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In-person vs Remote HRI: A Comparative Study of Robot Facilitated Dance with Older Adults in Long-term Care

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***Abstract*— As the global older population increases, a number of older adults need assistance in their daily lives. Social robots can be used to provide support for a number of activities including facilitating dance sessions. Research in this field has mainly considered physically embodied robots collocated in the same environment with the users. However, the experience of older adults with different robot presence conditions has not yet been explored. Robot presence can play an important role in investigating social human-robot interactions (HRI) with this vulnerable population. In this paper, we present a novel preliminary HRI study that investigates and compares how older adults' interaction behaviors vary during dance sessions facilitated by social humanoid robots in both in-person HRI and remote HRI conditions. Our study was conducted for the duration of a week with residents living in a long-term care home. Participation rates were higher in the in-person condition. However, caregiver questionnaire results found no statistically significant difference in engagement and enjoyment of the older residents between the two robot presence conditions. The caregivers observed the residents engaged and enjoying dancing with both the in-person and remote robot during the dance sessions. Our study is the first to show the potential of using remote social HRI to provide interventions to older adults.**

I. INTRODUCTION

By 2030, the population of the world that will be 65 years of age and older is projected to be one billion people [1]. This will result in an increase of the number of people that will need cognitive and physical support in their daily lives [2], [3]. In particular, approximately 20% of older adults between the ages of 65 and 74 years old and 40% of men and 53% of women over the age of 85 need assistance with activities of daily living [2]. With the increasing challenges that long-care homes face such as staff shortages and increased workload [4], socially assistive robots can assist this population with activities of daily living such as meal preparation and eating [5]–[7], dressing [8]–[10], exercise facilitation and monitoring [11]–[13], as well as rehabilitation for stroke recovery [14]–[16] and cardiac disease prevention and recuperation [17]–[19].

The aforementioned applications have all considered physically embodied robots co-present or collocated with the users in the same environment, defined as in-person human-robot interaction (HRI). However, social HRI can also occur when the robot and user are spatial separated and not collocated in the same physical space [20], defined as remote HRI. There have only been a handful of remote HRI studies with socially assistive robots [21]. This form of HRI has specifically been explored during the COVID-19 pandemic, when human social distancing regulations were limiting human-human interactions [22], [23].

HRI research has also investigated the different roles of robot presence in various applications including education and cognitive games [24]–[26], health habits in terms of exercise, diet, and mental well-being [27], and instruction following [28], [29]. Outcomes such as enjoyment [24], engagement [26], [27], and task performance [25], [28] were compared between in-person HRI and remote HRI conditions. In [30], a review of in-person and remote social HRI studies found that collocated robot interactions had a more positive effect on behavior measures as well as attitudinal measures. Our own meta-analysis study [20] quantitively analyzed in-person HRI and remote HRI with social robots for healthcare applications and identified a positive effect with respect to physical robot presence on perceptions and attitudes of users, and efficacy.

To-date, comparisons between in-person and remote HRI studies have been conducted mainly with adults below 65 years of age [24]–[29], [31] or children [32]–[34]. However, for the vulnerable older adult population, for which social robots have shown potential cognitive and physical benefits, a comparison between these two HRI types has not yet been explored. Furthermore, all comparison studies have considered only a single interaction between a social robot and a user in a one-to-one setting and have not considered multiple interactions nor interactions in a group setting.

Robot facilitated dance is an example of a group-based activity that can consist of multiple interaction sessions. In general, robots have been used to facilitate dance for older adults in long-term care settings [35]–[37]. Older adults have expressed acceptance and positive attitude towards these robot facilitated dance activities [35]. Namely, they have found them to be engaging [37], useful [36], easy to use [36], and enjoyable [36].

In this paper, we present the first HRI study to investigate and compare the interactions of older adults with an in-person and a remote social humanoid robot to determine if there are differences in overall experiences for this population in these two HRI conditions. The social robots autonomously facilitate dance sessions with groups of residents in a long-term care home over the course of one week. Namely, we explore the following novel research questions. Do older adults have:

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RQ1: higher participation rates for the in-person HRI condition versus the remote HRI condition?
RQ2: higher levels of engagement and enjoyment in the in-person HRI condition than in the remote HRI condition?
RQ3: higher level of group interactions during the in-person robot dance sessions than the remote robot dance sessions?

II. Related Works

Herein, we discuss the existing literature on: 1) user studies comparing in-person HRI and remote HRI, and 2) robot facilitated dance studies with older adults.

A. In-person HRI and remote HRI

There have been a handful studies comparing both in-person and remote HRI conditions primarily with different age groups of adults under 65 years of age [24]–[29], [31]. For example, in [24], a mobile robot was used to coach young adults in the Tower of Hanoi cognitive game in both in-person and remote conditions. In the in-person condition, the robot was placed in front of the participants, whereas in the remote condition, the robot was displayed on a screen. Results found that the in-person HRI condition was perceived as more watchful, helpful, and enjoyable. In [27], the nursebot Pearl conducted interviews regarding exercise, diet, and mental health. The in-person HRI was found to be more engaging, influential, and anthropomorphized.

In addition to health-related activities, these robots have also been used for tutoring and to provide instructions. For example, in [25], the chick-like Keepon robot was a tutor for nomogram puzzles. A higher game performance was reported in the in-person condition. In [28], the upper-torso robot Nico instructed adults to complete a set of tasks (e.g., greeting, placing a book) in a home-like environment. Higher task success rates and lower reaction times were observed in the in-person condition. This condition was also perceived as more natural than the remote condition. In [29], the humanoid robot RoboThespian was used in a shopping mall to provide instructions, greetings and ask shoppers to take photos with it. In the remote condition, the robot was shown on an LED screen on top of a stand. The robot was observed to have higher proactivity, reactivity, and commitment in the in-person condition. In [31], a Nao robot verbally provided instructions for solving a shape-matching game. Nao had a higher influence on participants' decisions in the in-person condition, with higher faith, attachment, and credibility. More recently in [26], Nao was also used as a tutor for teaching a second language to young adults. Higher learning outcomes and engagement were reported for the in-person condition.

A handful of studies have also investigated how children react to in-person and remote HRI conditions with similar results [32], [34]. For example, in [32], children interacted with the Nao robot in a motion-following game. Children with prior robot experience interacted with the Nao robot in both conditions, but less so in the remote condition. Whereas children with no prior robot experience, did not interact with the robot in the remote condition at all. In [34], the Robovie R3 robot was a sign language tutor to children. The children had higher performance accuracy in the in-person condition.

However, there have also been several other studies that have found no differences between in-person and remote HRI conditions [33], [38]–[41]. For example, in [33], the robot Kaspar played a drumming game with children in both the in-person and remote conditions. Results showed no significant difference in game accuracy between the two HRI conditions. In [38], Nao was used as an exercise instructor for adults. No statistically significant difference in robot's intelligence, anthropomorphism, animacy, likeability, and users' anxiety was found between the two conditions. In [39], the toy size robot Zenbo was used to provide instructions on a set of tasks (e.g., taking a photo, weather reporting) in both the in-person and remote conditions. No statistically significant differences were also reported between the two conditions in terms of experience, perception of, and attitude towards the robot. In [40], the Nao robot was also used to coach adults in a visual searching task. No statistically significant differences were found in compliance, inspection time and accuracy for the two presence conditions. Lastly, in [41], adults were asked to recognize the facial expressions, head orientations and gaze directions displayed by the social robot Ryan. No difference in recognition accuracies was found for the two HRI conditions.

More comprehensive comparison between in-person and remote HRI have been summarized and analyzed in [20], [30]. In [30], 39 comparative studies were qualitatively reviewed for social HRI. It was concluded that physical robot presence has more positive responses from users in terms of both behavior measures (e.g., performance, persuasion, physiological arousal) and attitudinal measures (e.g., attitudes towards robots, enjoyment, attraction to the agent and trust). More recently, we conducted a meta-analysis on 14 different studies on social robots on the role of robot physical presence [20]. The meta-analysis results indicate that the benefit of in-person HRI is more significant in the outcomes of user perceptions and attitudes, and efficacy, but not for overall positive experience. In addition, subgroup analysis suggested that participant age and activity type could potentially influence outcome differences between remote HRI and in-person HRI.

B. Robot Dance for Older Adults

There have been only a few HRI studies on robot facilitated dance with older adults [35]–[37]. In our previous pilot study [35], the Nao and Pepper social robots facilitated dance sessions in a long-term care home with older adults. Based on questionnaire results, both staff and residents found the robot facilitated dance useful, easy to use, safe and enjoyable. In [36], a human-sized wheeled robot with two arms was used as a dance partner for an older adult for simple forward/backward dance steps. Experiments with older adults in a lab environment found that they considered the robot useful, easy to use and enjoyable as a dance partner. In [37], the Nao robot served as a dance instructor for older adults living at a long-term care home. Residents sat surrounding the robot in a circle and were asked to follow the robot's dance movements to music. The participants danced or sang along with the robot and stated that they found the robot to be interesting.

(a) Example of in-person HRI dance (Groups 1,2,3) **(b) Example of remote HRI dance (Groups 4,5,6)**

Figure 1. Robot Conditions for HRI Robot Facilitated Dance Study

C. Summary

To date, both in-person HRI and remote HRI have been conducted and compared with either adults [24]–[29], [31], [38]–[41], or children [32]–[34] in single participant settings. In general, the majority of the conducted studies found preference for in-person HRI with respect to enjoyment [24], engagement [26], [27] and task performance [25], [28]; while a few studies found similar positive results for the two HRI conditions [33], [38]–[41]. However, the role of robot presence has not been investigated yet with older adults. Furthermore, the aforementioned studies have not considered group settings consisting of social interactions between the people in the group. Therefore, in this research, we investigate and compare, for the first time, if a robot's physical presence influences older adults' participation and behaviors in robot facilitated dance. We choose the specific recreational activity of dance, as older adults have shown acceptance, engagement and positive attitudes towards robot facilitated dance in long-term care settings [35]–[37]. Furthermore, there are significant health benefits for older adults with respect to dance in terms of both physical (e.g., muscle endurance and strength, balance and agility) [42] and cognitive (e.g., attention, concentration and memory) [43] health.

III. Robot Facilitated Dance Study

We conducted a one-week preliminary HRI study to investigate the impact of robot physical presence on older adults during robot-facilitated dance sessions. The study took place with residents at a long-term care home located in Toronto, Canada. Two different HRI conditions were explored: 1) in-person HRI (Fig. 1(a)) and 2) remote HRI (Fig. 1(b)) using humanoid social robots. Using a between-subjects design, the participants were randomly placed into the aforementioned conditions. Ethics approval was obtained from the University of Toronto Ethics Committee and written consent was obtained for each participant.

A. Participants

Twenty-three residents were recruited for our study with an age range of 67 to 97 years ($\bar{x} = 84.35,\ \sigma = 8.41$). Fifteen women and eight men participated. The participants were recruited through conducting a demo of the robot-facilitated dance activity at the home, distributing posters around the home and through staff invitations.

B. Study Design

Group sizes ranged from 3 to 5 persons, with a total of 6 groups for each experimental condition.

1) In-person HRI Condition

For the in-person HRI dance sessions, the humanoid robot was collocated with the participants, as shown in Fig. 1(a). The collocated robot was located at the front of a recreational room in the long-term care home, approximately 3 meters from the participants. Music was played by the robot using its on-board speakers. A computer was connected to the robot through a local network and was used to control the robot's dance movements.

2) Remote HRI Condition

For the remote HRI dance sessions, the humanoid robot was located in our research lab at the University of Toronto. A webcam was used to provide live video of the robot to the participants, Fig. 1(b). A large 60 inch screen in the recreational room displayed both the video and audio feed of the robot using Zoom teleconferencing software [44]. The remote robot in our research lab was connected through a VPN network to a computer in the recreational room to control the robot's dance movements and music.

3) Robot Dance Design

The staff and residents of the long-term care home recommended thirty-three songs for the robot to dance to for our study. These included songs by Elvis Presly, the Beatles, ABBA, Neil Diamond, Wham, etc. The robot's corresponding dance movements for each individual song was generated from a set of motion primitives developed in our previous work [35], which first detects the beat times of a song using the Librosa library [45] and then randomly selects a sequence of motion primitives to match the detected beat times. The dance movements of the robot were programmed in Python [46].

C. Experimental Procedure

The interaction sessions were staggered, with each group participating in a dance session every second day during the week, with a total of 3 sessions. Each session was 30 minutes.

At the beginning of a session, the robot first greeted the participants and invited them to dance with it. The robot played seven songs in a single dance session while dancing. During the dance sessions, the activities coordinator and care staff would observe the entire session to provide feedback to the researchers via a caregiver questionnaire. The residents'

behaviors were also recorded by a camera placed at the front of the room during the sessions for analysis.

D. Measures

The measures used in this study are: 1) participation rate for each session and each condition, and 2) caregiver observed participants' engagement, enjoyment, and group interactions as reported in a caregiver questionnaire, Table I.

The participation rate is a common measure to assess interest in a particular activity [47], [48]. In this study, the participation rate is computed as the percentage of residents attending a full dance session with respect to the total number of available residents assigned to the given condition.

Caregivers' observations have been used as a valuable resource to provide feedback on socially assistive robots [49]–[51]. Caregivers have daily knowledge of the residents' behaviors, moods, and personality traits. This is particularly useful for older adults with cognitive impairments, who may have difficulty providing their own feedback/opinions [52]. We developed a 5-point Likert scale caregiver questionnaire to be filled by care staff for each resident, consisting of questions on: 1) individual engagement [52] and enjoyment [51] and 2) group interactions and engagements [52]–[54].

TABLE I CAERGIVER QUESTIONNAIRE.

Q1 (individual engagement): How much of the sessions was the participant engaged in the dance activity?				
1 (None of the time)	2 (Less than half the time)	3 (About half)	4 (More than half the time)	5 (All the time)
Q2 (individual enjoyment): The participant enjoys the dance sessions.				
1 (Strongly disagree)	2 (Somewhat disagree)	3 (Neutral)	4 (Somewhat agree)	5 (Strongly agree)
Q3 (group interaction): During the dance sessions, group members interacted with each other.				
1 (Strongly disagree)	2 (Somewhat disagree)	3 (Neutral)	4 (Somewhat agree)	5 (Strongly agree)
Q4 (group engagement): It was observed that the participant is more willing to engage in conversations with other residents or staff.				
1 (Strongly disagree)	2 (Somewhat disagree)	3 (Neutral)	4 (Somewhat agree)	5 (Strongly agree)

IV. IN-PERSON VERSUS REMOTE HRI RESULTS

In total, 13 participants participated in the in-person HRI condition and 10 participated in the remote HRI condition. Non-parametric Mann-Whitney U (MWU) tests were conducted to determine statistical significance between the in-person and the remote conditions.

A. Participation Rate

The participation rates as percentages for the in-person HRI versus remote HRI conditions for session 1 (S1) to session 3 (S3) are presented in Fig. 2. For S1, the participation rates were r=91% (in-person) and r=56% (remote); for S2 participation rates were r=91% (in-person) and r=75% (remote); and for S3 participation rates were r=88% (in-person) and r=79% (remote). The in-person participation rates were consistent across all three sessions. The remote S1 had a lower overall participation rate as three participants left in the middle of the dance session as they required personal care. However, the rates were higher for the remote condition for S2 and S3. In general, the in-person condition had a higher participation rate.

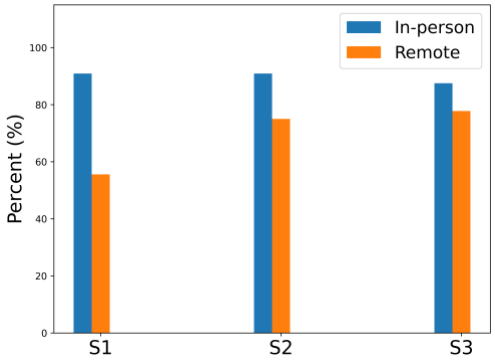

Figure 2. Participation Rate for Each Session (S).

B. Engagement and Enjoyment

Individual engagement was defined in our study to consist of any one of the following actions: 1) dancing along with the robot, and 2) focus of attention towards the robot (gaze and head pose). The boxplot for Q1 is presented in Fig. 3. In the remote condition, the majority of the participants were engaged in the dance activity for more than half of the dance sessions as noted by the care staff, remote condition: $\tilde{x} = 4.0$, $IQR = 1.0$. For the in-person condition, the care staff found the participants to be engaged for half of the dance sessions, $\tilde{x}$=3.0, IQR=1.5. However, a MWU test found no statistically significant difference for Q1 between the in-person and remote conditions: $\boldsymbol{U}$=13.0, $\boldsymbol{p}$=0.16.

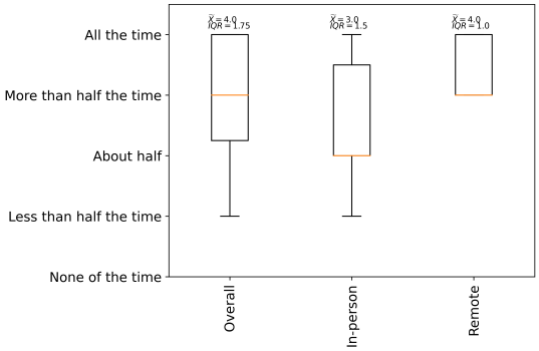

Figure 3. Boxplot for Q1 Individual Engagement.

Individual enjoyment was defined as singing, laughing, and smiling with the robot. The boxplot for Q2 (individual enjoyment) is presented in Fig. 4. The majority of the participants enjoyed the dance sessions with the robot with similar levels for both HRI conditions (in-person: $\tilde{x} = 4.0$,

$IQR = 0.5$, remote: $\tilde{x} = 4.0$, $IQR = 0.5$). No statistically significant difference was found for enjoyment between the in-person and remote conditions: MWU ***U***=15.5, ***p***=0.31.

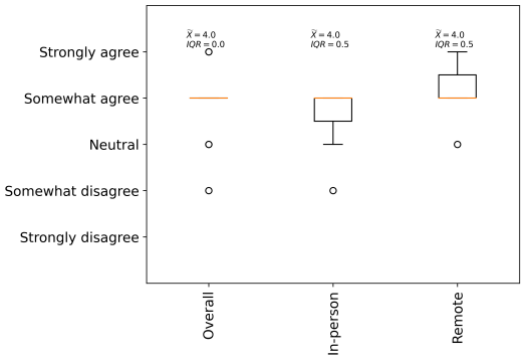

Figure 4. Boxplot for Q2 Individual Enjoyment.

B. Group Interactions and Engagement

Group interactions were defined as both verbal and non-verbal interactions between other residents in the group or between residents and care staff. This included smiling, talking, and touching. As presented in the boxplot in Fig. 5, the staff reported minimal group interactions for the members of each group in both conditions (in-person: $\tilde{x} = 2.0$, $IQR = 2.0$, remote: $\tilde{x} = 2.0$, $IQR = 2.0$). A MWU test found no statistically significant difference for Q3 between the in-person and remote conditions: ***U***=24.5, ***p***=1.0.

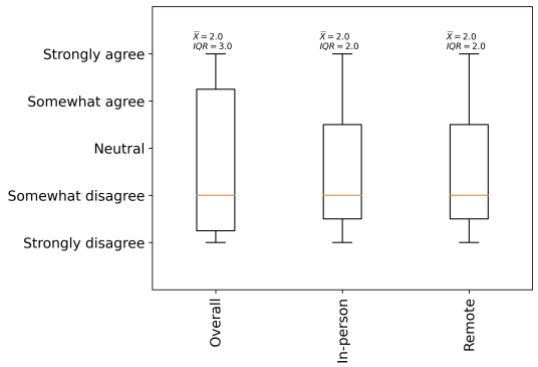

Figure 5. Boxplot for Q3 Group Interaction.

Group engagement was defined as verbal interactions between the residents themselves and with the staff. Group engagement was also observed to be low during the dance session for both HRI conditions (in-person: $\tilde{x} = 2$, $IQR = 0$, remote: $\tilde{x} = 2.0$, $IQR = 0.0$). The boxplot for Q4 is presented in Fig. 6. A MWU test found no statistically significant difference for Q4 between the in-person and remote HRI conditions: ***U***=21.0, ***p***=0.71.

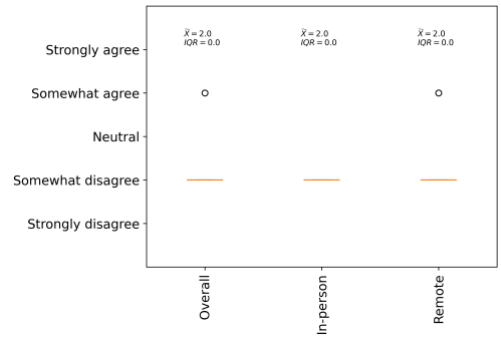

Figure 6. Boxplot for Q4 Group Engagement.

In general, participants showed limited overall group interactions and engagement during the dance sessions as observed by the staff. We also analyzed the video recordings for each condition and session. Namely, we identified the number of songs during which there was social interactions between the participants or between the participants and the care staff. We defined social interactions to be instances where a participant was observed speaking to, touching, or smiling at another person. The results are presented in Table II. We also observed limited social interactions in all the groups across all the sessions, with the exception of Group 1 and Group 4. There was consistent interaction throughout Group 1 for all three sessions and for Group 4 in S2 and S3 with both resident-to-resident and resident-to-staff interactions. It was also noted that verbal social interaction (e.g., speaking) occurred more often than the non-verbal social interactions (e.g., smiling), with the residents commenting on the music, or the robot's dance movements and expressions, or singling along together.

TABLE II . OBSERVED SOCIAL INTERACTIONS IN DANCE SESSION VIDEOS

Condition	**Group number**	**S1**	**S2**	**S3**
In-person	1	7/7	7/7	7/7
	2	0/7	0/7	1/7
	3	1/7	1/7	0/7
Remote	4	1/7	7/7	7/7
	5	2/7	0/7	2/7
	6	0/7	0/7	0/7

V. DISCUSSIONS

Herein, we discuss how the study results address the research questions for the role of presence in social HRI with older adults.

A. RQ1: Do older adults have higher participation rates in the in-person HRI condition than in the remote HRI condition?

Although a higher participation rate was observed in the in-person condition throughout the dance sessions, the participation rate in the remote condition did increase to 75% and higher for the S2 and S3. These rates are consistent with other (non-robot facilitated) physical activity interventions with older adults, which have typically range from 60% to 90% [47].

B. RQ2: Do older adults have higher levels of engagement and enjoyment in the in-person HRI condition than in the remote HRI condition?

We found no statistically significant differences with respect to individual engagement and enjoyment. Our previous meta-analysis on in-person and remote HRI [20] identified user age group and activity type as two moderators for the effect due to physical presence. Therefore, our results could be due to the potentially lower cognitive abilities of older adults living in long-term care, which can make them less sensitive to robot presence [55]. As for the activity, an

HRI study with a social robot as an exercise instructor for adults also found similar results with no statistically significant difference between the in-person and remote conditions for such measures as level of intelligence, likeability, and anxiety towards the robot [38].

C. RQ3: Do older adults have higher group interactions during the in-person robot dance sessions than remote robot dance sessions?

Older adults' personality traits can play an important role in their performance and interactions in group activities [58]. It was noted by caregivers and in the session videos that a number of residents in Groups 1 and 4 were more expressive, outgoing and talkative, having extrovert personality traits. Therefore, this increased the group interactions in these two groups compared to the other groups. It would be noteworthy to conduct further research on the influence of older adult personality traits and group interactions as well as social robot personality traits and their influence on participant interactions during robot facilitated dance activities. Furthermore, social distancing between participants due to COVID regulations during the dance sessions could have affected group interactions.

D. Study Considerations

The length of our preliminary study was one-week with three repeated interactions. This is longer than the existing HRI studies on comparisons of robot presence type, which have only consisted of one interaction session with each HRI condition. However, our study is shorter than some long-term HRI studies with a single robot presence condition [56]. There may be other factors that influence our results during long-term interactions.

We conducted our study during the COVID-19 pandemic, which required social-distancing rules to be applied in the long-terms care home. Therefore, this limited the number of participants in our study and dance session groups.

In S1 for the remote HRI condition, three participants did leave the session at various times after it had started. This was not related to the robot or the dance session itself and was due to personal reasons (e.g., family member showed up to see them unexpectedly, the need to use the restroom).

VI. Conclusions

In this paper, we present the first HRI study that directly compares in-person HRI and remote HRI with an autonomous humanoid social robot engaging older adults in a stimulating dance intervention. Participation rates were higher in the in-person dance sessions, however, results from our preliminary study from caregiver questionnaires and video analysis showed similar individual enjoyment and engagement, and group interactions in both HRI conditions, with no statistically significant differences. This study shows the potential of using remote HRI with humanoid robots to provide interventions to older adults. This is of particular benefit for long-term care homes which have limited number of staff. These robots have the potential to be simultaneously used in both the in-person and remote conditions to engage more residents. Furthermore, these robots can be shared across different locations, without having to transport the robots to multiple sites. Future research will include long-term interactions for both conditions for the dance activity. Furthermore, we will explore the influence of robot presence type on other assistive activities for older adults.

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