Assistant Robot Enhances the Perceived Communication Quality of People With Dementia: A Proof of Concept

Di Zhou, Emilia I. Barakova, Member, IEEE, Pengcheng An, and Matthias Rauterberg

Abstract—Almost all older people with dementia have progressive communication difficulties, which lead to increased social isolation and negative emotions. Thus, providing communication assistance for them is essential. This paper explores the feasibility of using social robots to assist older people with dementia in their face-to-face communication with others. We designed the behavior of a humanoid Pepper robot and made a Wizard of Oz prototype that the robot can serve as a personal memory assistant. The robot stores personal information for older people and assists in their communication through voice and screen display. In a video-based study with 88 participants, we investigated the effects of this assistive robot from a third-person observer perspective. Data were collected and analyzed using both three-way MANCOVAs for quantitative analysis and conventional content analysis for qualitative data. The results revealed that, by providing memory support, the robot significantly improved the observer’s perceptions of an older person with dementia, including her perceived communication ability and performance, and personal image. Meanwhile, the communication is perceived to be significantly more effective when the robot assisted an older person. The willingness of others to communicate with more senior people also increased accordingly. Based on these findings, we present guidelines that may inform the design and development of communication assistant robots for older people with dementia.

Index Terms—Communication assistant robot, enhance communication quality, human-robot interaction, memory support for dementia patient, third-person perspective.

I. INTRODUCTION

DEMENTIA is a complex neurodegenerative disorder that results in significant cognitive and functional decline [1]. Although symptoms of dementia vary greatly, progressive memory impairment is estimated to occur in almost all older people with dementia [2], thus leading to the loss of skill and increased negative emotions in their daily lives [3]. Of all affected areas, communication is the most noteworthy, not only because it is one of the areas in which older people with dementia and their caregivers experience the most challenges [4] but also because it is a fundamental need for everyone. Short-term memory loss, along with the significant reduction in word-finding, difficulties in topic maintenance, and disordered turn-taking, significantly affect meaningful communication [5]. Poor communication leads most older people with dementia to experience social isolation, loneliness, and depression [6], [7]. Studies have found that sustaining social interactions is essential for maintaining the quality of life and mitigating cognitive decline among people with dementia [8], [9]. Therefore, interest in supporting their communication through technological interventions has grown steadily in recent years.

Robotics is currently gaining attention as a promising field to aid in caring for older people with dementia. Researchers have been exploring ways to use robots for this population, including monitoring and supporting activities of daily living [10], [11], providing companionship [12], [13], promoting physical activities [14], [15], and social interaction that brings positive emotions and cognitive stimulation [16], [17]. Almost all these studies have shown that robots can help older people with dementia decrease their stress and loneliness and improve their engagement, mood, and well-being.

Attempts to develop a robot for communication support for older people with dementia have mainly focused on enabling the more senior people to communicate with a robot partner through natural language [see Fig. 1(a)]. Those robots help connecting family members and older people who do not live together by using the robot as a telepresence agent [see Fig. 1(b)]. In the literature, when robots act as a user’s one-on-one conversation partner, they are usually designed to accompany and monitor older people with dementia, provide required information, and prompt daily activities by communicating with the older people through an interactive interface [18]–[21]. However, although these robots can help to maintain older people’s communication abilities by stimulating them to speak more, they also have the potential to diminish older people’s contact with other people, thus increasing social isolation [22]. Studies have shown that...
older people prefer human assistance to robotic assistance, possibly because of loneliness and social isolation. They have further indicated that robots should not be used to replace human companionship [23, 24]. Mataric [24] has shown that using robots to enhance humans is more effective than replacing them in many cases. On the other hand, when working as telepresence agents, robots usually help connect families and older people with dementia via a video screen [25]–[27]. However, although robots provide more opportunities to connect families and older people with dementia, they do not substantially enhance communication ability, although this capability is essential to facilitating interactions with others.

In contrast to these studies, our research focused on exploring a new role of robots as communication assistants for older people with dementia, as illustrated in Fig. 1(c). In this role, the robot design focused on assisting older people with dementia with memory failure in face-to-face conversations with others to help them communicate effectively and smoothly. By improving observers’ perception of the older person with dementia, we wish our robot could promote more communication between older people with dementia and others, thereby reducing social isolation for older people with dementia. With developments in artificial intelligence, such as data mining and natural language processing, research in interaction design for memory support robots is needed to complement and streamline the development of these technologies and make robots equipped with natural language processing useful.

To better design communication assistant robots for older people with dementia, learning how assistant robots influence other’s perceptions of users is particularly important. However, this aspect has often been under-explored by previous studies on assistant robots. Studies have shown that other people’s perceptions are an important factor affecting the attitudes and adoption of assistive technology by special groups [28]. Robots are usually visible and difficult to ignore; many potential concerns must be explored in terms of the effects of such robots on others’ perceptions of the users. For example, when accompanied by the robot in a face-to-face conversation with others, would older people with dementia be perceived as even more vulnerable and less capable of communicating than they would without the robot? Or would they be perceived as more independent and confident in their lives? Additionally, other people’s perspectives are precious in the dementia context because cognitive decline would restrict people with dementia from self-reporting through questionnaires or other direct methods [29].

However, although conversation partners and third-person observers are both considered “other people,” they often differ in their judgments of social interaction [30]. To examine this previously unaddressed design opportunity, as the first study in the series, we explored the feasibility of using communication assistant robots by older people with dementia from a third-person perspective to determine the effects of the robot on the perception of the older people and their communication.

The primary objective of this study was to investigate the feasibility of using a humanoid robot as a communication assistant for older people with dementia. In this study, the following research questions were investigated:

1) How do communication assistant robots influence observer’s perceptions of older people with dementia?

2) How do communication assistant robots influence observer’s perceptions of the communication between older people with dementia and their conversation partners?

The contributions of this work are two-fold. First, we explored a new role of a robot as a communication assistant for older people with dementia in their face-to-face communications with others. Second, we assessed assistant robots for older people with dementia from a third-person perspective. Third-person observers’ perception not only affects their willingness to communicate with dementia patients but also dramatically affects dementia patients’ acceptance of assistive devices.

II. MATERIALS AND METHODS

A. Participants

We call the participants raters. A total of 88 valid raters were recruited, 50 of whom (13 females and 37 males) were Amazon’s Mechanical Turk (MTurk) users residing in The Netherlands, and 38 (25 females and 13 males) of whom were from Snowball sampling (which was added because of the low numbers of Dutch MTurk users). All raters were bilingual in Dutch and English.

Of the 88 raters, 38 (43.2%) were female, and 50 (56.8%) were male. Half the females and half the males were assigned to the intervention group, and the other half were assigned to the control group. The average age of this sample was 34.06 (SD = 11.35), ranging from 18 to 58 years old of age. A total of 25 participants had experience in working or living with people with dementia. Fourteen of them were from MTurk, and the remaining 11 were from Snowball sampling. They had an average of 4.23 (SD = 4.43) years of experience, ranging from 1 month to 20 years. From the statistics of the United Nations [31], the population in The Netherlands in 2020 is 8 598 000 females (50.2%) and 8 537 000 males (49.8%), respectively. For a Dutch population with ages ranging from 10 to 59 years, the average age is 35.65 (SD = 14.46). Under a normal approximation [32], we expected, for a research sample of 88 raters, that 95% of the sample counts of males would fall between 34.65 and 53.04, and 95% of the research sample’s average age was expected to fall between 33.27 and 38.02. This research sample’s count of males was 50, and the average age was 34.06, both of which were in the acceptable ranges. Therefore, this research sample represents The Netherlands population in the research setting regarding age and gender.
B. Procedure

To address our research questions, we gathered and analyzed both quantitative and qualitative data. We conducted an online experiment via both MTurk and Snowball sampling to obtain a more diverse population of raters.

Two online forms were made on the Jotform website to present our two between-subject conditions. Each form contains a stimulus video and a questionnaire. The video in the control condition depicted an older person with dementia chatting with a conversation partner alone. In contrast, the video in the intervention condition displayed her talking with the help of an assistant robot.

Informed consent was obtained on the first page of the online form. A demographic survey (gender, age, and experience of living/working with older people with dementia) was subsequently completed by each rater. All raters were randomly allocated to the control or intervention group to fill the online form. They first watched the stimulus video (cannot be fast-forwarded or skipped) on the video page, then rated their perceptions of the older person and the communication by the questionnaire on the next page. Spending at least 40 s on the questionnaire page was set as the criterion for a valid submission. All 88 raters passed this attention check, and each of them was compensated with €3.

After that, to gather additional qualitative insights, 12 semistructured online interviews (approximately 30 min each) were conducted after the questionnaire for 12 randomly selected people among all Snowball sampling raters. Six of them came from the intervention group, and the other six came from the control group. Before the interview, a second informed consent was completed, and raters from the intervention group were shown the control video, whereas those from the control group were shown the intervention video. During the interviews (using questions as below), their detailed feelings toward the older person, the conversation, and the robot in videos were discussed.

1) Did you feel any differences about the older person in these two conversations? If yes, what difference did you feel?
2) Did you feel any differences in the quality of these two conversations? If yes, what difference did you feel?
3) What do you think the function/appearance of this robot in the conversation? Do you have any suggestions for improving its function/appearance?

Each of these 12 raters was compensated with another €10. All the interviews were audiotaped. This study was reviewed and approved by the Ethical Review Board of Eindhoven University of Technology (ERB2019ID2).

C. Robot Design and Stimuli

Two videos were constructed as stimuli to show our design for robot functions (see at https://vimeo.com/402904963, https://vimeo.com/402903116). Both conversations in the stimulus videos were in Dutch. Each video had an approximate duration of 6 min. A female caregiver who was experienced with dementia (77 years old) and a 24-year-old student were carefully selected to play the roles of the older person with dementia and her conversation partner.

The Pepper robot from Softbank was used to build a semi-automated communication assistant robot prototype (see at https://www.softbankrobotics.com/emea/en/pepper). We made use of sound source localization to make Pepper automatically look to the person currently speaking. When it spoke, the Pepper robot automatically used co-speech gestures similar to those of humans. To achieve the expected assistive effect, we added a Wizard-of-Oz [33] to simulate an automatic speech recognition functionality. The Wizard controlled Pepper remotely through a computer (running Python script) to provide voice prompts and a screen display when needed.

1) Video Script: To prevent the raters (especially for those raters in interviews) from recognizing the actresses acted it, the contents of the conversation in two videos were set to be different. We divided the six topics which older people with dementia often talked about in their daily lives that we learned in the previous survey into two scripts. The two scripts were constructed with the same four-phase structure, and the three topics contained in each script were also similar in complexity to ensure comparability between both test settings.

1) Simple greetings. At the beginning of each video, the conversation partner entered the room where the older person was sitting. She sat across from the older person after they greeted each other.

2) Talking about three topics associated with the older person’s family. In the intervention video, the older person talked with the conversation partner about her family on the topics of a) the gift her grandson gave her last week, b) all her grandchildren, and c) a vacation with her husband several years ago. However, she had difficulty recalling what the gift was, the names of her grandchildren, and where they went on vacation. Every time memory failure occurred, the older person turned to Pepper for help by touching the robot’s hand. Pepper then provided her with memory assistance through voice and screen display, thus allowing the conversation to continue. In the control video, the older person talked with her conversation partner alone about 1) her daughters’ jobs, 2) the dinner her family took her to at a restaurant last week, and 3) the place where she lived in the past. Similarly, she had memory failure in the key information on each topic. The conversation partner comforted her and moved to the next topic when the older person tried and failed several times to recollect the memories.

3) Asking for an object. In each video, the older person asked the conversation partner to get an item for her. The older person touched Pepper’s hand for help in the intervention video when she could not make the partner know what she wanted. Pepper then showed a series of photographs of everyday objects that she often used and asked her whether the item she wanted was among them [see Fig. 2(a)]. However, in the control video, although the older person tried very hard to describe what it was, the partner could not determine what she wanted because she was unable to express it clearly [see Fig. 2(b)].

4) Repeated questions. In the intervention video, the older person asked twice about the current time. One was after...
Fig. 2. Screenshots of the stimulus videos. The intervention setting (top) and the control setting (bottom).

the short greetings, whereas the other was after talking about family. Pepper answered both questions. Instead of asking about time, the older person asked twice about the weather outside in the control video. This time, the conversation partner was the one who answered these repeated questions.

2) Instructions and Stimulus Validation: To help the actress portray an older person with dementia, we first provided her with two sample scripts describing two real conversations between patients with dementia and their partners. These sample scripts described the speech characteristics in detail, including the struggle to get certain words out, difficulties in recalling past activities, vague and rambling language, and a slow pace with longer pauses. An example selected from the sample script describing the word-finding difficulty is as follows:

Patient: “Err… Kyra brought me a … She gave me a … you know.”
Partner: “She is so nice. What’s that?”
Patient: “A … I like it … She bought for me.”

The use of sample scripts helped to guide the actress in her manner of speaking. In addition, on the basis of her observation of patients with dementia for more than 40 years, the actress imitated and added patients’ facial expressions and body gestures during both conversations in the stimulus videos.

Two clips from each stimulus video were randomly selected and shown to seven caregivers in the Vitalis Berckelhof Home for the Elderly in Eindhoven. Each clip had an approximate duration of 1 min. None of these caregivers had met the actress before, nor did they know about this study. Four of them had more than 19 years of experience caring for people with dementia, whereas the remaining three caregivers have also cared for people with dementia for 3, 4, and 12 years, respectively. Before the debriefing indicating that she was an actress, the caregivers were asked to assess the cognitive impairment of the older person in the video clips, with the question Q9 in Table I. Their assessments indicated that all of them believed that the older person had dementia, with ratings from 1 to 3, \( M = 2.29, SD = .76 \). Thus, the actress’s performance was satisfactory.

D. Questionnaire

Participants’ perceptions of the older person and the communication were quantified with a 20-item questionnaire after the video was watched. The questionnaire was designed to include two constructs: 17 items assessed the participants’ perception of the older person, and the remaining three items assessed their perception of the communication. Participants were asked to indicate their agreement with each statement on the questionnaire by using an 11-point bipolar Likert Scale ranging from \(-5\) to \(+5\). For most items, \(-5\) and \(+5\) represented “strongly disagree” and “strongly agree,” respectively.

For those in the intervention group, there was an additional question, Q21: “Please rate the relationship between this robot and this older person.” Participants were asked to rate from \(-5\) (the robot has dominance over this older person) to \(+5\) (this older person has dominance over the robot).

1) Perception of Older People:

Of all 17 items used to measure the older person’s perception, nine items assessed her communication ability and performance, and the remaining eight items assessed her personal image.

Perceived communication ability and performance: Based on Douglas’s La Trobe Communication Questionnaire (LCQ) [34], Savundranayagam’s Communication Problems Scale [35], and Corrigan’s Self-stigma of Mental Illness Scale [36], we selected and modified nine items to assess the communication ability and performance of the older person, shown as Q1–Q9 in Table I. We changed the presentation of the original items to adapt to this study (e.g., Q2 was modified from “Need a long time to think before answering the other person” of LCQ).

These items described several common characteristics of speech and language in people with dementia, including word-finding difficulties, memory failure, prolonged pauses, and cognitive impairment shown in communication. Q1–Q8 were negative
The quality of communication questions of the Older Person’s Perceived Personal Image

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q10</td>
<td>This older person like socializing with people.</td>
</tr>
<tr>
<td>Q11</td>
<td>This older person is in control of this situation.</td>
</tr>
<tr>
<td>Q12</td>
<td>This older person can live independently.</td>
</tr>
<tr>
<td>Q13</td>
<td>This older person is self-confident.</td>
</tr>
<tr>
<td>Q14</td>
<td>This older person is competent.</td>
</tr>
<tr>
<td>Q15</td>
<td>This older person is lonely.</td>
</tr>
<tr>
<td>Q16</td>
<td>This older person is vulnerable.</td>
</tr>
<tr>
<td>Q17</td>
<td>This older person shows strong willingness to communicate with others.</td>
</tr>
</tbody>
</table>

The sample to variable ratio was 10. The Kaiser Meyer Olkin (KMO) value was 0.78, which was well above the acceptable limit of 0.50. The sample to variable ratio was 9.78. These nine items showed high internal consistency, with a Cronbach’s α of .78. The Kaiser Meyer Olkin (KMO) value was 0.78, which was well above the acceptable limit of 0.50. The sample to variable ratio was 9.78.

Perceived personal image: Q10–Q17 were used to assess the personal image of the older person, as shown in Table II. Personal image significantly affects how others treat a person in a social environment. Dementia-related stereotypes often include incompetence, vulnerability, lack of autonomy, loss of independence, and self-imposed isolation [37], leading to prejudice and discrimination against older people with dementia. Therefore, the items in Table II were designed to measure whether the robot could improve these negative stereotypes of people with dementia. Of all these items, Q15 and Q16 were negative questions. A lower rating indicated a better perception of the older person. The others were positive questions. These items were found to have decent reliability and construct validity, with Cronbach’s α = .70, KMO = .73. The sample to variable ratio was 10.

2) Perception of Communication: The quality of communication usually depends on whether one party in a conversation can receive and understand the message in the same way that the other party sent the message. According to Schulz Von Thun [38], messages communicate at two levels: content and relationship. The content level refers to facts and appeals transferred in the message. Facts are the information on the event or people that the sender sends to the receiver; thus, item Q18 in Table III was used to assess the amount of information that the interaction partner received from the older person. Appeals related to the desire or command that the sender intends, e.g., the older person asked for an object from her partner in both stimulus videos. Item Q19 was used to measure the partner’s perceived understanding of the older person’s appeal. The relationship level includes the estimation of the mutual relationship between the sender and receiver, which is important for the continuation of communication. Thus, Q20 was used to assess the partner’s perceived willingness to communicate with the older person.

These three items were positive questions, in which a higher rating indicated a more positive perception of the communication. Acceptable reliability was found, with Cronbach’s α = .68. The sample to variable ratio was 29.33. However, a KMO of .47 indicated that these items were not suitable for use together to measure the perception of communication. Thus, we will test and discuss them separately.

E. Statistical Analysis

The intervention video contained an assistant robot, while the control video did not. Therefore, the following three independent variables were analyzed: 1) robot. 2) rater gender (female vs. male). 3) rater experience of living/working with older people with dementia (with experience vs. without). Specifically, rater experience was measured by the question, “Do you have any experiences of living/working with an older person with dementia? If yes, how long?”

In addition to the above, we planned to control for potential effects due to rater age carefully. To do so, we used rater age as a covariate in the analyses reported below.

To assess the effects of the independent variables, three-way MANCOVAs were conducted for all items in the questionnaire (considering the covariate). As a result, all significant effects are reported (an α of p < .05 was applied to the variables), and Bayer Factor analysis [39] was performed to express confidence in the hypothesis.

Additionally, all interviews were transcribed, and conventional content analysis [40] was performed. Quotes selected from the transcripts were grouped to form major categories and subcategories. Two coders were involved in the subsequent collaborative coding session to guarantee the reliability of the coding results. All the quotes were divided equally over the two coders. They presented their initial coding results to each other and discussed until reaching an agreement on a combined set of categories.

III. Results

A. Quantitative Results

1) Effects on the Perception of Older People: Perceived communication ability and performance: Overall, the ratings on all items of perceived communication ability and performance in the intervention group were lower than those in the control group, as shown in Fig. 3. Using Pillai’s trace, we found that the observer’s perception of the older person’s communication ability and performance was significantly improved with assistance by the robot. Pillai’s trace = .36, F(9, 71) = 4.52, p < .001. With additional univariate analyses (compared with those in the control group) the ratings of the intervention group showed that the older person had significantly fewer deficits hindering the
Similarly, raters who viewed the intervention video rated all items of the perceived personal image of the older person more favorably than those who viewed the control video (see Fig. 4). The robot significantly improved how the raters perceived the personal image of the older person, with a Pillai’s trace = .34, $F(8, 72) = 4.65, p < .001$. Univariate analyses indicated an effect of the robot in making the older person appear more social ($Q_{10}, F(1, 79) = 16.09, p < .001$), more in control of the situation ($Q_{11}, F(1, 79) = 13.05, p < .001$), more independent ($Q_{12}, F(1, 79) = 8.28, p < .005$), more self-confident ($Q_{13}, F(1, 79) = 6.65, p < .012$), more competent ($Q_{14}, F(1, 79) = 17.46, p < .001$), and less vulnerable ($Q_{15}, F(1, 79) = 4.31, p ≤ .041$). As shown in Table V, extremely strong evidence of an effect of the robot was found in $Q_{10}$, $Q_{11}$, and $Q_{14}$, with BF$_{01} < .01$. Very strong evidence and moderate evidence of an effect of the robot were observed in $Q_{12}$ and $Q_{13}$, respectively. Additionally, $Q_{16}$ and $Q_{17}$ were inconclusive. A BF$_{01} = 4.60$ provided moderate evidence of an absence of an effect of the robot in improving the perception of loneliness ($Q_{15}$).

A significant multivariate effect was found for gender. Pillai’s trace = 0.20, $F(8, 72) = 2.29, p ≤ .030$, thus indicating a difference in the perceived quality of communication between males and females. Compared with females, males tended to give more negative ratings in most questions. Univariate analysis showed that males perceived that the older person had more difficulty in being in control of the situation ($Q_{11}, F(1, 79) = 6.72, p ≤ .011$) and had significantly less willingness to communicate with others [$Q_{17}, F(1, 79) = 4.96, p ≤ .029$]. Additionally, no significant main or interaction effects were found for the rater experience.

Table IV: Ratings and BF$_{01}$ for the Older Person’s Perceived Communication Ability and Performance

<table>
<thead>
<tr>
<th>No.</th>
<th>The Intervention Group Mean</th>
<th>Std dev</th>
<th>The Control Group Mean</th>
<th>Std dev</th>
<th>BF$_{01}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Q_1$</td>
<td>.77</td>
<td>2.31</td>
<td>1.50</td>
<td>2.66</td>
<td>2.57</td>
</tr>
<tr>
<td>$Q_2$</td>
<td>1.50</td>
<td>1.97</td>
<td>2.16</td>
<td>2.78</td>
<td>.85</td>
</tr>
<tr>
<td>$Q_3$</td>
<td>3.45</td>
<td>1.84</td>
<td>4.23</td>
<td>1.49</td>
<td>.72</td>
</tr>
<tr>
<td>$Q_4$</td>
<td>1.07</td>
<td>2.12</td>
<td>3.30</td>
<td>2.02</td>
<td>.00</td>
</tr>
<tr>
<td>$Q_5$</td>
<td>2.09</td>
<td>1.67</td>
<td>3.41</td>
<td>1.78</td>
<td>.022</td>
</tr>
<tr>
<td>$Q_6$</td>
<td>3.16</td>
<td>1.45</td>
<td>3.30</td>
<td>1.88</td>
<td>5.72</td>
</tr>
<tr>
<td>$Q_7$</td>
<td>.59</td>
<td>2.55</td>
<td>2.77</td>
<td>1.94</td>
<td>.001</td>
</tr>
<tr>
<td>$Q_8$</td>
<td>.02</td>
<td>2.48</td>
<td>1.00</td>
<td>3.07</td>
<td>1.76</td>
</tr>
<tr>
<td>$Q_9$</td>
<td>.68</td>
<td>1.71</td>
<td>2.02</td>
<td>1.39</td>
<td>.005</td>
</tr>
</tbody>
</table>

Table V: Ratings and BF$_{01}$ for the Older Person’s Perceived Personal Image

<table>
<thead>
<tr>
<th>No.</th>
<th>The Intervention Group Mean</th>
<th>Std dev</th>
<th>The Control Group Mean</th>
<th>Std dev</th>
<th>BF$_{01}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Q_{10}$</td>
<td>3.45</td>
<td>1.41</td>
<td>2.07</td>
<td>1.65</td>
<td>.003</td>
</tr>
<tr>
<td>$Q_{11}$</td>
<td>.68</td>
<td>2.18</td>
<td>1.73</td>
<td>2.55</td>
<td>.00</td>
</tr>
<tr>
<td>$Q_{12}$</td>
<td>-1.11</td>
<td>1.72</td>
<td>-2.61</td>
<td>2.29</td>
<td>.029</td>
</tr>
<tr>
<td>$Q_{13}$</td>
<td>.41</td>
<td>1.96</td>
<td>-.91</td>
<td>2.28</td>
<td>.14</td>
</tr>
<tr>
<td>$Q_{14}$</td>
<td>.07</td>
<td>1.65</td>
<td>-1.86</td>
<td>1.90</td>
<td>.00</td>
</tr>
<tr>
<td>$Q_{15}$</td>
<td>-2.0</td>
<td>1.88</td>
<td>.14</td>
<td>2.20</td>
<td>4.60</td>
</tr>
<tr>
<td>$Q_{16}$</td>
<td>2.16</td>
<td>2.01</td>
<td>2.93</td>
<td>2.32</td>
<td>1.69</td>
</tr>
<tr>
<td>$Q_{17}$</td>
<td>3.45</td>
<td>1.41</td>
<td>2.93</td>
<td>1.53</td>
<td>1.70</td>
</tr>
</tbody>
</table>

Fig. 3: Average ratings on perceived communication ability and performance.

Fig. 4: Average ratings on perceived personal image.
In the extra item Q21, in only the intervention group, the raters perceived that the older person had dominance over the robot by giving ratings averaging 1.90 (SD = 2.01). No significant effects were observed for rater gender or experience.

2) Effects on the Perception of the Communication: The intervention group raters Q18 to Q20 much more favorably than those who viewed the control video (see Fig. 5). Univariate analyses indicated an effect of the robot on improving others’ understanding of what the older person was talking about [Q18, F(1, 79) = 17.67, p < .001], as well as their appeal [Q19, F(1, 79) = 4.29, p ≤ .042]. Others’ willingness to communicate with the older person was also believed to be significantly promoted by the robot [Q20, F(1, 79) = 10.77, p ≤ .002]. As shown in Table VI, very strong evidence and strong evidence of an effect of the robot were observed in Q18 and Q20, respectively, whereas Q19 was inconclusive. No significant main or interaction effects were found for participant gender and experience.

B. Qualitative Results

A total of 12 interviews with 12 randomly selected raters (R1–R12) from Snowball sampling were transcribed, and a conventional content analysis approach was performed. Total 264 quotes were examined to identify major categories and subcategories related to raters’ perceptions toward the older person and the communication and the design suggestions.

1) Effects on the Perception of Older People: Perceived communication ability and performance: 26 quotes mentioned fluency and 14 quotes related to logic in expression. When the robot did not assist the older person, all raters reported that she had severe difficulties in expressing herself, e.g., “She often hesitates. … She is very stumbling over words (R10)” and “She struggled to determine what to say. … It is limited to whatever she could recall (R2).” Four raters said that the older person switched the topic too soon. Two raters indicated that there was too much “repeating” by the older person.

However, the raters reported that the older person was more “expressive” when assisted by the robot, e.g., “She definitely used a wider vocabulary … and could maneuver the conversation (R10)” and “She conveys her message more easily and completely (R2).” Five raters observed higher efficiency in the older person’s expression. Four raters indicated that the older person’s words sounded more “believable”, e.g., “She is still uncertain, but less … and [the] robot is a kind of proof for her words that would make her story believable (R3).” Raters also reported the older person’s improvement in topic maintenance: e.g., “She spends more time talking about a topic in-depth … less topic jumping (R3).”

Perceived personal image: 34 quotes describe her personality and 29 quotes mentioned the older person’s emotion. Without the robot, the word most often used by raters to describe the older person was “frightened”, e.g., “She’s pretty frightened and closing herself. … feels nervous to express [herself] (R1).” Four raters also reported that the older person was “shameful,” “a bit angry,” “in bad mood,” or “defensive.” Almost all raters agreed that the older person had low independence and capability. Four raters mentioned negative emotion toward the older person: e.g., “I’m scared that I’ll offend them by asking something that they cannot remember (R3).”

However, the word they frequently used to describe the older person when assisted by the robot became “confident”: e.g., “She is more confident in knowing the details of what happened and keep[ing] conversation going (R3).” Five raters described that the older person was more “competent” and “independent” with the robot: e.g., “She’s more in control of her own fragility and disability (R10).” Additionally, six raters considered the older person to be more “happy,” “friendly,” “approachable,” and “open” to the conversation partner. Notably, some raters described the older person as “respectable”: e.g., “We know she has dementia, but we also know she’s not afraid of it, and she’s very self-aware (R9).” “She takes the robot, (that) means she wants to be independent. … That’s respectable, and we shouldn’t make fun of her (R10).” Similarly, R3 and R12 described the older person as “cool” and having “good acceptance of the outside world.”

Additionally, most raters believed that the older person could not be perceived as lonely in both videos because she had some activities (e.g., went out for dinner) with her “big family” that “didn’t sound like she was very lonely (R2).” Half the raters believed that the older person looked less lonely in the intervention video because “she could be understood.”

2) Effects on the Perception of the Communication: We collected 67 quotes toward the communication, which consists of three sub-categories: the amount of information conveyed (31 quotes), communication efficiency (22 quotes), and emotions in communication (10 quotes).

Six raters claimed that the conversation in the control video did not “convey too much information from the older person.”
Four raters used the words “stuck”: e.g., “The conversation stuck for several minutes. … She cannot go elaborate any further (R11).” Most raters reported that the conversation lacked logic: e.g., “They have a loop in conversation and cannot get out (R1)” and “many topics don’t have [an] ending (R4).” They indicated that the conversation in the control video was “inefficient”: e.g., “They waste a lot of time understanding each other … but there is not always a solution for understanding (R8).” Three raters bluntly said that the conversation was too “difficult”: e.g., “The conversation stagnated every time she couldn’t remember words (R3).”

In contrast, when describing the conversation in the intervention video, the most frequently used word was “deeply.” Almost all raters reported that more information and feeling were transmitted in the conversation when the robot was there. The conversation became more “fluently” and “understandable.” Interestingly, R12 said that the conversation was more “natural” when the robot was involved. Similarly, five raters reported that the conversation became “comfortable,” “relaxed,” and “fun”: e.g., “The conversation is more fun because of photos on [the] tablet (R2).”

3) Robot’s Function and Appearance: We collect 43 quotes regarding the robot’s function and 21 quotes related to the appearance.

All raters claimed that the memory assist function of the robot was very “helpful” for both the person with dementia and the conversation partner: e.g., “[The] remind function is good for other people to understand her and to help her… Answer repeated questions function is also good, (because) not everyone has enough patience. … Both sides would have [a] more pleasant experience of conversing and have more to talk about (R1).” Specifically, R9 and R10 claimed that the robot was “especially useful” for the conversation partner unfamiliar with the patient. Eleven raters reported that if someone in their family were to have dementia, they would like to buy such a robot for the person, but they would consider the cost (R2, R3, R6, and R12) and whether the person would accept the robot (R3, R5, R6, R8, and R11). Only R9 said that she would not buy the robot because “I could do what he (the robot) could do.”

We asked all raters to imagine themselves as people with dementia and told them that the robot would accompany them for many years to collect information to provide a better memory aid after their dementia symptoms appear. Most raters claimed that they should decide for themselves what information would be gathered. However, two raters did not mind the device automatically collects their information: e.g., “I feel like we’re already wearing such devices. We have phones on ourselves 24/7; they collect data about us even when we are sleeping (R2).”

When choosing between a tangible robot and an application on the smartphone, assuming that both have the same functions in providing memory support, most raters preferred the tangible robot: e.g., “When using [the] robot, it could feel like there is a third person in the room (R3).” “It’s hard for you (the patient) to see how an application could help you. But with a physical being, you could understand more (R10)”

When asked what kind of tangible form the robot should take, four raters preferred an animal shape because they thought it could provide a “warm” and “cozy” feeling. Others preferred a humanoid shape because it gives a natural appearance to the conversation. R1 and R10 suggested that the robot should be made smaller in size and easier to move. R2 suggested making the robot the same height as that of a seated older person.

IV. DISCUSSION

We performed a video-based study to explore the feasibility of communication assistant robots for older people with dementia. As a complement to live interactions, video-based studies have their particular values in HRI research [41]. Live HRI is usually costly and has a relatively small number of participants. Additionally, for those live trials with a robot, the robot’s behaviors might be different with different participants, which causes difficulty in comparing [42]. In contrast, video-based HRI allows greater control for the same robot behaviors and could reach larger numbers of participants. Thereby it is suitable to test initial assumptions with less cost [41], as we did in this study.

We ensured the credibility of stimulus videos from the contents of scripts and the performance of actresses. First, the topics in the scripts were all typical ones in the actual daily lives of older people with dementia. The two scripts were constructed with the same structure to ensure comparability, and the topics included were similar in number and complexity. Second, the actress’s 40 years of caring for patients with dementia and the sample scripts’ guidance ensure her performance in the stimulus videos. Finally, the credibility of stimulus videos was additionally checked with experienced caregivers in the Vitalis Berckelhof Home for the Elderly in Eindhoven.

The difference between this study and previous studies is that our research explores a new role of robots as a communication assistant for older people with dementia in their face-to-face communications with others. Our assistant robot aims to promote more communications between older people with dementia and other people, thereby reducing social isolation. Our research also differs from previous work by assessing social robots from a third-person perspective. Not only because their perception would significantly affect dementia patients’ acceptance of assistant robots but also affect their willingness to communicate with dementia patients. Our findings may contribute to the further design of such robots.

A. How Do Communication Assistant Robots Influence Other People’s Perceptions of Older People With Dementia?

Previous studies have confirmed stigmatization associated with assistive technology use among people with acquired disabilities [43]. Dementia-related stigmatization usually includes three different levels of belief (stereotypes, e.g., danger, lower competence, or loss of self-esteem), emotion (prejudice, e.g., fear, anxiety, disgust, pity, or sympathy), and behavior (discrimination, e.g., social distance, particularly avoidance) [44]. According to stigma theory, negative belief leads to prejudice, which, in turn, leads to discrimination [44]. However, as revealed by both the quantitative and qualitative results, our assistant
robot significantly improved other people’s perceptions of the older person with dementia in terms of her communication ability and performance, as well as her perceived personal image. In agreement with the stigma theory, the improvement in beliefs further led to changes in emotions and behaviors due to the robot. The qualitative results demonstrated emotional reactions to older people with dementia were improved. Descriptions of the older person were changed from “scary” to “respectable” and “cool.” The quantitative results showed that other’s willingness to communicate with older people was also believed to increase accordingly. These positive effects were stable and were not affected by the observer gender or whether they had experience in contact with people with dementia.

First, the quantitative results showed that the robot improved the observers’ perceptions of older people’s communication ability and performance. As one of the most common symptoms of dementia, word-finding difficulty usually diminishes social confidence and leads to isolation [45]. However, our robot was designed to assist when such difficulties arise. Second, the qualitative results revealed that the older person was perceived to have a more extensive vocabulary because the robot reminded her of the right words when she was stuck. The vocabulary improvement enabled her expression to be more in-depth and more straightforward, with less topic switching and easier comprehension by others.

Additionally, the reduced difficulty in finding words also contributed to significantly more fluent expression. Less hesitation, pausing, or repetition was perceived in the communication, thus further increasing the communication efficiency. The older person conveyed richer information and, more importantly, believability, not only because she appeared more confident in her statement but also because the photographs displayed by the robot served as validation for her words. These all help explain the quantitative findings that the robot significantly improved older people’s believability and perceived cognitive function.

Second, the quantitative results demonstrated strong evidence of robots positively affecting others’ perceptions of older people’s self-image. Especially in making the older person appear more social, more in control of the situation, more independent, more self-confident, and more competent. In agreement with Bandura’s theory [46] that self-confidence comes from self-belief in one’s ability to execute the desired behavior successfully, the older person in our research was perceived as confident when the robot reinforced her communication ability. This self-confidence made others more positively perceive her independence and competence in life. Meanwhile, her improved competence and reduced fear in expression also made her appear more cheerful, expressive, and social. Specifically, the qualitative results showed the high-tech impression of a robot made the older person seem more open to the outside world and more capable of using advanced technology.

Additionally, although the robot assisted the older person, she did not seem like a puppet controlled by the robot. Confidently, the older person dominated the robot. All these aspects contributed to a more positive personal image of the older person and made others more willing to communicate.

B. How Do Communication Assistant Robots Influence Other People’s Perceptions of the Communication Between Older People With Dementia and Their Conversation Partners?

The quantitative results revealed that when the robot assisted the older person, the communication was improved at both the content and relationship levels. The qualitative results also support this conclusion.

Specifically, on the content level of communication, the quantitative results showed a significant effect of the robot in improving others’ understanding of the older person. The qualitative results further revealed that with the help of the robot, both sides in the conversation could transmit more information more smoothly. They could discuss more details and extend the topic in natural ways. In addition to more information, more feelings could also be shared because the robot’s reminders decreased meaningless repetition and allowed the conversation to proceed further. The messages of the older person were conveyed faster and were better understood in a shorter time.

Additionally, the communication became more relaxed and active on the relationship level when the robot joined the conversation. The older person engaged more in discussion with the robot and appeared more comfortable because of less worry about getting stuck. When the robot displayed photographs on the tablet and gave reminders in a childlike voice, there was more fun in the conversation. The partner had less pressure to talk to the older person with dementia because there was no need to worry about what questions might cause memory failure. Additionally, there was no need to take responsibility for helping the older person find the right words, thus further contributing to relaxation. These aspects explain why robots can significantly increase people’s willingness to communicate with older people with dementia.

C. Design Considerations

Based on the qualitative results on the robot’s function and appearance, we present design implications in this section.

1) Robot Function: Our robot was designed to assist when people with dementia have memory failure in face-to-face conversations with others. This situation is similar to the function we demonstrated via a Wizard-of-Oz simulation in our robot prototype, equipping a robot with a natural language understanding system. The robot had sufficient knowledge about the user (such as past life, lifestyle, or speaking habits) can automatically provide prosthetic memory (PM, [47]) when the user forgets what to say. There have been studies on lifelogging and episodic memory recall [48], [49]. Kalnikaité and Whittaker [47] have indicated that the main reason that previous PM devices (e.g., note-taking systems or digital voice recorders) are often abandoned by users is the low efficiency in manually retrieving information from the PM. However, our robot was designed to address this problem through automatic retrieval. Another consideration in designing the robot function is to update the communication assistant strategy automatically as dementia progresses. Enable the robot to understand what the users and conversation partners are talking about, detect the time when the user has memory failure, and then the robot could provide appropriate reminders when triggered.
The more the user forgets, the more reminders the robot can provide. Hand touch could be used as a natural trigger when the user’s dementia is not too severe, while a long time without a response from older people could be used as another more automatic trigger when they forget how to interact with a robot as dementia worsens. The form of the reminders can also be automatically updated. Suppose the frequency of a user’s memory failure increases, thus indicating that the dementia is worsening. In that case, the robot could increase the volume, lower the speed of reminders, and increase the sizes of photographs shown in the tablet, thus compensating for the shortcomings of common memory assistant strategies, such as electronic/non-electronic memory books [50], [51] and interactive reminiscence games [52], [53].

To better provide memory support for owners with dementia, the robot must make its owner trust it [54] and have sufficient knowledge about the owner. This challenge requires the robot to collect information about its owner daily to form a personal external memory. This information gathering should start before the owner develops symptoms of dementia. At that time, the device need not be a robot. A small wearable device or even a smartphone would be sufficient for gathering daily information. Privacy issues apply, such as what kind of information is worth collecting and how to store the collected information safely. According to our qualitative results, it is best to provide users with suggestions on what information will be gathered and make the final decision.

Our focus in this study was on the new roles of robots as communication assistants. However, this role is not mutually exclusive with two other previously studied roles of robots as conversation partners and telepresence agents. These roles can compensate for one another. With a mechanism to switch automatically among these three roles, the robot could provide better support for people with dementia.

2) Robot Appearance: The first consideration in designing the appearance of the communication assistant robot is to avoid bringing negative attention to the user and appears like a part of the conversation. However, it won’t get negative attention if the robot looks like some other daily necessity, such as a smartphone. Our results revealed an interesting point: when choosing between a tangible robot and an application on the smartphone, assuming that they have the same functions in providing memory support, most people preferred the tangible robot over the smartphone application. Furthermore, because compared with the smartphone, the robot offers a more natural conversation and allows people with dementia to more easily understand how they could get help from the robot. Therefore, it’s helpful for the robot to mimic the human interaction behaviors in conversations, such as turning around to examine the person speaking, using a hand touch to trigger help, etc.

However, as in previous work [55], our results indicated disagreement in what tangible form the robot should have. We found that an animal shape was considered cozier, but a humanoid shape was considered more natural in the conversation scenario. More research on the appearance, including the size of the robot, is necessary. Providing the user with multiple appearance options appears reasonable to adapt to different scenarios, such as outdoor or indoor.

D. Limitations and Future Work

Our results were produced under an ideal experimental environment. Every time the user had a memory failure in our intervention video, the robot always immediately provided the correct reminder. However, robots cannot wholly avoid mistakes. Therefore, the effects of the robot’s mistakes on the user and conversation partner must be studied. For example, when the robot provides the wrong reminder or fails to detect a user’s memory failure, how will others perceive the user and the communication? If a mistake occurs, what should the robot do to minimize the adverse effects? More research on mistakes in robot service design is needed.

Compared with the conversations in our intervention videos, the success of communication with dementia people in real life depends on many factors. Even if a robot is present to provide memory support, communication may still be unsuccessful. Because we did not address such situations in our research, they should be investigated in future studies.

In our intervention video, hand touch interaction was used to trigger memory support from the robot. But it probably is not suitable for those older people with severe dementia. In general, the triggering method should update as dementia progresses. More research on the trigger and user tests is needed here.

Additionally, we tried to measure the perception of communication from the content level and relationship level. However, the three items adopted in this study did not meet the requirement of construct validity. Therefore, we have analyzed them separately, but they should be fixed in future work.

ACKNOWLEDGMENT

We are grateful to Ank Keereweer and Jingcai Liu as actresses. We thank Sylvia Van Aggel and Maikel Zee (Vitalis Berckelhof, Eindhoven, The Netherlands) for full support in knowledge of dementia.

REFERENCES
