understand how to convey expressive movement with such a limited form and mechanism, we collaborated with four professional dancers and conducted a gesture elicitation study. The dancers were invited to stand near each other in a row (similar to the robotic object's four pillars), to minimize feet movement and hand movement, and to use their body language to communicate specific behaviors we defined for them (see Figure 3). One researcher guided the session and another performed various daily actions in front of the dancers: walking into a room, walking by the dancers and looking towards the dancers. The dancers reacted with their improvised "feedback": "welcoming" him, "following" him, and "inviting" him.

Step 3: Mapping of movement to the constraint morphology

The dancer's movement videos were viewed by the research team and a small set of movements was selected based on the key gestures needed for the evaluation study: Welcome, Follow, Bow, and Turn. The animator analyzed the dancers' videos with special focus on both individual and collective movement, looking for common movement aspects. Then, she mapped each of the selected gestures to the 1.5 DoF morphology using an animation software (see Figure 4), and the gestures were converted to the robot movement platform.

Technical implementation: the robotic object system includes hardware, software, mechanism, and casing. A Raspberry Pi shield and Dynamixel smart servo motors with onboard computation enable motor control and position reading. The hardware-software control is done using a custom robotics prototyping platform called Butter [18, 55]. It includes a Raspberry Pi shield, software and firmware. Robotic gestures were designed using the Blender 3D animation toolset. A WoZ interface for remote operation was developed to control gesture triggering, and disable torque in the motors to enable physical manipulation by participants during the evaluation study.

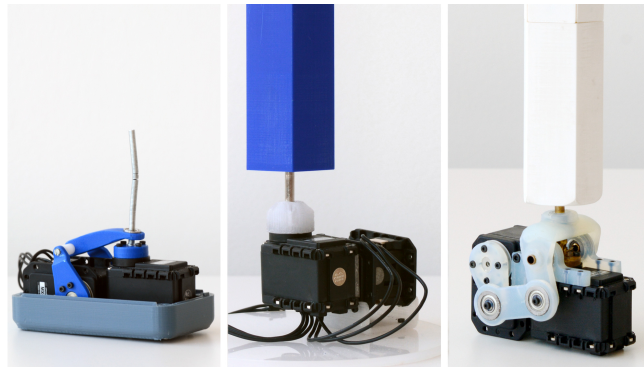

Figure 5. Exploring different motor setups, using 3D printed shapes, in an effort to find the ideal mechanism for the desired movement.

EVALUATION STUDY

We report on a lab study conducted using the Wizard-of-Oz methodology. The goals of the lab study were to validate the robot's design by studying: 1) whether minimal gestures of a non-humanoid robotic object are associated with the feeling of "being-seen", and whether this effect is compromised by a primary function that is not associated with companionship; (2) whether the robot's function influences participants' willingness to accept such a robot into their home. Our lab-based validation is a first step towards an in-situ study at older adults' homes.

Method

Participants

39 cognitively-intact older adults participated in this study (M = 75.00, SD = 6.59; 18 male, 21 female). Participants were recruited from two sources, a weekend campus lectures group and a data-base of older adults who have previously participated in academic studies on campus. We verified that participants live independently at home (with or without a partner, balanced across conditions). They received reimbursement for their transportation to the university and a "coffee and pastry" gift card to a local coffee chain. The study was approved by the ethics committee of the research institute.

Participants' general health and cognitive state were assessed by performing an informal conversation at the beginning of study. A formal assessment was not conducted to avoid stereotype threat [9], that may affect participants' reactions to the

Figure 6. The prototypes used in each of the three conditions: Cognitive-Game, Companion-Function, and No-Function.

robot. The conversation included questions derived from the mini-mental and Montreal Cognitive Assessment [27, 60]. All participants were deemed cognitively capable.

Experimental design

A between-participants experimental design was used in order to evaluate the influence of the robot's primary function on participants' perception and acceptance of the robotic object. Participants were randomly assigned to one of the 3 conditions: (1) Companion-Function, (2) Game-Function, or (3) No-Function. The same robotic object was used in all conditions excluding the difference in the tiles placed on each pillar. Letter tiles were used in the Game-Function condition, plain gray and blue tiles were used in the No-Function conditions and colorful tiles were used in the Companion-Function condition (see Figure 6). The robot's function was introduced to participants before the interaction with the robot. In the Game-Function condition, participants were told that "soon we will enter a room, on the table there will be a robotic object designed to be a game that stimulates thinking". The game was described as an anagram word game with a goal to create as many words as possible from a set of four letters. In the Companion-Function condition, participants were told that "soon we will enter a room, on the table there will be a robotic object designed to be a type of companion for people at their own home". In the No-Function condition, participants were told that "soon we will enter a room, on the table there will be a robotic object". No further framing or explanation was given. We note that while there was no framing for the robot's function, the interaction with the robot involved non-verbal gestures designed to create a social experience. The robotic object performed the exact same gestures in all three conditions. Participants were randomly assigned to conditions based on their order of arrival and gender matching.

Measurements

To gain an understanding of participants' experience in the interaction and willingness to accept the robot, we conducted a qualitative semi-structured interview and used a quantitative acceptance questionnaire.

Semi-structured interviews: interviews were conducted during and after the interaction with the robot. The semi-structured interview included questions about the robot's activity, such as: "did you notice the robot's movement?", "please describe your experience when the robotic object moved" and "what do you think about the robot's movement?". The specific choice of a semi-structured interview allowed for flexibility during data collection while remaining grounded in a particular framework [10, 32]. In addition, it allowed to understand participants' attitudes towards the robot while also providing a more general and rich description of the experience [79].

Figure 7. Participant interacting with the Game-Function prototype during the interview phase of the evaluation study.

Acceptance questionnaire: the acceptance questionnaire included 8 questions adapted from the Robot Opinions Questionnaire [78] (Cronbach's α: 0.95). Selected questions include: "I believe I will use the robotic object if I will take it home", "I believe that I will enjoy using the robotic object", "I find the robotic object boring".

Procedure

The study was conducted in a dedicated experiment room with controlled lighting, two chairs, a table and a camera placed near the table. The robotic object was placed on the table (see Figure 9). The robot's gestures were triggered using the Wizard-of-Oz (WoZ) technique, a common method in HRI studies [59, 68], to maintain experimental control over the robot's behavior. The "wizard", a research assistant, watched the live video stream from a different room and triggered the gestures based on a strict protocol. Participants' were unaware of the WoZ control and perceived the robotic object's responses as autonomous. Participants were welcomed into the lab by another research assistant, completed an informed consent form, and engaged in a short conversation with the RA who leveraged the informal discussion to assess the older adult's general cognitive state, and to form a communicative relaxed atmosphere.

The robotic object was initially presented using a picture, and then the specific function was described, based on the condition, as mentioned above in "experimental design". The participants were then led into the experiment room. As the participant entered the room, the robotic object performed a "Welcome" gesture while the older adult was invited to sit on a chair in front of the robot. The researcher sat beside him/her. The participant was then invited to touch and explore the robot. After this initial exploration the participant performed a short task, aimed to enhance the robot's function. In the *Game-Function condition* participants were asked to create words using the letters on the four pillars, by rotating each of the pillars with their hands. They were told it is possible to construct up to thirty words with the specific set of four letters presented on the robotic object, and that the average number of words created by other participants is ten. This was done to make sure the game is not perceived as too easy. After participants found a few words by rotating the pillars with their hands, the researcher asked them to remove a specific letter from each pillar and switch it with another letter given to them, to verify a certain level of physical interaction with the robot that could be replicated in all conditions. In the *Companion-Function condition* there were no letters on the tiles (i.e. blank gray tiles), and participants were asked to customize the color arrangement of the tiles. They were given additional colored blank tiles (red, yellow and blue) and

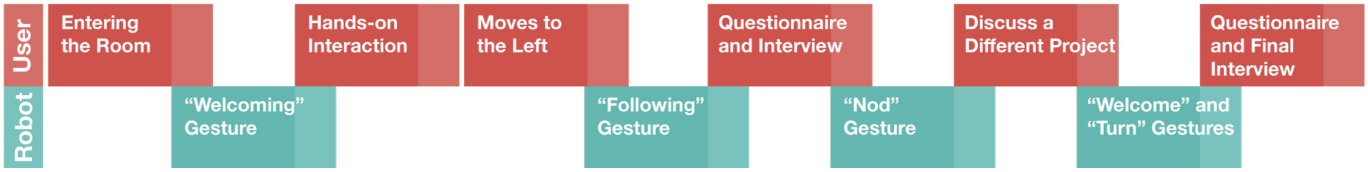

Figure 8. Evaluation study stages: top line represents the user's action, bottom line represents the robot's feedback to the user's action.

were asked to create color combination choices that were personally meaningful to them. This task required rotating each of the pillars and exchanging tiles, making the interaction as similar as possible to the Game-Function condition. In the *No-Function condition* participants were asked to replace the gray tiles on the robot with blue tiles and to report if they feel it is a convenient mechanism for tile replacement. Participants in this condition could not choose the tiles' color (see table 1). After the participant performed the task he/she was asked to move slightly to the left in order to fill out a short demographic questionnaire using a tablet. As the participant moved to the left, the robotic object performed a "Follow" gesture. The short demographic questionnaire was followed by a short semi-structured interview and the participant was asked about the robotic object's movement (see Figure 7).

The researcher then explained that the first part of the study that includes the interaction with the robot is over. At this point the robotic object performed a "Bowing" gesture and the participant was asked to leave the experiment room in order to provide his/her opinion on another project developed in the lab. Outside the room, the participant commented on an educational device designed for children that was placed outside the experiment room. We created this procedure to change the topic before returning to experiment room to experience additional gestures. After a short conversation, the participant was asked to re-enter the experiment room and the robotic object performed a "Welcome" gesture again. As the participant took a seat the robotic object performed a "Turn" gesture to "Gaze" at the participant. A short semi-structured interview was conducted and the participant completed the acceptance questionnaire (see Figure 8). The experiment ended with a debriefing, in which the mild deceit involved in the experiment was discussed and all older adults stated that they understood why it was required.

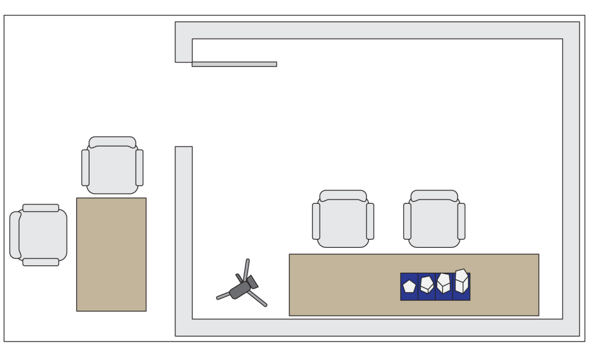

Figure 9. Experiment room setup and the welcoming area outside the room. Robotic object placed on the table and operated via WoZ.

Analysis

The qualitative data was analyzed using the Thematic Coding method [14] that involved four stages. First, participants' responses were transcribed and read several times to develop a general understanding of the data before the coding process began. Second, two individual raters reviewed all transcripts and identified initial themes. The themes were presented to a third researcher and discussed in-depth, inconsistencies were discussed until resolved and a list of mutually-agreed themes was defined. Third, the two raters analyzed a selection of the data independently, inter-rater reliability was verified (Kappa = 88%). Fourth, following inter-rater reliability validation, the raters analyzed the rest of the data until completion.

The quantitative data gathered from the acceptance questionnaire was analyzed using a one-way ANOVA comparing the conditions (after we verified lack of interaction between the function conditions and whether participants live with or without a partner).

Findings

The qualitative analysis revealed two main themes addressing the study goals. (1) Association of the robot's gestures with feelings related to "being-seen". This theme was similar across conditions; (2) Participants' willingness to accept the robot, based on its function. This theme was different across conditions. We note that the word "it" is not a common way to relate to objects in participants' native language, therefore in participants' quotes the words "he" or "the robot" were documented. Following the qualitative findings we report the quantitative analysis of the acceptance questionnaire.

Theme 1: Association of the robot's gestures with feelings related to "being-seen"

Almost all participants (32/39), in all conditions, described the robot's gestures using terms such as "paying attention", "attending", "caring", "listening", and "seeing", collectively associated with feelings of "being-seen". This interpretation of the robot's gestures was evident despite the robot's non-humanoid appearance and its inability to mimic human behavior directly. In all conditions, participants discussed interpretations related to the feeling of "being-seen", both when it was consistent with the robot's primary function (12/13 Companion-Function), and

	Game-Function	Companion-Function	No-Function
Tiles	4 Letters 1 White	4 Gray 1 White	4 Gray 1 White
Task	Find words and change letter tile	Change the colors of the tiles to users preference	Change all the gray tiles to blue tiles

Table 1. The evaluation study conditions, the tile changes that represent the various functions, and the tasks performed by users.

when it was not relevant to the robot's function (10/13 Game-Function; 10/13 No-Function), indicating that participants in all conditions associated the non-verbal gestures with a social context. Three sub-themes were identified within Theme 1: Interpretations related to the feeling of "being-seen"; Interpretations related to alleviating feelings of loneliness; and mechanical aspects of the robot's gestures.

Interpretations related to the feeling of "being-seen": responses in this sub-theme describe the robot's behavior as "seeing" them, "attending" to them, "listening" to them, and "caring": *"there is someone there, seeing me, listening to me"* (p.42; Companion-Function), *"it's as if someone is paying attention to you, caring"* (p.7; Game-Function). They associated the robot's behavior with positive emotions *"It's nice that someone recognizes you, it feels good that he is paying attention to me"* (p.24; No-Function). Some participants provided interpretations related to closeness *"It's as if there is a connection between us"* (p.25; Game-Function), *"this gesture indicates closeness and acceptance"* (p.2; Companion-Function). Participants attributed emotions to the robot indicating its willingness to interact with them *"I felt that he was happy to see me, he wanted me to be with him"* (p.42; Companion-Function). Some participants suggested the possibility of using the robotic object specifically for increasing feelings related to "being-seen" in their home. They stated that they would place the robot in the their home's entrance, kitchen, or living room *"I would place it in a central location, I live alone so it would be nice to have a daily experience of the robot's attention when I pass by him"* (p13; No-Function). Other participants suggested that the robotic objects can be used as another entity at their empty home *"it's like having another being in the house, instead of coming back to an empty home"* (p.5; No-Function). In some cases they associated the robot's behavior with the behavior of a pet *"It's like a dog, welcoming you and happy to see that you came home"* (p.10; Game-Function), *"It's similar to having a dog that's jumping and moving to show that he is happy to see you and following you, attending you as you come home"* (p.9; Companion-Function).

Interpretations related to alleviating feelings of loneliness: responses in this sub-theme, coming from 14/39 participants, describe the robot's potential to relieve loneliness, emptiness, and sadness. These associations were independent of the robot's function (4/13 Game-Function; 5/13 Companion-Function; 5/13 No-Function). Participants stated that the robotic object has the potential to alleviate loneliness *"I live alone now, and something like this can appease my loneliness, if for example the robot will welcome me every morning when I come out of the kitchen with my coffee"* (p.26; Companion-Function), some participants explained that the robot's potential to relieve loneliness is associated with it's empathic behavior *"he is empathic, listening and showing a lot of interest, I imagine he can be very meaningful for people who experience great loneliness"* (p.2; Companion-Function). Participants suggested that a connection with the robot may support the feeling that there is someone to communicate with *"you are connected with him, there is a feeling that there's someone you can talk to"* (p.29; Game-Function). Others offered that since the robot *"makes you feel wanted and is asking for your attention"*, it has the potential to improve well-being of older adults who are *"sad and lonely"* (p.14; Game-Function).

Mechanical aspects of the robot's gestures: participants responses also revealed an interesting duality, associating the robotic object with feelings related to "being-seen", together with mechanical aspects of the gestures. All participants (39/39) described the mechanical aspects of the robot's movements *"[The robot] turned back and forth, right and left."* (p.34; Game-Function) and some mentioned the robotic object was programmed in advance to perform the movements *"I think that's how you programmed it so when someone comes in it will perform the movement to draw attention"* (p.40; Companion-Function). Participants were intrigued by the robot's mechanism and tried to understand how it works *"It's magnets I see, but I want to understand where the sensor is, maybe its internal and there's an induction coil..."* (p.37; Companion-Function). Discussing the mechanical aspects did not compromise or limit participants' feelings related to "being-seen". Participants were comfortable blending both technical and social interpretations in the same sentence *"He probably has sensors, so he can move and make me feel that he's paying attention to me"* (p.23; Companion-Function) *"It's probably a magnet, when I came in he bowed and respected me"* (p.42; Companion-Function).

Overall, the qualitative analysis shows that it is possible to design non-verbal gestures for a robotic object, that will be associated with the feeling of "being-seen". In addition, these social interpretations were not compromised by a primary function that isn't companionship. These findings, while constrained by the limitation of the lab study, provide encouraging indication for the potential of using non-humanoid robots for increasing the feeling of being seen.

Theme 2: Willingness to accept the robot based on its function

Participants in all conditions (13/13 Game-Function; 13/13 Companion-Function; 11/13 No-Function) mentioned the robot's function as a key factor influencing their willingness to accept the robot. In the Game-Function and Companion-Function conditions, participants' responses were directly associated with the robot's pre-defined function. In the No-Function condition, 7/13 participants intuitively came up with their own ideas for possible functions, without being prompted to do so, which in turn influenced their willingness to accept the robot. We present participants' responses according to the experimental conditions: Game-Function; Companion-Function; and No-Function.

Game-Function: most participants in the Game-Function condition perceived the game as an acceptable function for a robot. 8/13 participants liked the game and stated that it is "engaging", "a thinking challenge", "nice & fun", and "interesting". They compared it to crossword puzzles and rummikub and believed they would enjoy playing it *"I like it, it reminds me of crossword puzzles"* (p.21; Game-Function). 4/13 participants did not feel that the game was challenging enough for them and stated that it is more relevant for children who are learning to read *"it can be good for my grandchildren, they can learn how to spell words"* (p.22; Game-Function). 1/13 participant, rejected the game as a sufficient function for a robot and suggested to add more essential functions *"If it could keep track of people entering the room so that you'll have an indication if a thief breaks in"* (p.25; Game-Function). An identical pattern was found for the willingness to accept the robot. The same 8/13 participants stated that they would like to have a robotic object like this at their home. They described various reasons including it's game functionality *"it's a new cognitive game, I love playing with new games"* (p.20; Game-Function), *"it is good for times when you are bored"* (p.19; Game-Function). Participants who rejected the robot also used its function as a justification for the rejection *"I do not find the game interesting, I wouldn't want it even as a gift"* (p.1; Game-Function).

Companion-Function: all but one participant in this condition rejected the robotic object (12/13). 5/13 rejected it completely, 7/13 stated that it is appropriate for someone else but not for them. Only one participant was willing to take the robot home, but stated that he will change it and add new features. Participants who rejected the robot clearly stated they do not accept companionship as a valid function *"It is not practical and not efficient, it will just stand there getting covered with dust"* (p.37; Companion-Function) and strongly rejected it *"It has no other value beyond social interaction, therefore it has no place in my home or in my life"* (p.15; Companion-Function). In many cases they made an explicit effort to explain that they find the robot meaningless, useless, and that it will not contribute to their lives. Participants who believed the robot is for someone else suggested older and lonelier people as potential users that will benefit from using the robot *"It can be good for people that feel invisible, it will respond to them every time they are near it. I am not there yet, I don't need it"* (p.28; Companion-Function). They stated that the robot should be used with specific populations as those living in a home-care program *"This can be good for lonely older adults living in a nursing home, greeting them when they enter their private space after spending time at a public space"* (p.9; Companion-Function).

No-Function: participants in the No-Function condition were either preoccupied trying to understand the missing robot's function (6/13), or intuitively attributed to it a new function that they came up with (7/13). Participants in the first category asked the researcher about the robot's function *"The question is if you'll tell me what it's for"* (p.27; No-Function) and explicitly stated that they do not understand the robot's purpose *"I do not understand what it is good for, what's its purpose?"* (p.12; No-Function). Participants who attributed a new function to the robot, came up with various functions that are meaningful to their own lives: a meditative object, a calming object, an object for supporting concentration, or a decorative object. Two participants attributed it with a social companion function *"I feel like they're my friends, they want to talk to me"* (p.38; No-Function). Participants' own interpretation of the robot's function directly influenced their willingness to accept the robot. The participants that attributed a meaningful function to the robot were also more willing to accept the robot *"I would put it in my living room and use it for meditation, when I have all sorts of thoughts I'll sit and play with it"* (p.27; No-Function). On the other hand, the two participants that associated it with companionship, rejected the robot *"It doesn't do anything practical. I do not want anything like this in my house"* (p.32; No-Function). Similar to participants in the Companion-Function condition they suggested that the robot is appropriate for someone else but not for them *"It's for lonely people, I would put it in a hospital, people there are lonely and it would give them the feeling they can connect with someone... I wouldn't want it"* (p.39; No-Function). The six participants who did not understand the robot's function, either rejected the robot *"I do not want this in my home"* (p.16; No-Function) or refused to express their attitudes regarding its acceptance *"First I need to understand what it is good for, I do not understand its purpose"* (p.31; No-Function).

Overall, the qualitative analysis shows that participants' willingness to accept the robot was highly associated with the robot's function.

Acceptance questionnaire: quantitative findings

The quantitative analysis of the acceptance questionnaire revealed a significant effect of the robot's function on acceptance levels. Results from the No-Function condition could not be included in the acceptance analysis, as the new functions participants associated with the robot prevented the comparison of this condition to the single-function conditions (i.e. Companion-Function and Game-Function). We therefore compared the acceptance ratings of participants in the Companion-Function and Game-Function conditions. The analysis show significantly higher acceptance ratings in the Game-Function condition ($F(1,24)=5.58$, $p=0.02$) (see Figure 10).

DISCUSSION

One of the challenges faced by healthy and active older adults is experiencing feelings of "not being-seen": invisible, set aside, and unacknowledged. Companion robots, commonly designed with zoomorphic or humanoid appearance (e.g. Paro, iCat, and Care-O-bot) show success among clinical older adults [43, 65, 83]. However, these robots are commonly rejected by healthy and active older adults who find them degrading, artificial, and pretending to be a "friend" while they are not [69]. Non-humanoid robots were proposed as a possible solution, yet their limited communication abilities may present a barrier.

We presented the design and technical implementation of a novel non-humanoid robot, designed to increase feelings of "being-seen" among healthy older adults, using non-verbal gestures. The findings from the study suggest that non-verbal gestures performed by a non-humanoid robot can be successfully perceived by healthy older adults as a social interaction, associated with feelings related to "being-seen". This social experience was evident despite the robot's inability to directly mimic human behavior. Participants described the robotic object's gestures as "seeing", "understanding", "listening", "respecting", "comforting", "accepting", and "caring". While constrained by the limitations of a lab study, these results suggest that a robotic object has the potential to increase feelings of "being-seen". Furthermore, the robot's primary function had a significant impact on older adults' willingness to accept the robot into their home. When the robot's function was perceived as appropriate by healthy older adults (e.g. cognitive

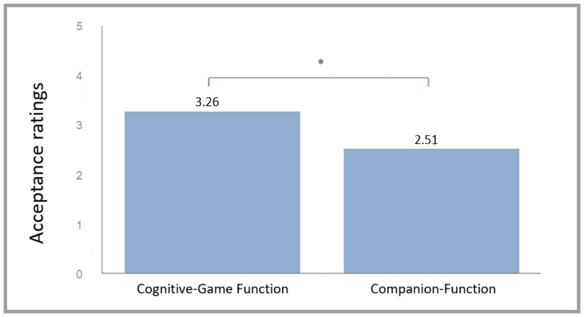

Figure 10. Acceptance ratings indicating higher acceptance in the Game-Function compared to the Companion-Function; the X axis represents the conditions and the Y axis represents the acceptance ratings average.

game), their willingness to accept the robot increased. However, when the robot's function was perceived by healthy older adults as inappropriate (e.g. companion), they rejected the robot.

We report on several insights, following participants' interpretation of the robot's gestures as related to the feeling of "being-seen". First, a non-humanoid robot that doesn't mimic human behavior can evoke a social experience. This is supported by previous studies indicating the automatic human tendency to perceive the world through a social lens [23, 25], and implies the possibility that companion robots should not be constraint to a humanoid and zoomorphic designs. Designing non-humanoid robots, in contrast to humanoid robots, provide designers with great freedom of design, both in the robot's appearance and function. Such a wide range of robots' appearances and functions has the potential to overcome the existing rejection of companion robots by healthy older adults. Second, all participants explicitly mentioned the mechanical aspects of the robot, and many of them were intrigued by it. This implies that non-verbal gestures can generate a social experience related to "being-seen" without "hiding" the mechanical nature of the robotic object. Within the constrained context of a lab study, it suggests that there can be great flexibility in companion robot design, that may look like regular objects and can even expose mechanical parts, instead of hiding robot's mechanisms and designing them to look "cute" or "affable". Lastly, our findings suggest, that a primary function that is not associated with companionship does not compromise the association of the robot's gestures with feelings related to "being-seen". Presenting the robot as a Cognitive-Game involved no social context and had no pre-defined association with the feeling of "being-seen", yet 10/13 participants in this condition described the interaction with the robot using terms related to "being-seen" and in some cases (5/13) even used terms related to loneliness. Participants' descriptions were similar to those offered in the Companion-Function condition.

The robot's primary function directly influenced participants willingness to accept the robot. The quantitative analysis revealed that the cognitive game function led to significantly higher levels of acceptance compared to the companion function. The qualitative analysis revealed that participants' evaluation of the robot's function directly influenced their willingness to accept the robot into their home. When the game was perceived as a valid function, participants were willing to use the robot at their home. When the game was not perceived as a valid function, participants rejected it. A similar pattern was observed in the Companion-Function condition. Participants justified their rejection by stating that the robot is useless.The function's influence on willingness to accept the robot was observed in the No-Function condition. Participants who suggested ideas for functions that are meaningful for them, were willing to accept the robot, while participants who suggested companionship or did not suggest any function, rejected the robot or stated that it is appropriate for someone else.

Regarding the game itself, the cognitive game that increased the robot's acceptance was perceived by participants as appropriate but (as expected) not extremely exciting. This suggests that even a mildly appealing function can be sufficient for overcoming healthy older adults' initial rejection of robots with the primary function of companionship. Companionship as a secondary function (through non-verbal gestures) was not perceived as degrading, and during the interviews participants explicitly mentioned that the experience was pleasantly surprising. This implies that even a mildly appealing primary function can serve as a "bridge" that will increase older adults' initial willingness to accept a robot into their home.

CONCLUSION

To conclude, we suggest that healthy older adults can associate the non-verbal gestures of a robotic object with feelings related to "being-seen". While constrained by the limitations of a lab study, this finding implies that companion robots can take various forms and designs. The effect was not compromised by a non-companion primary function, which increased older adults' willingness to accept the robot. These insights set the foundation towards future in-situ, longitudinal studies, at older adults' homes. For HCI designers, our findings suggest the following insight. Companionship can be designed as a secondary function enabling a wide variety of primary functions, by leveraging non-humanoid robots that are liberated from humanoid or zoomorphic limitations.

LIMITATIONS AND FUTURE WORK

Qualitative interviews are subjected to bias, we followed a strict interview protocol to limit this effect. Due to the WoZ methodology, some participants were preoccupied with the robot's "invisible sensor". We verified it did not alter the findings and most participants perceived the robot as both mechanical and social simultaneously. The seamless functioning of the system, activated by the "wizard", limits the generalization of the findings to real-world uses, suggesting that the effect should be further tested in a long-term field study with a fully-autonomous system. Some of the variance in the No-Function condition may have been due to participants' anticipation of the robot's function. This unique population includes individuals from a wide range of ages, we verified that the average age in the three conditions was balanced. In addition, participants may be less influenced by the robot's gestures over time. Future work should include more challenging game mechanics, a proximity sensor for autonomous reaction, and an Artificial Neural Network (ANN) to generate a variety of gestures to prevent boredom from repetitive gestures.

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