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Using a Social Robot to Promote Interaction Among Older Adults at a Day Center in Japan: a Pilot Study Based on Sociograms

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Abstract

This pilot study examines whether the introduction of a social robot can enhance social interaction among older adults attending a day care center in Japan. A quasi-experimental within-subject design with repeated measures was implemented across four group sessions held over one month: one baseline session without the robot and three sessions with the robot. Using structured observation, sociomatrices, and sociograms, the study analyzed human-human, human-robot, and human-robot-human interaction episodes during guided group activities. Network indicators such as in-degree, out-degree, mean degree, closeness, betweenness centrality, and authority were compared across sessions to assess changes in relational structure. Brief descriptive interpretation was also complemented by field notes and post-session user evaluations. The baseline session showed a low-density network with a small active core and several peripheral participants. After the robot was introduced, the volume of exchanges increased and the networks became more cohesive, with higher mean degree values and shorter relational distances. Overall, the findings suggest that the robot functioned not only as an object of direct interaction but also as a mediator that

stimulated human-robot-human dynamics and helped activate less connected members of the group. Despite these promising results, the study should be interpreted cautiously due to its pilot nature, small sample, and single-site design. The findings support the potential of social robots as facilitators of group engagement in adult day care settings and highlight the usefulness of social network analysis for examining interactional change in gerontechnology research.

Keywords: Social robot, older adults, daycare, social interaction, Human-Robot-Human Interaction

1 Introduction

Society faces one of its greatest challenges: rapid population aging. Population aging is not inherently a negative phenomenon; rather, it reflects improvements in healthcare and life expectancy. However, it also creates important social challenges, as many older adults experience loneliness, reduced opportunities for social participation, and an increase in dependency. Evidence suggests that limited opportunities for meaningful social interaction are associated with poorer mental health, functional decline, and reduced quality of life among older adults[1]. These findings highlight the importance of promoting social participation as a fundamental component of active and healthy aging. Adult day care centers provide valuable community settings that foster daily social interaction and peer support among older adults. However, sustaining meaningful social engagement over time remains a significant challenge, highlighting the need for innovative approaches that support continued participation in these environments [2, 3].

Social participation in later life should not be understood solely as physical presence in shared activities, but as the opportunity to build meaningful relationships and develop a sense of belonging within a social network. Evidence shows that social participation is associated with better psychological well-being, lower feelings of loneliness, and better health indicators among older adults[4]. From this perspective, day care centers represent especially relevant community spaces, as they offer shared routines that can strengthen peer contact[5]. However, the availability of these services does not guarantee sustained, balanced, or inclusive social interaction, as patterns of centrality, passivity, and social isolation often persist within participant groups [6].

In recent years, gerontechnology and social robotics have attracted growing interest as complementary approaches to supporting the well-being and participation of older adults. Social robots have shown potential to improve psychosocial well-being among older adults; however, existing evidence remains methodologically heterogeneous and findings are not yet conclusive [7, 8]. A systematic review on the effectiveness of social robots for older adults reported promising improvements in interaction and engagement, but also emphasized limitations such as small sample sizes, risk of bias, and the need for more robust studies. More recent studies in care settings suggest that

social robots can support not only direct human–robot interaction, but also interpersonal interaction by facilitating communication and engagement within group settings [9, 10].

Despite this progress, an important gap remains in the literature: much of the existing work has focused on subjective outcomes, technology acceptance, or individual effects, while studies that closely examine how a group's interaction network is reorganized when a social robot is introduced into an everyday adult day care context remain less common [11]. This limitation is significant because the practical value of these devices lies not only in whether one person interacts with the robot, but also in their capacity to act as relational mediators and trigger human-robot-human interaction dynamics. Analyzing who interacts with whom, which nodes occupy central positions, how exchanges circulate, and whether new relational bridges emerge makes it possible to understand more precisely the robot's actual social role within the group [12, 13].

In this context, this pilot study investigates whether introducing a social robot into an adult day care center in Japan enhances social interaction among older adults. An observational approach based on sociomatrices and sociograms was used to compare interactions before and after the robot's introduction. More specifically, the study examines whether the robot promotes Human–Robot–Human Interaction (HRHI) by increasing the frequency and reciprocity of peer interactions and by fostering a more evenly distributed interaction network during group activities. Based on this, two hypotheses are proposed: first, that the rate of peer human-human interactions will be higher in sessions with the robot than in the baseline session; and second, that the robot will function as a social mediator by facilitating connections between participants within the interaction network.

2 Objectives and Hypotheses

The present study has one main objective: to determine whether the presence and use of a social robot in an adult day care center enhances social interaction among older adults compared with a baseline condition without the robot. To this end, we define one specific objective: to analyze whether the introduction of the robot facilitates human-robot-human (H-R-H) interaction by increasing the frequency and reciprocity of interactions among participants during group activities at the adult day care center.

Based on the existing scientific literature, two hypotheses are proposed:

H1. The rate of human-human (H-H) peer interactions will be higher in sessions with the robot than in the baseline session without the robot.

H2. The robot will serve as a mediating link that facilitates interaction among participants within the interaction network.

3 Social Robot Prototype Used

3.1 General concept and functional purpose

The prototype is a tabletop social robot designed under the conceptual framework of Human-Robot-Human Interaction (HRHI), whose main function is to act as a social

mediator or facilitator that promotes shared attention and reduces barriers to social participation in groups of older adults. Its morphology is based on symmetry, a critical design decision intended to enable equitable multidirectional interactions and prevent the exclusion of users seated at the periphery of a shared table. The robot measures 238 mm in height, 273 mm in width and 246 mm in depth (not including the tail extension). Structurally, it is divided into three functional components, which can be seen in Fig. 1:

- Head: Ellipsoid in shape, it incorporates two "eyes" as visual cues of attention. According to [14], these elements are essential for generating "shared gaze" that initiates interaction and fosters trust. It has a horizontal rotation of ±180 and a vertical rotation of ± 20.
- Body: It provides stability and serves as the main surface for tactile contact.
- Tail: A dynamic element with 180 mobility, designed to elicit curiosity and physical contact. Following [15], the design relies on minimal and abstract movements to communicate emotional states, which increases social appeal without requiring a complex human-like appearance.

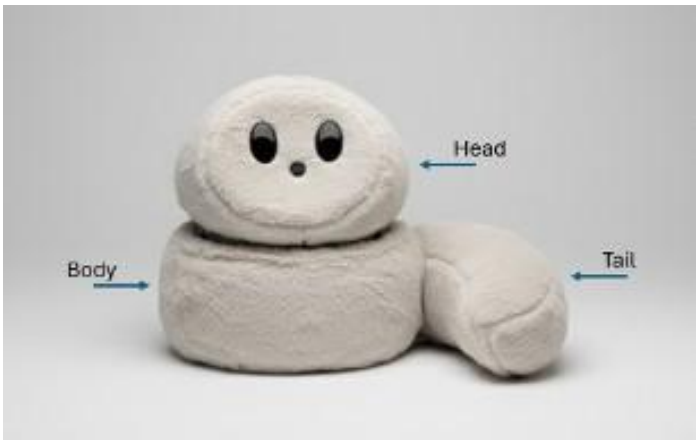


Fig. 1 Final prototype of the tabletop social robot

The manufacturing process combined digital fabrication techniques with hand-finished details. The internal structure and main shells were designed in Autodesk Fusion 360 and manufactured through three-dimensional printing in ABS plastic. For the head joints, 3 mm aluminum parts cut by laser were used to ensure mechanical precision. To guarantee "tactile safety" and reduce older adults' psychological resistance toward technology, the rigid structure was covered with a 5 mm layer of polyurethane foam and finished externally with a soft mocha-colored polyester fabric. Control was centralized in an ESP32 microcontroller that manages three high-precision servo motors to execute the mediating movements.

3.2 Control system during the intervention

During the intervention, the robot had six predetermined movements, which expressed different emotions toward the participants. Although the robot has only two moving parts (head and tail), combining them by modifying speed, movement angles, and the number of times those movements are repeated can generate different expressions. The robot's ranges of movement can be seen in the diagram in Fig. 2, and the specifications for each movement are shown in Table 1.

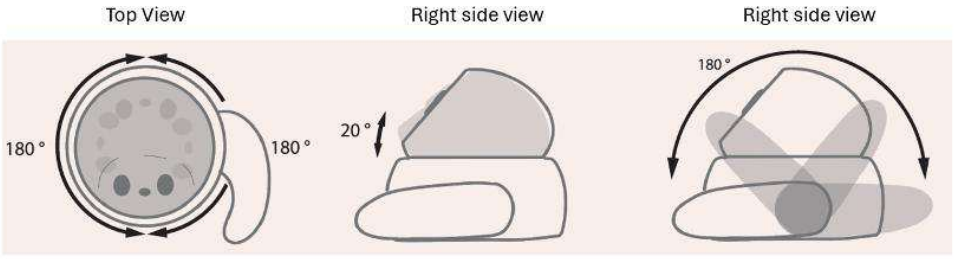


Fig. 2 From left to right: top view showing the head movement from left to right over 180°; right-side view showing the head's vertical movement of 20° from top to bottom; right-side view showing the tail's movement over 180°.

4 Methodology

4.1 Design

The study used a quasi-experimental within-subjects design with repeated measures and structured observation. The same group of older adults participated in four group sessions of approximately 30 minutes over one month: one baseline session without the robot (Session A) and three sessions with the social robot (Sessions B, C, and D). All sessions were conducted during the same time slot to minimize variations related to daily routines and participant fatigue. Each session included a guided group activity with a comparable duration and structure, including moments of open interaction among participants [16–18].

4.2 Participants

The study was conducted in the common room of the Sasarindo adult day care center. This space was appropriate because it provided a familiar environment for participants, with suitable lighting and acoustic conditions.

Because attendance varied across weeks, the number and composition of participants were not fully identical across the four sessions. Therefore, the analysis distinguished between the total number of attendees in each session and the subgroup of participants who were present across repeated observations. For transparency, the

Table 1 Movement patterns implemented in the social robot prototype.

Movement Name	Meaning / Purpose	Robot Part	Movement Description	Angle Range	Speed	Frequency
Neutral	Initial posture / Calm	Head	Moves slowly and slightly from left to right.	±15°	Slow	Continuous
Greeting	Greeting or recognition expression	Head	Tilts the head forward and returns, resembling a bowing action.	−20° → 0°	Slow	Once
Invitation	Invite silent users	Tail	Moves slowly up and down.	±10°	Fast	Three times
Empathy	Show empathy or agreement	Tail + Head	Tail: rapid ±10° movement. Head: slight ±15° movement.	±10°/ ± 15°	Fast	Twice
Happy	Show joy or positive emotions	Tail + Head	Combination of head movements, left–right and up–down. Moves the tail rhythmically at ±15°.	±15°	Fast	Three to four times
Goodbye (bye–bye)	End of conversation / Farewell signal	Tail	Moves quickly up and down twice at ±20°.	±20°	Fast	Twice

number of participants present, absences, and changes in group composition were reported for each session. This allowed the network indicators to be interpreted in light of participant variation. Efforts were made to maintain the same group across sessions, except in cases of unavoidable absence.

The inclusion criteria were regular attendance at the center, the ability to participate in group activities, and signed informed consent. Individuals whose sensory or behavioral conditions prevented safe participation, or who declined to be observed or recorded, were excluded. Each session also included one center facilitator, one social robot operator, and two to three observers responsible for the systematic recording of interactions.

4.3 Ethical considerations

The study was conducted after receiving approval from the relevant institutional ethics committee. Participants received an explanation of the study objectives and provided informed consent for observation and, where applicable, video and audio recording. They were informed that they could withdraw at any time without any consequences for the care they received. Data were anonymized using alphanumeric codes and stored securely, with access restricted to the research team. Audiovisual recordings were

scheduled to be deleted once the analysis had been completed and the necessary review period had elapsed.

4.4 Equipment and procedure

The sessions were conducted in the same room, and the arrangement of chairs and tables was kept as consistent as possible. The group was also placed in similar positions in each session. The social robot was positioned at the center of the table, where it was visible to all participants and could function as a shared focus of attention to encourage interaction among them. The facilitator followed a standardized script in all sessions, controlling the pace of the activity while the robot performed predefined behaviors intended to stimulate participation without targeting any specific participant. Video and audio recordings were used to complement the observers' notes and to support the verification of inter-observer reliability.

In the first week, baseline Session A was conducted without the robot. During this session, participants took part in a regular group activity organized by the center, and a 30-minute block of interaction was observed, including interaction episodes and the group's overall dynamics. At the end of the first week, Session B introduced the social robot to the group and incorporated it into the group activity; another 30-minute block of interaction was recorded. In the third week, Session C followed the same structure with the robot, with slight variations in the activity while maintaining the same overall format. This allowed the observation of changes after repeated exposure to the robot. Finally, Session D was conducted in the fourth week using the same format. In all sessions, the same guidelines regarding duration, facilitator script, and robot position were applied, and absences, technical incidents, or changes in group composition were recorded.

4.5 Data collection

An overt observational research method was followed, in which the researchers introduced themselves and explained the reason for the observation. The primary unit of analysis was the interaction episode, recorded within standardized 30-minute observation blocks in each session. The same time segment within the activity was selected whenever possible to improve comparability across sessions and reduce the influence of routine fluctuations or transitional moments at the beginning and end of the activity.

A structured observation matrix was used in which observers recorded episodes of interaction among participants and with the robot, both in real time and from the video recordings. In addition, field notes were collected on the context, relevant incidents, and brief verbatim quotations to provide richer qualitative information for the observations. Alongside this, a brief post-session Likert-type scale was administered to participants to assess their perception of interaction and the robot's role in the group dynamic. The covariates recorded included the size of the group present, the staff-to-participant ratio, the level of ambient noise, the specific content of the activity, and the room layout and physical characteristics [19].

4.6 Analysis method

To analyze the interaction network, sociomatrices and sociograms were constructed for each observation block to record who interacted with whom in H-H, H-R, and H-R-H episodes.

The unit of analysis was the interaction episode. An interaction was coded when a participant or the robot initiated a clearly directed verbal, gestural, or tactile communicative act toward an identifiable target, followed by either an observable response or sustained shared attention.

Based on these matrices, interaction network density and basic measures of participant centrality were calculated. These indicators were used to compare the baseline session without the robot with the sessions involving the robot. In line with graph theory and centrality measures, these indicators provide insight into patterns of connection, communication, and group cohesion [20–23]. Differences between sessions were analyzed descriptively and complemented by a brief thematic analysis of the field notes to identify illustrative examples. To support coding reliability, a subset of the recordings was double-coded. The post-session evaluations were also analyzed descriptively [24, 25].

5 Results

In the first session, corresponding to the baseline condition without the robot, interactions were observed among six participants, coded as A1–F1. The resulting sociogram showed a low-density network in which only some members assumed a clearly active role. The analysis of in-degree and out-degree indicated that A1, B1, and F1 presented the highest number of incoming and outgoing ties, whereas C1 and E1 remained relatively peripheral within the interaction network. Overall, this produced a pattern characterized by a small active core and several peripheral participants.

Table 2 Network centrality measures for the first session.

Id	In-	Out-	Degree	Eccentricity	Closeness	Harmonic Closeness	Betweenness Centrality	Authority
A1	2	2	4	3.0	0.571	0.708	1.0	0.577
B1	2	2	4	3.0	0.571	0.708	4.0	0.428
C1	1	0	1	0.0	0.000	0.000	0.0	0.000
D1	1	1	2	1.0	1.000	1.000	4.0	0.228
E1	0	1	1	4.0	0.416	0.516	0.0	0.000
F1	2	2	4	2.0	0.666	0.750	6.0	0.656

As we see in Table 2 the baseline network shows that A1 played a predominant role. Interactions initiated by A1 with the rest of the group, together with reciprocal responses, especially between A1 and B1, accounted for most of the exchanges. F1 participated more actively than other participants, but their role served more as a bridge among participants than as a primary initiator of interaction. By contrast, C1 and E1 were only occasionally involved, either as recipients of interactions or as

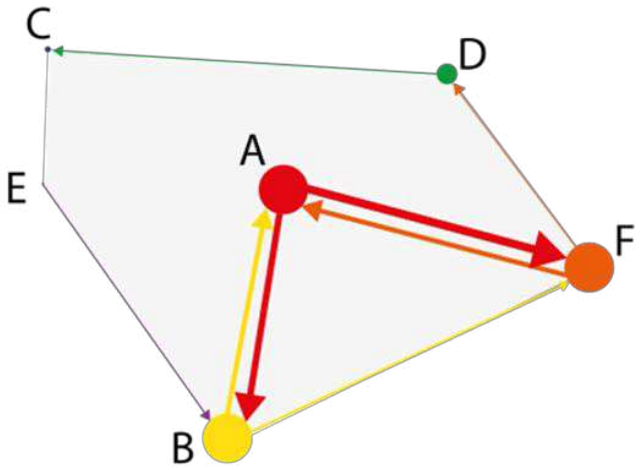


Fig. 3 Sociomatrix of Session 1

isolated initiators, while D1 maintained a low level of participation, although with greater connectivity than C1 and E1.

The edge weights also show that the most frequent interactions were concentrated around A1 and B1. Figure 3, illustrates this pattern, with C1 and E1 showing fewer connections to the rest of the network. This points to an unequal group structure in terms of participation. Overall, the first session represents the group's baseline interaction pattern without the robot, characterized by a low volume of interactions and moderate connectivity among a small number of nodes, while others remained largely isolated. This configuration serves as the starting point against which the robot sessions are compared, in order to assess whether the presence of the device helps redistribute centrality and increase the participation of less connected participants [26, 27].

In the second session, the robot was introduced for the first time. As we see in table 3 the net-work included six participant nodes and one robot node, R2. Compared to the baseline session, the directed and weighted network showed a higher volume of exchanges. The in-degree and out-degree data indicate that R2 and A2 had the highest number of incoming and outgoing connections. Both became central nodes in the group's inter-action network. In contrast, the remaining participants showed lower degree values, occupying intermediate positions, although their levels of connectivity were higher than those observed in the first session [20].

R2 emerged as the most connected node, with the highest values for both incoming and outgoing connections and a total weighted degree of 12, followed by A2 (11) and B2 (5). This pattern is consistent with the emergence of a hub-like structure, in which one node concentrates a large share of the interaction flow. In the context of social robotics, the central position of the robot is consistent with its design as a facilitator

Table 3 Network centrality measures for the second session.

ID	In-degree	Out-degree	Degree	Eccentricity	Closeness	Harmonic Closeness	Betweenness Centrality	Authority
A2	5	6	11	1.0	1.0	1.0	7.33	0.44
B2	3	2	5	2.0	0.6	0.66	0.5	0.35
C2	2	2	4	2.0	0.6	0.66	0.0	0.29
D2	2	2	4	2.0	0.6	0.66	0.0	0.29
E2	2	3	5	2.0	0.66	0.75	0.0	0.29
F2	3	2	5	2.0	0.6	0.66	0.33	0.39
R2	6	6	12	1.0	1.0	1.0	10.83	0.50

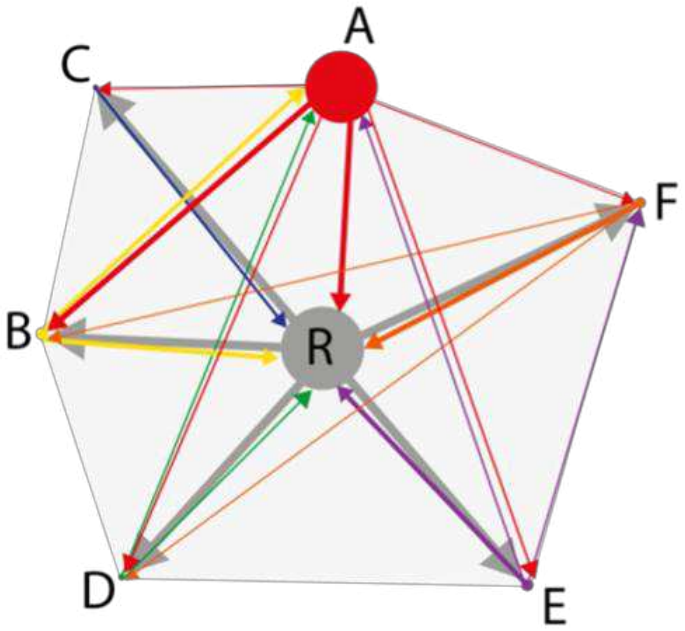


Fig. 4 Sociomatrix of Session 2

of group dynamics and resembles findings from studies in which robots act as activity facilitators, receiving and generating a large number of interaction turns [10, 18].

The eccentricity, closeness, and harmonic closeness metrics also placed R2 and A2 in strategically central positions, with maximum structural closeness values (1.0). This indicates that they were positioned at the shortest distance from the other nodes within the network. Figure 4 shows us that his profile is consistent with nodes that may facilitate the circulation of interaction and participation within the network, a key aspect in the literature on cohesion and social capital in groups of older adults. The remaining nodes showed closeness values between 0.6 and 0.75, suggesting that these participants were less directly connected to the group conversation, but had more opportunities for indirect connection through the presence of the robot [26].

The centrality of the interconnection reinforces this interpretation. R2 reached the highest value (10.83), followed by A2 (7.33), indicating that both often lay on the shortest paths connecting other participants. This configuration suggests that the robot was not only the receiver and sender of numerous messages, but also acted as a mediator through which many connections between participants appeared to be facilitated. This pattern is similar to that identified in studies on social robots that function as facilitators of conversation among older adults (6). Nodes such as B2, C2, D2, E2, and F2 showed null or very low betweenness values, suggesting that they played a less central role in connecting different parts of the network.

In terms of authority, both R2 and A2 obtained relatively high values, indicating that they occupied relevant positions within the pattern of incoming connections. This dual centrality positioned the robot and participant A2 as the main reference points within the network, while the rest of the group showed varying levels of participation and connectivity. The sociogram of Session 2 shows this more concentrated, star-like structure, with R2 and A2 at the center and the remaining participants organized around them, in contrast to the more fragmented and less cohesive network observed in the baseline session.

In the third session, also conducted with the robot present, the network again included six participant nodes. It showed a highly connected structure in which the robot retained a prominent role while sharing that prominence with several participants. The centrality measures for Session 3 are summarized in Table 4.

Table 4 Network centrality measures for the third session.

ID	In-degree	Out-degree	Degree	Eccentricity	Closeness	Harmonic Closeness	Betweenness Centrality	Authority
A3	3	4	4	3.0	0.45	0.53	0.25	0.25
B3	3	5	8	1.0	1.0	1.0	0.58	0.36
C3	3	4	7	2.0	0.83	0.9	2.25	0.45
D3	4	2	6	2.0	0.83	0.9	0.33	0.39
E3	4	4	8	2.0	0.62	0.7	4.0	0.41
R3	4	5	9	1.0	1.0	1.0	3.58	0.42

This session showed a more evenly distributed pattern of participation than the previous sessions, with participation spread across a broader set of nodes. This pattern, in which participation was shared between the robot and active human subgroups, is consistent with literature on technology-mediated interaction dynamics in aging contexts, where repeated exposure to the device may support a more shared pattern of participation [18].

Degree metrics show that the robot (R3) retained the highest value (9), followed closely by B3 and E3 (8), while C3 and D3 (7 and 6) also showed substantial participation, and A3 remained at a more modest level (4). This configuration, with the robot as the most connected node and several participants showing similar degree values, suggests that the robot may have supported a higher overall level of participation within the group without monopolizing the interaction. In the initial observation block, interactions were distributed more evenly than in the baseline session, with B3

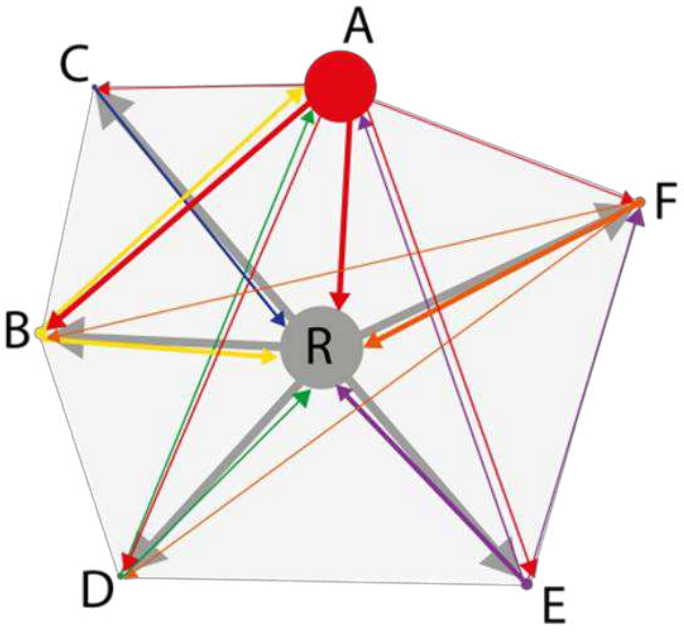


Fig. 5 Sociomatrix of Session 3

and E3 emerging as active senders and receivers, suggesting that the robot may have helped involve more participants in the group conversation.

From the standpoint of structural proximity, R3 and B3 showed minimum eccentricity (1.0) and maximum closeness and harmonic closeness values (1.0), positioning them as highly central nodes with short paths to the rest of the network. C3, D3, and E3 also showed high closeness values (between 0.83 and 0.90), indicating a more cohesive and less fragmented structure than the one observed in the session without the robot. This pattern is consistent with sociological literature that associates stronger network connectivity with higher levels of perceived social capital and lower relational isolation in groups of older adults. A3 showed lower values (0.45 and 0.53), suggesting fewer direct connections to the rest of the network, although A3 remained part of the overall interaction structure.

At the same time, betweenness centrality adds important nuance. E3 had the highest value (4.0), followed by the robot R3 (3.58) and C3 (2.25). This indicates that, although the device continued to mediate several short paths between pairs of participants, some human participants also occupied bridging positions within the network. This partial shift in betweenness toward human nodes is consistent with the idea that the robot not only promotes direct interactions with the device, but may also support participant-to-participant interactions beyond direct interaction with the robot, contributing to a more balanced interaction structure. In the main block of the session, sequences were observed in which E3 and C3 connected participants who in

previous sessions had interacted only minimally with one another, using the robot's interventions as a common starting point.

In addition, Figure 5 helps us understand prestige-related metrics that reinforce the idea of shared centrality: B3 and R3 stood out as hubs, while authority values were distributed between C3, D3, E3 and the robot, indicating that several nodes functioned as relevant destinations for incoming connections. This balance in prestige contrasts with the greater concentration observed in the earlier sessions and resembles patterns described in research on social support in old age, where networks with multiple central or highly connected nodes have been associated with stronger perceptions of reciprocity and collective belonging. The sociogram visually represents this denser and more distributed structure, with R3 and B3 in central positions and more frequent ties among human participants who had previously been less connected.

Finally, in Session 4, also conducted with the social robot present, the network included seven nodes (A4, B4, C4, D4, E4, F4, and R4/the robot), forming a highly connected network in which the robot again occupied the most central position as the main hub, while the other participants maintained moderate and distributed levels of participation.

Table 5 Network centrality measures for the fourth session.

ID	In-degree	Out-degree	Degree	Eccentricity	Closeness	Harmonic Closeness	Betweenness Centrality	Authority
A4	1	2	3	2.0	0.60	0.0	0.109	0.44
B4	2	1	3	2.0	0.55	0.0	0.130	0.35
C4	2	1	3	2.0	0.54	0.0	0.203	0.29
D4	2	2	4	2.0	0.60	0.0	0.126	0.29
E4	3	3	6	2.0	0.66	1.5	0.219	0.29
F4	1	2	3	2.0	0.60	0.0	0.000	0.39
R4	6	6	12	1.0	1.00	23.5	0.210	0.50

As we see in Table 5 the degree metrics highlight R4 as the node with the highest value (12), twice the value observed for E4 (6), the second most active node, while the remaining participants ranged between 3 and 4. This imbalance reinforces the robot's role as the main sender and receiver of interactions. Across the observation blocks, many exchanges were organized around R4, with E4 emerging as the most connected human participant, although no other nodes reached comparable levels of interaction. In terms of structural proximity, R4 showed minimum eccentricity (1.0) and maximum closeness and harmonic closeness values (1.0), indicating that it occupied the most central position in the network. E4, A4, D4, and F4 showed closeness values close to 0.6, indicating moderate levels of connectivity, partly dependent on their links to the central hub, while B4 and C4 remained slightly below that level (0.54 and 0.55).

The centrality of the interconnection was distributed more evenly between R4 (0.210) and several human nodes, with E4 (0.219) showing the highest value, followed by C4 (0.203), B4 (0.130) and D4 (0.126). Although R4 continued to mediate a relevant number of short paths, the presence of human participants with comparable betweenness values suggests that the network developed alternative routes of participant-to-participant connection. Figure 6 shows us this pattern, which

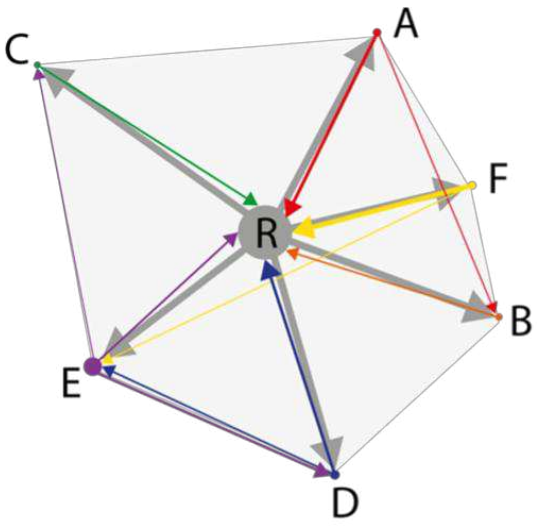


Fig. 6 Sociomatrix of Session 4

may reflect the gradual emergence of interactions among participants supported by repeated exposure to the robot (Lin et al., 2022). During the main observation blocks, sequences were observed in which E4 and C4 acted as bridges between less connected participants, using the robot's interventions as an initial trigger.

Prestige metrics showed R4 leading in authority (0.50), followed by A4 (0.44) and F4 (0.39), indicating that the robot functioned as the main destination for incoming connections. However, several human participants also maintained relevant positions within the pattern of incoming connections. This moderate distribution of prestige contrasts with the stronger concentration observed in the degree values. The sociogram illustrates this star-shaped architecture, with R4 at the core and ties among human participants that, although less intense, added some density to the less connected areas of the network.

6 Discussion

Overall, the introduction of the robot was associated with changes in the interaction network, including a higher volume of exchanges and a more connected structure. Mean degree increased, suggesting greater interactional connectivity among nodes. The robot accounted for a substantial share of the observed interactions and appeared to influence how participants connected with one another. This effect is consistent with the idea of social robots as attractors of shared attention and enhancers of group engagement, as described in studies on social robotics with older adults. At the same time, the high dependence on a central node raises questions about the sustainability of peer interaction once the robot is removed, an issue also emphasized in the literature on hubs and network resilience [10].

The comparison between the baseline session and the sessions with the robot shows an increase in the volume of interactions and in network density, suggesting that more participants became involved in the group dynamic. The robot's presence was associated with a more cohesive structure, with shorter average distances between nodes and greater mutual accessibility, suggesting potential for reducing less connected positions and promoting opportunities for interpersonal contact. Importantly, even when the robot was removed from the network calculation, an increase in peer-to-peer interactions was still observed. In this sense, the robot functioned as an interactional link, but not necessarily as the sole center of authority, as suggested by the network indicators. This finding is particularly relevant because the focus of the study is Human–Robot–Human (H-R-H) interaction rather than only Human–Robot (H-R) interaction.

Although the robot tended to occupy positions of high centrality, as expected, this centrality was especially pronounced in the early sessions. As the sessions progressed, greater participation was observed among certain participants who functioned as bridges within the network. This suggests that the H-R-H pattern not only increased interaction with the device, but may also have supported conversations among participants who had shown limited interaction in the baseline session. The robot may therefore have acted as a shared focus of attention and an interactional mediator, helping the network move from a pattern with few interactions to a more connected interaction structure.

From the perspective of gerontechnology, these findings support further exploration of social robots as tools for activating and sustaining interaction during group activities in adult day care centers. However, the pilot design of the study, the small sample size, and the fact that it was conducted in a single center limit the generalizability of the findings and highlight the need for longitudinal and comparative studies to verify the stability of the results. In addition, several contextual limitations must be considered. Hearing difficulties, sensory limitations, and other participant-specific needs may affect participation, communication, and the observation of interaction patterns. The arrangement of the tables should also be considered, since rectangular or large tables may make it more difficult for participants to interact with one another depending on their seating position. These issues should be taken into account in future studies.

7 Conclusion

This pilot study suggests that introducing a social robot into an adult day care center may increase social interaction, enhance relational density, and support a more cohesive organization of the group network among older adults, especially when the device acts as a mediator of human-robot-human dynamics rather than merely as a focus of individual attention. These results are broadly aligned with previous evidence suggesting that social robots can improve engagement, interaction, and certain indicators of well-being among older adults, although the empirical base remains heterogeneous and limited in terms of methodological quality [9].

Likewise, the findings suggest that the value of the robot lies not only in its capacity to attract direct exchanges, but also in its function as a catalyst for peer-to-peer relationships, facilitating the more frequent integration of participants who were initially less connected to the group. This interpretation is consistent with longer-term community-based studies showing that the presence of a social robot can increase social connectedness and community engagement among older adults, helping to cre-ate opportunities for shared attention and interpersonal connection during group activities.

Nevertheless, the results should be interpreted with caution, as the literature continues to emphasize the need for more robust designs, larger samples, and longitudinal assessments to confirm the stability and scope of these effects. Along the same lines, systematic reviews of controlled trials have concluded that the potential of social robots is promising, but also underscore the risk of bias and the lack of high-quality studies, which reinforces the need to replicate this work across more centers and with comparative designs [15, 28].

A further implication of this study is that the future development of social robots for adult day care centers should not be oriented exclusively toward improving technical performance, but also toward designing devices that are tailored to the real needs, abilities, and preferences of older adults. Recent research on participatory and immersive design with older adults emphasizes the importance of incorporating feedback from older adults, caregivers, and professionals. Such involvement can help personalize robot functions, improve technology acceptance, and support the development of robots that are more useful, understandable, and socially meaningful in care settings.

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Statement and Declarations

Ethics approval: The study was approved by the Takushoku Ethics Committee and was conducted in accordance with the Declaration of Helsinki and its later amendments.

Consent to participate: Freely-given, informed consent to participate was obtained from all participants.

Consent to publish: Written informed consent for publication of anonymized data was obtained from all participants.

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Competing interests: The authors have no relevant financial or non-financial interests to disclose.

Data availability: The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

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