JAMDA 25 (2024) 105084

JAMDA

journal homepage: www.jamda.com

Original Study

Care Providers' Perspectives on the Design of Assistive Persuasive Behaviors for Socially Assistive Robots

Cristina Getson BASc *, Goldie Nejat PhD, PEng

Autonomous Systems and Biomechatronics Laboratory (ASBLab), Department of Mechanical and Industrial Engineering, University of Toronto, Toronto, ON, Canada

Keywords:
Care provider perspectives
cognitive activities
engagement and motivation
older adults
robot persuasive behaviors
socially assistive robots

ABSTRACT

Objectives: The main objectives of this research are (1) to uniquely design assistive behaviors for socially assistive robots using the principles of persuasion from behavioral psychology, and (2) to investigate caregivers' perspectives and opinions on the use of these behaviors to engage and motivate older adults in cognitive activities.

Design: We developed 10 unique robot persuasive assistive behavior strategies for the social robot Pepper using both verbal and nonverbal communication modes. Robot verbal behaviors were designed using Cialdini's principles of persuasion; nonverbal behaviors included expansive movements of the body. Care providers' perceptions of the quality, strength, and persuasiveness of these robot persuasive behaviors were assessed based on the Perceived Argument Strength Likert scale.

Setting and Participants: Eighteen formal and informal care providers caring for older adults including those living with mild cognitive impairments participated.

Methods: An online survey was designed consisting of short videos of the Pepper robot displaying each behavior. After viewing each video, care providers completed the Perceived Argument Strength Likert scale to evaluate 6 attributes for each behavior. They also provided comments.

Results: Results show robot assistive behaviors using praise with emotion, along with emotion with commitment were the most positively rated by care providers. Qualitative responses indicate robot body language and speech quality were influencing factors in how a person perceives assistance in human-robot interactions.

Conclusions and Implications: Our findings provide new insights into incorporating persuasive strategies into the design of assistive social robot behaviors with the aim of engaging and motivating older adults in an activity. The majority of care providers rated the robot persuasive behaviors positively. In designing a persuasive socially assistive robot for older adults, it is beneficial to display a combination of persuasive strategies, such as praise and commitment with emotion, to address individual users' needs and cognitive levels.

The COVID-19 pandemic has exacerbated the critical staffing shortages in long-term care (LTC), with LTC homes and assisted living communities still experiencing significant job losses.[1] Now more than ever, technological solutions are increasingly being considered in health interventions. These solutions include socially assistive robots (SARs) designed to supplement human care by allowing caregivers to monitor and care for multiple residents at one time.[2] SARs can lead exercise sessions,[3] facilitate recreational activities,[4] engage users in cognitive activities including memory games,[5] and assist with activities of daily living.[6] Such SARs have been shown to improve cognitive and/or psychological functioning in older adults.[7] This includes enhancement of motivation and improvement of verbal memory functions,[8] lower anxiety,[9] and decreased stress levels.[10] SARs can also assist with monitoring residents throughout the night, helping to reduce caregiver rounds.[11] With adaptable and personalized social skills such as knowing a resident's name and past history, SARs can be successfully deployed for LTC.[12]

The physical embodiment and multimodal interaction capabilities (eg, speech, gaze, gestures, facial expressions) of SARs aid in the

This work was supported by the HeRo NSERC CREATE in Healthcare Robotics, Canada grant, AGE-WELL NCE, and the Canada Research Chairs (CRC) Program.

* Address correspondence to Cristina Getson, Autonomous Systems and Biomechatronics Laboratory (ASBLab), Department of Mechanical and Industrial Engineering, University of Toronto, 5 King's College Rd, Toronto, ON M5S 3G8, Canada.
E-mail address: cristina.getson@mail.utoronto.ca (C. Getson).

https://doi.org/10.1016/j.jamda.2024.105084
1525-8610/

promotion of a rich interactive environment.[13,14] With respect to other available technologies, it has been shown that older adults feel more confident interacting with a robotic assistant and are more willing to frequently use one compared with a tablet.[15] In particular, older adults prefer to interact with a robot that (1) naturally interacts using both verbal and nonverbal communication, and (2) is adaptive to their changing needs as they age.[16]

In LTC environments, care providers frequently need to engage residents in social activities through encouragement.[17] This includes using praise or telling jokes, with the aim of promoting social engagement.[4] There are 3 types of social interactions that have been identified to be effective between caregivers and residents[17]: (1) activating (recruiting or encouraging participation), (2) relating (interactions based on social/emotional bonding), and (3) attending (addressing individual physical or psychosocial needs). SARs have been used in all 3 of these interaction types. For example, encouraging and motivating older adults suffering from cognitive decline to play a cognitive game,[5] supporting dementia care by improving social engagement and bonding,[18] and providing dressing assistance to older adults.[19]

Approximately 50 million people live with dementia in the world, and this number is expected to increase to 152 million by 2050.[20] Mild cognitive impairment (MCI) is the transitionary stage between healthy aging and dementia and provides a window for interventions designed to delay progression to dementia.[21] Globally, the prevalence of MCI in people aged 50 or older living in community dwellings or LTC homes is from 15% to 21%.[22,23] Informal caregivers, such as family members, provide an estimated 75% of home care for those living with MCI.[24] Therefore, it is important to consider caregivers' experience working with individuals with MCI.

As we increasingly explore the use of SARs in health care and eldercare applications to assist, stimulate, and provide companionship, it is important to understand how their assistive behaviors are used and perceived in a persuasive capacity. There has been limited research on persuasive robotics for health care–related tasks for older adults. Furthermore, caregiver perspectives on the efficacy of different SAR persuasive behaviors have not yet been explored. There are also contradicting results on whether human persuasion theories can be applied in human-robot interaction (HRI),[13] in particular, assistive HRI with vulnerable populations. More research is needed to design autonomous SARs that can support both care providers and older adults in resource constrained environments.

In this article, we present our research in the novel design of robot assistive behavior strategies using insight from persuasive human-human interaction (HHI). We aim to inform the general design of SAR behavior strategies that can be used to engage, support, and motivate older adults in an activity by first obtaining caregiver expertise on specific attributes of these behaviors. Caregiver input is critical in the codesign of SARs and their behaviors, which directly supports the adoption of SARs.[24,25] The second future stage of our research will be to validate these persuasive behaviors by the robot directly engaging in HRI with older adults. The main contributions of this article are twofold: (1) integrate the principles of persuasion from behavioral psychology to uniquely design SAR assistive behaviors, and (2) investigate caregivers' perceptions on the use of these behaviors to engage and motivate older adults.

Methods

The objective of this study is to investigate care providers' perspectives on different multimodal robot persuasive behaviors and their corresponding verbal and nonverbal feature designs to engage and motivate older adults in cognitive activities.

Participants

Formal and informal caregivers, caring for older adults including those living with MCIs, were recruited through e-mail lists of LTC homes and home care organizations as well as nonprofits, and technology and aging networks across Canada. Eighteen participants completed an online survey. Demographic information including age group range, gender, and previous experience with robots was obtained. Eleven participants were 18 to 55 years old, and 7 were older than 55. Three men and 15 women participated in the survey. The majority of participants (14) reported they had no prior or beginner robot experience (seen robots at museums, science centers, or on TV), 3 had intermediate experience (seen robots used in their workplace), and 1 person reported having advanced experience (hands-on experience using a robot). All participants provided written consent before completing the survey. Ethics approval was obtained from the University of Toronto Research Ethics Board.

Robot Behavior Design

We used the Pepper robot from Softbank Robotics and designed 10 different robot behavior strategies. The socially assistive robot Pepper has been designed by us in our study to have multimodal capabilities to enable the incorporation of both verbal and nonverbal (vocal intonation, gestures, eye color) communication modes to help convey a specific behavior to older adults and those with MCI. Namely, it has been found when a caregiver communicates with older adults with MCI, both verbal and nonverbal communication strategies should be used[26]: (1) getting the person's attention, such as by waving; (2) speaking slowly and clearly, maintaining an open, calm, and friendly manner; (3) using short, simple sentences; (4) avoiding open-ended questions; (5) repeating a question; and (6) using nonverbal communication modes such as tone, posture, and gestures. We have used a mix of these communication strategies in our robot behavior design and have developed our behavior strategies to work across different levels of cognition, so that they can be used as needed, depending on individual needs and progress in an activity.

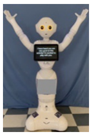
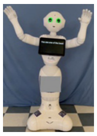
Our own research has shown that for older adults with no cognitive disorders, Pepper can use a combination of multimodal behaviors to help keep them engaged and prolong social interactions.[27,28] For those with MCI, Pepper's behaviors can be designed to (1) include repetition of instructions, (2) minimize distractive behaviors by using pointing gestures for visual focus of attention, (3) provide more time for each step of an activity, and (4) give positive reinforcement when completing an activity step. The level of robot assistance for an older adult based on their cognitive level can be established ahead of the activity with the help of the caregiver.[2] Namely, for those with mild cognitive impairments, the robot can provide clear demonstrations on how to perform an activity through verbal support and gestures, and for those with moderate cognitive impairments, provide activity assistance by helping them complete a step of the activity through targeted instructions and pointing gestures.[29]

The speech was also presented as text on Pepper's tablet. Table 1 presents an overview of the design of the robot behavior types and their corresponding modes. We discuss these behaviors in more detail as follows.

Robot Verbal Communication Design

Cialdini's principles of persuasion are among the most widely used and established persuasion strategies in human behavioral psychology,[30,31] and have been applied in both HRI[32-35] and HHI.[31,36,37] However, the perceived strength of these persuasive strategies has not yet been investigated with older adults. We designed the Pepper

Table 1
Robot Behavior Type and Corresponding Verbal and Nonverbal Communication

Behavior Type	Verbal	Nonverbal (Gestures, Eye Color, Speech Text)
1: Appeal via others https://youtu.be/mZEP4Pw99rU	"So many people have completed this activity, it is their favorite one! Let's see if it will be your favorite, too." *Theory: Social proof (Increase compliance by stating that others have already complied)*	
2. Praise with emotion https://youtu.be/4hkWEm6Gx6o	"I have heard you are very good at this activity! I'm excited to play with you." *Theory: Use praise and compliments to increase liking and compliance, along with emotion*	
3. Appeal with emotion https://youtu.be/oVF7UOD8NN4	"It would make me happy if you could complete this activity." *Theory: Use emotion for gaining compliance*	
4. Praise with amazement https://youtu.be/zRMwCKkMVhU	"You are one of the best!" *Theory: Use praise and compliments to increase liking and compliance*	
5. Expertise https://youtu.be/lou8zxyO8-8	"You should do this activity because I know it can improve your skills." *Theory: Authority (Show expertise)*	
6. Reciprocity https://youtu.be/9cIw3u2noFE	"I have already completed the first step in the activity for you. Now it is your turn to complete the next step." *Theory: Reciprocity (Give something before asking for return favor)*	
7. Encouragement with amazement https://youtu.be/95g4G1aYy-E	"Wow, you are doing even better than everyone else on this activity! Keep it up!" *Theory: Social proof (Increase compliance by stating that others have already complied)*	
8. Commitment with engagement https://youtu.be/oZOyNstyoKI	"That was fun! Let's do this again at the same time tomorrow." *Theory: Consistency and commitment (Engage user in making a commitment)*	
9. Commitment with emotion https://youtu.be/earbrjN2dpY	"It would make me happy if you would do this activity again with me tomorrow." *Theory: Use emotion for gaining compliance, along with commitment*	
10. Compliment with anticipation https://youtu.be/lhgRqU-G2EM	"You did great at this activity! I can't wait to see how you do next time." *Theory: Use praise and compliments to increase liking and compliance*	

robot's speech using 5 of these principles of persuasion. Namely, to exemplify social proof (or consensus), Pepper alludes to other people who have completed the activity (behaviors 1 and 7). Praise was exemplified by personal compliments on activity success (behaviors 2, 4, and 10). Expertise was demonstrated with the robot stating it has knowledge of the activity (behavior 5). To engage in Reciprocity, the robot stated it had already completed an activity step (behavior 6). Commitment was illustrated by Pepper alluding to meeting again tomorrow (behaviors 8 and 9). The compliance gaining behavior strategy of emotion was represented in combination with some of the preceding principles (behaviors 2, 3, and 9).

Robot Nonverbal Communication Design

The SAR's approachability, associated with emotional warmth and empathy, is linked to stretching, opening, and moving/leaning forward movements of the body.[38] The open arm gestures used by Pepper have been supported by a previous HRI study on engagement in which elated joy and interest were effectively displayed through a social robot by stretching trunk, opening arms, and overall upward and forward motions.[39]

We used LED eye colors of yellow, orange, and green, informed by Plutchik's color wheel.[40] In HRI, a combination of color and movement provides an effective method of communicating basic emotions in SARs such as joy, sadness, fear, and anger.[41] Yellow has previously been used to express joy,[41,42] and to congratulate a win.[43] Orange has been shown to express anticipation, and yellow-green expresses trust, acceptance, and admiration.[44] Therefore, we used yellow eye color to express joy, orange to express anticipation and interest, and green to express admiration.

Questionnaire

Our online survey was developed using Research Electronic Data Capture (RedCap) software to investigate care providers' perspectives on the engagement and motivational impact of the different robot behaviors. The survey consisted of 10 sections, with each section starting with a short video (approximately 10 s) of a specific behavior, followed by a questionnaire on the behavior in the video. The questionnaire consisted of 2 parts: (1) a 5-point Likert scale questionnaire (1 = strongly disagree, 5 = strongly agree), and (2) open-ended questions. The order in which the participants viewed the videos was randomized to minimize carryover effects.

The Likert scale questionnaire was adapted from the Perceived Argument Strength Scale, which has been used with adults in a health care context and assesses perceptions of the quality, strength, and persuasiveness of communication.[45] Measures of perceived argument strength have been shown to be a reliable predictor of the effects of persuasion when acquiring data on actual attitude change is difficult.[46] The 5-point Likert portion of our survey questions used the same 6 components from the Perceived Argument Strength Scale,[45] and consisted of rating these 6 attributes for the observed robot behavior: (1) Believability, (2) Convincingness, (3) Importance, (4) Engagement, (5) Promotion of Positive Feelings, and (6) Compliance. The open-ended questions were on caregivers' opinions on their likes/dislikes about the individual behavior features including speech, gestures, and LED eye color. Caregivers also provided general impressions on behaviors that would engage and motivate an older adult from their own care experience. These open-ended questions, answered in free-form text, enabled participants to share details that the researchers may not have anticipated, capturing the "why" that complements quantitative results.[47] Furthermore, LTC administrators provided their feedback on these questions prior to the study. The full questionnaire is presented in the Supplementary Materials.

Results

We investigated both (1) caregiver perceptions of robot behavior types using the 6 attributes, and (2) caregiver opinions on nonverbal and verbal robot behavior features. Data analysis and results are discussed as follows.

Perceptions of Robot Behavior Types

Figure 1 presents the box and whisker plots for caregiver ratings across the 6 attributes for all 10 robot behavior types. We plotted Likert responses for the 10 behavior types across the 6 attributes to assess overall positive (score of 4–5), neutral (score of 3), or negative (score of 1–2) perceptions of each behavior.

The behavior types that were overall positively perceived by caregivers were Praise with emotion (#2), Commitment with emotion (#9), and Compliment with anticipation (#10), followed by Appeal via others (#1) and Commitment with engagement (#8).

Praise with emotion (#2) had overall positive perception for all 6 attributes, with a consistently high central tendency ($\tilde{x} = 4$), and variability ($IQR = 1.75–2.5$). Commitment with emotion (#9) had overall positive perceptions, with a consistently high central tendency ($\tilde{x} = 4$) and lower variability ($IQR = 1$) for all 6 attributes. Compliment with anticipation (#10) had overall positive ratings for the attributes, with a high central tendency for 5 of them ($\tilde{x} = 4$) and low variability ($IQR = 1–1.25$). The Compliance attribute had a neutral perception ($\tilde{x} = 3$, $IQR = 1.25$).

Last, 3 attributes had positive perceptions for Appeal via others (#1): Convincingness, Engagement, and Positive feelings ($\tilde{x} = 4$, $IQR = 1–2$); and for Commitment with engagement (# 8): Convincingness, Importance, and Engagement ($\tilde{x} = 4$, $IQR = 1–1.75$), with the remaining attributes perceived neutrally.

Praise with amazement (#4), Reciprocity (#6), and Encouragement with amazement (#7) had central tendencies ranging from 3 to 4, and variability ranging from 1 to 2. Less than half of the attributes were positively perceived ($\tilde{x} = 4$): Importance and Positive feelings for Praise with amazement (#4); Believability and Engagement for Reciprocity (#6); and Positive feelings for Encouragement with amazement (#7). The rest were perceived neutrally ($\tilde{x} = 3–3.5$).

Appeal with emotion (#3) and Expertise (#5) were neutrally perceived overall ($\tilde{x} = 3$, $IQR = 1.75–2$), with the exception of the Importance attribute perceived positively ($\tilde{x} = 4$, $IQR = 2$) for Expertise.

Care Provider Opinions on Robot Behavior Features

Caregivers were asked their opinions and provided open-ended comments on the specific behavior features of (1) body language and gestures, (2) speech quality, (3) eye colors, and (4) speech content. Answers were analyzed using an inductive thematic analysis approach, in which patterns and underlying themes were identified, then coded and grouped together. We also used content analysis to determine if a comment was positive or negative.

Body Language and Gestures

Most comments on behavior features were on the body language and gestures displayed by the robot (43 comments in total). The main comments were on the variety and synchronization of gestures with speech and ranged from positive:

"*I like the variety of gestures*."

"*I really liked that the robot almost appeared to be dancing.*"

to negative:

"*The movements distract from what is being said.*"

"*They were not in sync with the speech*."

They also noted that the body language and gestures were engaging and kept them interested:

"*I was focused on the arms and hand movement. That created interest to keep watching to see what will happen next.*"

The bigger faster movements, for example in Appeal with emotion (#3), did not appeal to some participants:

"*I would not include the arms up gesture it may be received as a bit frightening.*"

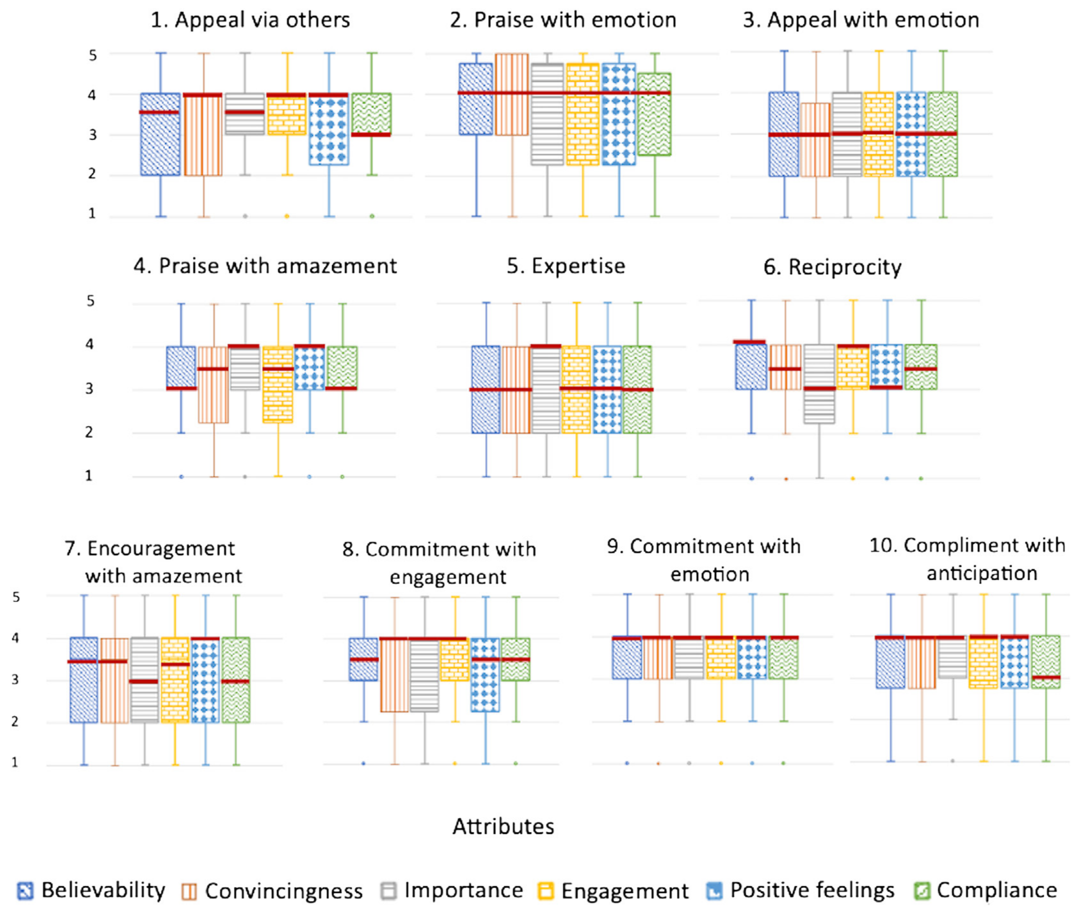


Fig. 1. Box and whisker plots for the 6 attributes across the 10 robot behaviors. The median is represented by bold red lines, quartiles by the boxes, and the minimum/maximum values by the whiskers.

Speech Quality

There were 24 comments on the robot's speech quality. The main comments were with respect to volume and tone, and varied from positive:

"*Voice and intonation were good.*"

to negative:

"*Speech should be louder, more cheerful.*"

Eye Colors

Twelve comments were on the eye colors used with the behaviors, and discussed perceptions of emotions linked to the different colors:

"*I liked the green color, represented something more positive.*"

"*Don't like the warm tone of the eyes; it looks like the robot has an eye infection.*"

Speech Content

There were 6 comments on the robot's speech content. There were positive comments for Compliment with anticipation (#10):

"*Choice of words are good.*"

and for Praise with amazement (#4):

"*I liked that the sentiment was factual and not phrased as 'I think you are one of the best.' This sort of statement is not as believable coming from a robot.*"

Two concerns for Encouragement with amazement (#7):

"*I don't like the saying because it puts everyone else down and it's not heartfelt and not too much encouragement.*"

"*Why compare to others? This does not seem good social behavior.*"

Two were negative remarks; 1 for Commitment with emotion (#9):

"*The phrase 'It would make me happy' seems disingenuous coming from a robot.*"

and 1 for Reciprocity (#6):

"*Vocal delivery is stiffly worded.*"

General Overall Comments

Participants provided general open-ended comments in relation to the application of robot assistive interactions with older adults. The comments were analyzed and categorized for 2 main themes: (1) personalization and presentation of behavior, and (2) proxemics. The comments on personalization focused on adaptability to the person's needs:

"*We have to ask them between the activities if we have to stop the activities or continue.*"

"*Very person dependent. I think could be very helpful for some, and others will not understand*."

and preferences for the robot to have human-like behavior:

"Would engage a person with a musical background/Dalcroze experience to create gestures that (1) stem from natural human movements, (2) match the rhythm and phrase of speech."

"I think having robots exhibiting social behaviors could be helpful, but only if the gestures are not offensive or awkward."

and more inclusive/participatory speech:

"I think it would be beneficial to make the statements participatory using 'would you' invitations to imply agency and to help with activity initiation."

The comments on proxemics focused on the distance between the robot and older adult user:

"*My only concern at this moment would be the distance of the robot to the person. The closer the robot is and if any physical arm movements move towards the person, this could be alarming and frightful*."

Discussion

Discussions are presented on the investigated robot behavior types and caregivers' comments on behavior features.

Robot Behavior Types

We assessed both the central tendency and variability of the ratings to identify the spread of responses (Figure 1). Behaviors using praise and compliments, when combined with other strategies such as anticipation for a future encounter, were among the most positively perceived, as evidenced with behaviors Praise with emotion (#2) and Compliment with anticipation (#10), which had a positive central tendency ($\tilde{x} = 4$). Praise with emotion (#2) had the greatest variability in responses ($IQR = 2.5$), which was also observed in the comments about gestures, where some care providers stated they liked the large arm gestures and others stated they did not like them. Combining an emotional appeal with commitment (#9) also had a positive central tendency ($\tilde{x} = 4$), while exhibiting the lowest variability ($IQR = 1$). Differences in central tendency across specific attributes for each behavior could be due to (1) personal preference, as well as (2) watching videos of robot behaviors, which may not be as convincing as interacting with a robot in-person.

The principle of using praise and compliments increases likability, compliance and promotes persuasion between people.[30] In HRI, SARs have used encouragement and praise using speech alongside gestures to successfully motivate older adults to perform physical exercise.[35] Appealing to a person's emotions has been effective for persuasion between people.[48] In particular, when comparing the persuasiveness of social robots using logic or emotion-based behaviors, the emotion strategy had higher persuasive influence.[49] Our findings show that the specific attribute of Promotes positive feelings was rated high for all behaviors using praise and compliments (#2, #4, #10). However, Compliance was rated neutral in 2 of these behaviors (#4, #10). Although compliments from a robot may be positively perceived, they may need to be combined with various persuasion strategies to achieve compliance. For example, using a compliment with anticipation (#10) was rated more positively overall than using a compliment on its own (#4).

The use of commitment in the robot's behavior aligns well with the principle of consistency, which states that people follow through when they make clear commitments, and even a small commitment can influence their future actions.[30] SARs have been used to provide reminders to older adults for appointments or for taking medication[50]; however, compliance while following through with a stated commitment has not been investigated in HRI studies with older adults. In our study, we found that when emotion was incorporated with commitment (#9), this behavior had the highest central tendency and lowest variability compared with all the others.

The principle of reciprocity has been successful in persuasion between people, as it can elicit a desired behavior by displaying it first.[51] Reciprocity has also been effective in HRI. It was shown that when playing trivia with a robot teammate, if the robot helped by providing correct answers, the likelihood of compliance increased for young adults to then complete a secondary pattern recognition task.[33] In our study, the Reciprocity behavior had neutral-positive ratings, with the Importance, Positive feelings, Convincingness, and Compliance attributes rated neutral whereas Believability and Engagement were rated positive. Further investigation of this particular behavior is needed.

Social proof (or consensus) can increase compliance between people by reaffirming that others have already complied.[30] One HRI study investigating social conformity found that children conformed to a group of small humanoid robots in a visual judgment task, whereas adults resisted social pressure from robots (but not from peers).[52] In our study, the robot behaviors of Appeal via others (#1) and Encouragement with amazement (#7) that used social proof received neutral to positive ratings. Although both behavior types promoted positive feelings, they were rated neutral on Compliance and Importance. As our study is the first to incorporate social proof in robot assistive behaviors for older adults, a larger study would provide further insight on the use of this persuasive behavior.

The use of expertise has shown that people tend to defer to experts, and that stating one's expertise can exert influence on others.[30] Contrary to HHI, it has been shown in HRI that a robot is more persuasive in a peer expert role than in an authority expert role.[34] Our results show that Expertise (#5) was rated neutral overall, yet with a positive rating for Importance. One caregiver commented on the need to use inclusive words, such as "*would you like*" as opposed to "*you should*." Further investigation is needed, as applying the wrong persuasive strategies may be counterproductive, leading to noncompliance or adverse user behaviors,[53] especially for older adults with MCI.

The Likert scale results, as shown in Figure 1, range from "Strongly disagree" to "Strongly agree." We postulate the disparities may have been caused by the following reasons.

1. Care provider personal experiences in providing care for older adults: The 2 participants who consistently had negative ratings (strongly disagree or disagree) on the Likert scale also provided negative comments to the open-ended questions for each video. Namely, these participants were concerned that older persons with dementia could not relate to the robot, and that there was a need for human touch and interaction with seniors. In general, their comments did not explicitly focus on the different behaviors exhibited by the robot, but rather the actual presence of a robot in general (which they disagreed with). This is consistent with previous research that has shown certain concerns can generally affect the perceived usefulness of robots for care—common concerns are fear that robots will replace people, the dehumanization of treatment, and increased loneliness in older adults.[54] On the other hand, participants who had overall positive ratings (agree or strongly agree) provided direct comments to the open-ended questions that suggested improvements or ways to enhance the robot's specific behaviors for human-robot interactions with older adults. These comments included (1) increasing the volume of the robot's voice to ensure it is clear for older adults, and (2)

improving the synchronization of the robot gestures and speech.

2. Care providers' prior experience with robots: Most participants (78%) stated they had either no previous robot experience or only beginner experience, where the latter included having seen robots in the media. The remaining participants reported having intermediate experience (17%), or advanced experience (5%). This limited prior experience with robotic technology could have also impacted the range of answers, as there may be an expectation gap.[55] This can be especially true if care providers have seen fictional robots in the media displaying a high level of social and physical intelligence, which may increase their expectations of the capabilities of SARs.[56] However, as social robots in real life are still not capable of the physical and cognitive abilities portrayed by robots in mass media, seeing one may not meet people's expectations; on the other hand, some people may be relieved to see that robots are not as advanced as those portrayed in science fiction.[56] In our study, in the no prior robot experience category, 1 participant had all negative Likert scale ratings (strongly disagree) for all the robot videos, and 1 participant had all positive Likert scale ratings (strongly agree) for all the robot videos. With respect to advanced experience, the Likert scale ratings of robot behaviors were overall neutral, with the comment provided that the robot "*would help with staffing issues in retirement homes and LTC and consistent reliable activity engagement.*" The intermediate group ratings included Likert scale ratings ranging from 1 to 4.
3. The inclusion of online videos of robot behaviors: We used online videos so that we could gather a greater number of responses from a wider demographic. However, this may have influenced overall perceptions and acceptance of the SAR. Several studies have compared co-present (physically embodied robots sharing users' environments), tele-present (physical robots in another location, being shown either on video or using streaming services), and virtual agents (a computer graphics model of a robot).[57-60] Results from these studies have shown that physically present robots were perceived more positively and considered more persuasive than a tele-present robot or virtual agent.[58-60]

In summary, our preliminary findings show that (1) combining a compliment with anticipation (#10) is rated more positively overall than using a compliment on its own (#4); and (2) combining emotion with praise (#2) and emotion with commitment (#9) invokes a more positive response than using emotional appeal alone (#3). However, for the single strategy of (1) Reciprocity (#6), more than half of the attributes were rated neutral; (2) Social Proof when exhibited as Appeal via others (#1), half of the attributes were rated neutral, and when exhibited as Encouragement with amazement (#7), the majority of the attributes were rated neutral; and (3) Expertise (#5), the majority of the attributes were rated neutral. These single persuasion strategies should be further investigated in combination with emotional appeal or with praise and compliments, which, when combined with other behavior strategies (#2, #9, #10) have shown to have more positive overall ratings.

It has been shown that multimodal robot behaviors (speech and gestures) can make HRI more engaging than single-modal behaviors,[61] and that verbal and nonverbal cues should be strategically used in response to participants' current attentional state.[62] However, the specific situation and modes used may not necessarily increase persuasiveness. For example, when a robot looks away from the user during HRI, the use of gestures makes the robot less persuasive.[14] Some key elements for personalization of SARs to facilitate and encourage older adult engagement in an activity include different engagement strategies and use of feedback and positive reinforcement, which are linked to a participant's intrinsic motivation and cognition[35]; these help to inform the quantity, communication style, and approach of motivational messages.[63]

To the authors' knowledge, the effect of the content of persuasive strategies in HRI with older adults, and the exploration of 1 or multiple persuasive behavior strategies to promote effective engagement and motivation of older adults has not yet been investigated. Based on our preliminary results, we posit that potentially combining persuasive behavior strategies may be more effective than using a single strategy to engage and motivate older adults.

Robot Behavior Features

As the popular saying goes, "*It's not what you say, it's how you say it.*" In general, care provider comments on body language and speech quality showed their importance in influencing how a person perceives assistance in HRI.

The influence of persuasive behavior is transmitted through communication; however, it has been found that only a small fraction of persuasion involves words; the role of nonverbal communication is critical.[48] In HHI, nonverbal immediacy, or the degree of perceived bodily and psychological closeness between people, plays a key role in persuading others.[64] Social cues in an agent, including type of voice, can positively affect social response to the agent.[65] An HRI study on the comparison of compliance with a robot's suggestions using (1) no vocal or bodily cues, (2) using 1 of these modes, or (3) using both of these modes, found that university students complied more when a robot used nonverbal cues than when it did not, and bodily cues alone were more effective in persuasion than vocal cues alone.[66]

Care provider comments regarding the importance of synchronization of robot speech and gestures show it is an important design consideration. A robot that displays appropriate gestures can elicit greater participation in an interaction.[67]

The green LED eye color received the most positive comments, whereas warm LED eye colors (yellow and orange) received negative comments. However, in our study, eye color did not seem to be an influencing factor in caregiver perceptions of engagement and compliance.

Limitations

Our study was online using videos of robot behaviors to increase accessibility—an in-person study could yield different perspectives on robot behaviors. We also had a small sample size ($n = 18$) of care providers due to the current situations in LTC homes.[1] We will continue to design and investigate variations of persuasive behaviors, combining different speech and gestures for a given strategy, with input from a larger number of both caregivers and older adults.

Conclusions and Implications

Our preliminary results on care provider perspectives of different robot assistive persuasive behavior types show the majority of care providers rated the persuasive behaviors of a socially assistive robot as positive or neutral. Specifically, behaviors using praise and compliments, and emotion appeal with commitment were the most positively rated. There was not a single behavior that received overall negative ratings. Although the most effective robot persuasive strategies to use will be dependent on the user group and the context of the interaction, our preliminary findings reveal that combining persuasive behavior strategies may lead to more effective engagement and compliance, as shown with the behavior strategies of Commitment with Emotion, Praise with Emotion, and Compliment with Anticipation, with the caveat that this was an online study conducted with care providers. Moreover, robot nonverbal behaviors received the majority of comments from care providers, confirming that robot body language and speech quality play an influential role in persuasive HRI. These findings will be further assessed in a follow-up in-person study with older adults and care providers.

Our findings provide the first insights into the design of persuasive SAR behaviors with the aim of engaging and motivating older adults, who may respond differently to social robots exhibiting persuasive strategies. In designing a persuasive SAR for older adults, it is beneficial to display multiple behaviors that have variability in persuasive strategies to adapt to individual users' needs and cognitive levels. In general, more research is needed to define general persuasive assistive strategies for SARs in the context of a healthcare−related task, such as engagement and compliance in a cognitive activity for older adults.

Disclosures

The authors declare no conflicts of interest.

Acknowledgments

The authors would like to thank everyone who helped distribute the online survey, and all who completed it.

References

1. Mapp LJ. Senior care providers race to address caregiver shortage. San Diego Union-Tribune. Accessed September 5, 2023. https://www.sandiegouniontribune.com/caregiver-2019/story/2021-11-16/senior-care-providers-race-to-address-caregiver-shortage
2. Andriella A, Alenyà G, Hernández-Farigola J, Torras C. Deciding the different robot roles for patient cognitive training. *Int J Hum Comput Stud*. 2018;117:20−29.
3. Shao M, Alves SFDR, Ismail O, Zhang X, Nejat G, Benhabib B. You are doing great! Only one rep left: an affect-aware social robot for exercising. In: *2019 IEEE International Conference on Systems, Man and Cybernetics (SMC)*. Bari, Italy: IEEE; 2019. p. 3811−3817.
4. Louie WYG, Nejat G. A social robot learning to facilitate an assistive group-based activity from non-expert caregivers. *Int J of Soc Robotics*. 2020;12:1159−1176.
5. Tapus A, Tapus C, Mataric MJ. The use of socially assistive robots in the design of intelligent cognitive therapies for people with dementia. In: *2009 IEEE International Conference on Rehabilitation Robotics*. IEEE; 2009. p. 924−929.
6. Robinson F, Cen Z, Naguib H, Nejat G. An intelligent socially assistive robot-wearable sensors system for personalized user dressing assistance. *Adv Robot*. 2023;37:1534−1551.
7. Lee EH, Kim BR, Kim H, et al. Four-week, home-based, robot cognitive intervention for patients with mild cognitive impairment: a pilot randomized controlled trial. *Dement Neurocogn Disord*. 2020;19:96.
8. Tanaka M, Ishii A, Yamano E, et al. Effect of a human-type communication robot on cognitive function in elderly women living alone. *Med Sci Mon Int Med J Exp Clin Res*. 2012;18:CR550−CR557.
9. Moyle W, Cooke M, Beattie E, et al. Exploring the effect of companion robots on emotional expression in older adults with dementia: a pilot randomized controlled trial. *J Gerontol Nurs*. 2013;39:46−53.
10. Wada K, Shibata T. Living with seal robots—its sociopsychological and physiological influences on the elderly at a care house. *IEEE Trans Robot*. 2007;23:972−980.
11. Obayashi K, Masuyama S. Pilot and feasibility study on elderly support services using communicative robots and monitoring sensors integrated with cloud robotics. *Clin Therapeut*. 2020;42:364−371.e4.
12. Rossi S, Conti D, Garramone F, et al. The role of personality factors and empathy in the acceptance and performance of a social robot for psychometric evaluations. *Robotics*. 2020;9:39.
13. Liu B, Tetteroo D, Markopoulos P. A systematic review of experimental work on persuasive social robots. *Int J of Soc Robotics*. 2022;14:1339−1378.
14. Ham J, Cuijpers RH, Cabibihan JJ. Combining robotic persuasive strategies: the persuasive power of a storytelling robot that uses gazing and gestures. *Int J of Soc Robotics*. 2015;7:479−487.
15. Hammer S, Kirchner K, André E, Lugrin B. Touch or talk?: comparing social robots and tablet PCs for an elderly assistant recommender system. In: *Proceedings of the Companion of the 2017 ACM/IEEE International Conference on Human-Robot Interaction*. ACM; 2017. p. 129−130.
16. Heerink M. How elderly users of a socially interactive robot experience adaptiveness, adaptability and user control. In: *2011 IEEE 12th International Symposium on Computational Intelligence and Informatics (CINTI)*. IEEE; 2011. p. 79−84.
17. Ryvicker M. Staff−resident interaction in the nursing home: an ethnographic study of socio-economic disparities and community contexts. *J Aging Stud*. 2011;25:295−304.
18. Hung L, Liu C, Woldum E, et al. The benefits of and barriers to using a social robot PARO in care settings: a scoping review. *BMC Geriatr*. 2019;19:232.
19. Robinson F, Cen Z, Naguib H, Nejat G. Socially assistive robotics and wearable sensors for intelligent user dressing assistance. In: *2022 31st IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. Napoli, Italy: IEEE; 2022. p. 829−836.
20. *World Alzheimer Report*. Accessed April 18, 2024. https://www.alzint.org/u/World-Alzheimer-Report-2023.pdf
21. Anderson ND. State of the science on mild cognitive impairment (MCI). *CNS Spectr*. 2019;24:78−87.
22. Bai Wei, Chen Pan, Cai Hong, Zhang Qinge, Xiang Yu-Tao. Worldwide prevalence of mild cognitive impairment among community dwellers aged 50 years and older: a meta-analysis and systematic review of epidemiology studies. *Age Ageing*. 2022;51:afac173.
23. Chen P, Cai H, Bai W, et al. Global prevalence of mild cognitive impairment among older adults living in nursing homes: a meta-analysis and systematic review of epidemiological surveys. *Transl Psychiatry*. 2023;13:88.
24. Moharana S, Panduro AE, Lee HR, Riek LD. Robots for joy, robots for sorrow: community based robot design for dementia caregivers. In: *2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. Daegu, Korea (South): IEEE; 2019. p. 458−467.
25. Arthanat S, Begum M, Gu T, LaRoche DP, Xu D, Zhang N. Caregiver perspectives on a smart home-based socially assistive robot for individuals with Alzheimer's disease and related dementia. *Disabil Rehabil Assist Technol*. 2020;15:789−798.
26. Emergency Medical Consultants, Inc. Communicating with cognitively impaired patients (Alzheimer's and Other Conditions). 2016. Accessed April 18, 2024. https://www.emcmedicaltraining.com/wp-content/uploads/2016/12/2016-communicating-with-cognitively-impaired-packet.pdf
27. Shao M, Pham-Hung M, Alves SFDR, et al. Long-Term Exercise Assistance: Group and One-on-One Interactions between a Social Robot and Seniors. *Robotics*. 2023;12:9.
28. Li Y, Liang N, Effati M, Nejat G. Dances with Social Robots: A Pilot Study at Long-Term Care. *Robotics*. 2022;11:96.
29. Chisholm D, Toto P, Raina K, Holm M, Rogers J. Evaluating Capacity to Live Independently and Safely in the Community: Performance Assessment of Self-Care Skills. *Br J Occup Ther*. 2014;77:59−63.
30. Cialdini RB. In: *Harnessing the Science of Persuasion*, 79. Boston: Harvard Business School Press; 2001. p. 10.
31. Orji R, Mandryk RL, Vassileva J. Gender, Age, and Responsiveness to Cialdini's Persuasion Strategies. In: MacTavish T, Basapur S, eds. *Persuasive Technology. Vol 9072. Lecture Notes in Computer Science*. Springer International Publishing; 2015. p. 147−159.
32. Ghazali AS, Ham J, Barakova E, Markopoulos P. Assessing the effect of persuasive robots interactive social cues on users' psychological reactance, liking, trusting beliefs and compliance. *Adv Robot*. 2019;33:325−337.
33. Lee SA, Liang YJ. The Role of Reciprocity in Verbally Persuasive Robots. *Cyberpsychol, Behav Soc Netw*. 2016;19:524−527.
34. Saunderson SP, Nejat G. Persuasive robots should avoid authority: The effects of formal and real authority on persuasion in human-robot interaction. *Sci Robot*. 2021;6:eabd5186.
35. Fasola J, Matarić MJ. Socially Assistive Robot Exercise Coach: Motivating Older Adults to Engage in Physical Exercise. In: Desai JP, Dudek G, Khatib O, Kumar V, eds. *Experimental Robotics. Vol 88. Springer Tracts in Advanced Robotics*. Springer International Publishing; 2013. p. 463−479.
36. Cialdini R. *Influence: The Psychology of Persuasion*. HarperCollins; 2007.
37. Josekutty Thomas R, Masthoff J, Oren N. Adapting Healthy Eating Messages to Personality. In: De Vries PW, Oinas-Kukkonen H, Siemons L, Beerlage-de Jong N, Van Gemert-Pijnen L, eds. *Persuasive Technology: Development and Implementation of Personalized Technologies to Change Attitudes and Behaviors. Vol 10171. Lecture Notes in Computer Science*. Springer International Publishing; 2017. p. 119−132.
38. De Meijer M. The contribution of general features of body movement to the attribution of emotions. *J Nonverbal Behav*. 1989;13:247−268.
39. McColl D, Nejat G. Recognizing Emotional Body Language Displayed by a Human-like Social Robot. *Int J of Soc Robotics*. 2014;6:261−280.
40. Plutchik R. The Nature of Emotions. *Am Sci*. 2001;89:344.
41. Löffler D, Schmidt N, Tscharn R. Multimodal Expression of Artificial Emotion in Social Robots Using Color, Motion and Sound. In: *Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction*. ACM; 2018. p. 334−343.
42. Maggi G, Dell'Aquila E, Cucciniello I, Rossi S. "Don't Get Distracted!": The Role of Social Robots' Interaction Style on Users' Cognitive Performance, Acceptance, and Non-Compliant Behavior. *Int J of Soc Robotics*. 2021;13:2057−2069.
43. Manca M, Paternò F, Santoro C, et al. The impact of serious games with humanoid robots on mild cognitive impairment older adults. *Int J Hum Comput Stud*. 2021;145:102509.
44. Terada K, Yamauchi A, Ito A. Artificial emotion expression for a robot by dynamic color change. In: *IEEE RO-MAN: The 21st IEEE International Symposium on Robot and Human Interactive Communication*. IEEE; 2012. p. 314−321.
45. Zhao X, Strasser A, Cappella JN, Lerman C, Fishbein M. A Measure of Perceived Argument Strength: Reliability and Validity. *Commun Methods Meas*. 2011;5:48−75.

46. Dillard JP, Weber KM, Vail RG. The Relationship Between the Perceived and Actual Effectiveness of Persuasive Messages: A Meta-Analysis With Implications for Formative Campaign Research: Perceived and Actual Effectiveness. *J Commun*. 2007;57:613–631.
47. Allen M. *The SAGE Encyclopedia of Communication Research Methods*. SAGE Reference; 2017.
48. André E, Bevacqua E, Heylen D, et al. Non-verbal Persuasion and Communication in an Affective Agent. In: Cowie R, Pelachaud C, Petta P, eds. *Emotion-Oriented Systems. Cognitive Technologies*. Springer Berlin Heidelberg; 2011. p. 585–608.
49. Saunderson S, Nejat G. Investigating Strategies for Robot Persuasion in Social Human–Robot Interaction. *IEEE Trans Cybern*. 2022;52:641–653.
50. Casey D, Barrett E, Kovacic T, et al. The Perceptions of People with Dementia and Key Stakeholders Regarding the Use and Impact of the Social Robot MARIO. *IJERPH*. 2020;17:8621.
51. Gouldner AW. The Norm of Reciprocity: A Preliminary Statement. *Am Socio Rev*. 1960;25:161.
52. Vollmer AL, Read R, Trippas D, Belpaeme T. Children conform, adults resist: A robot group induced peer pressure on normative social conformity. *Sci Robot*. 2018;3:eaat7111.
53. Roubroeks M, Ham J, Midden C. When Artificial Social Agents Try to Persuade People: The Role of Social Agency on the Occurrence of Psychological Reactance. *Int J of Soc Robotics*. 2011;3:155–165.
54. Coco K, Kangasniemi M, Rantanen T. Care Personnel's Attitudes and Fears Toward Care Robots in Elderly Care: A Comparison of Data from the Care Personnel in Finland and Japan. *J Nurs Scholarsh*. 2018;50:634–644.
55. Kwon M, Jung MF, Knepper RA. Human expectations of social robots. In: *2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE; 2016. p. 463–464.
56. Horstmann AC, Krämer NC. Great Expectations? Relation of Previous Experiences With Social Robots in Real Life or in the Media and Expectancies Based on Qualitative and Quantitative Assessment. *Front Psychol*. 2019;10:939.
57. Liang N, Li Y, Nejat G. In-person vs Remote HRI: A Comparative Study of Robot Facilitated Dance with Older Adults in Long-term Care. In: *2023 IEEE-RAS 22nd International Conference on Humanoid Robots (Humanoids)*. IEEE; 2023. p. 1–7.
58. Bainbridge WA, Hart J, Kim ES, Scassellati B. The effect of presence on human-robot interaction. In: *RO-MAN 2008 - The 17th IEEE International Symposium on Robot and Human Interactive Communication*. IEEE; 2008. p. 701–706.
59. Li J. The benefit of being physically present: A survey of experimental works comparing copresent robots, telepresent robots and virtual agents. *Int J Hum Comput Stud*. 2015;77:23–37.
60. Wang B, Rau PLP. Influence of Embodiment and Substrate of Social Robots on Users' Decision-Making and Attitude. *Int J of Soc Robotics*. 2019;11:411–421.
61. Aly A, Tapus A. Towards an intelligent system for generating an adapted verbal and nonverbal combined behavior in human–robot interaction. *Aut Robots*. 2016;40:193–209.
62. Szafir D, Mutlu B. Pay attention!: designing adaptive agents that monitor and improve user engagement. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM; 2012. p. 11–20.
63. Winkle K, Caleb-Solly P, Turton A, Bremner P. Social Robots for Engagement in Rehabilitative Therapies: Design Implications from a Study with Therapists. In: *Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction*. ACM; 2018. p. 289–297.
64. Mehrabian A. *Silent Messages*. Wadsworth Publishing Company; 1971.
65. Atkinson RK, Mayer RE, Merrill MM. Fostering social agency in multimedia learning: Examining the impact of an animated agent's voice. *Contemp Educ Psychol*. 2005;30:117–139.
66. Chidambaram V, Chiang YH, Mutlu B. Designing persuasive robots: how robots might persuade people using vocal and nonverbal cues. In: *Proceedings of the Seventh Annual ACM/IEEE International Conference on Human-Robot Interaction*. ACM; 2012. p. 293–300.
67. Kennedy J, Baxter P, Belpaeme T. Nonverbal Immediacy as a Characterisation of Social Behaviour for Human–Robot Interaction. *Int J of Soc Robotics*. 2017;9:109–128.