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Initial study of verbal and nonverbal communication training through the collaborative operation of a humanoid robot for individuals with autism spectrum disorder

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ABSTRACT

Individuals with autism spectrum disorder (ASD) experience difficulties in both verbal and nonverbal communication. Collaborative work allows them to use and develop their nonverbal communication abilities. Therefore, we developed a collaborative work training program for individuals with ASD. This study aimed to assess the feasibility of the proposed intervention for both verbal and nonverbal communication. A single humanoid robot was operated by two people, with each person operating different parts of the robot: one person moved the right half of the body while the other moved the left. The participants' roles were separated to promote verbal and nonverbal communication. Fourteen individuals (aged 18–27 years) participated in a training experiment that was conducted once a week for a maximum of seven sessions over two months. A comparison of the amount of communication between the first and last training sessions showed that both verbal and nonverbal communication increased ($p = 0.044$ and $p = 0.024$, respectively), indicating that the proposed training facilitated both verbal and nonverbal communication. Future studies are needed to establish evidence supporting the generalizability of the acquired skills to daily life activities by considering longitudinal designs.

1. Introduction

The Autism and Developmental Disabilities Monitoring (ADDM) Network is an active surveillance program that estimates the prevalence of ASD among eight-year-old children (Maenner et al., 2024). The ADDM Network (Maenner et al., 2021) states that approximately 1 in 36 children in the United States has autism spectrum disorder (ASD). The estimated cost of supporting individuals with ASD is $3.6 million, which poses a social problem (Cakir et al., 2020). Labeling has been applied to communication in individuals with ASD, which potentially reinforces harmful stereotypes. Moreover, it is essential to note that not all individuals with ASD experience the same communication difficulties, such as a lack of theory of mind (Zaneva et al., 2024). Hence, we describe the characteristics of communication in individuals with ASD. Individuals with ASD may behave, communicate, and interact in ways that differ from those of most other individuals. They may also experience difficulties in both verbal and nonverbal communication (Burzawa, 2018). They frequently misperceive others' intentions, including their facial expressions and gestures (Bishop and Lahvis, 2011). These difficulties may prevent them from building good relationships with others and performing well in their daily lives and social activities (Johnson and Myers, 2007; Rao et al., 2008). Currently, few evidence-based nonverbal communication training programs exist for individuals with ASD; therefore, several tutors have found it difficult to teach nonverbal skills, as such skills are abstract, context-dependent, and often acquired through experience rather than direct instruction (Dubreucq et al., 2022; Otero et al., 2015).

One possible method for developing nonverbal communication skills is collaborative work. In collaborative work, individuals work together on a project or task that allows them to use and develop their nonverbal communication abilities. However, individuals with ASD are not adept at collaborative work (Bowman et al., 2021) and tend to not participate

Abbreviations: ASD, Autism Spectrum Disorder; AQ-J, Japanese version of the Autism Spectrum Quotient; IQ, Intelligence Quotient; WAIS-III, Wechsler Adult Intelligence Scale, 3rd edition.

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positively.

Lego-based therapy is an example of such collaborative work. The sample sizes in previous studies (Huskens et al., 2015; Pang, 2010), such as those in case reports or other studies that used only three pairs of individuals, were extremely small. Only one case study demonstrated improved nonverbal communication; however, the participants were extremely young (i.e., younger than 3 years) (Pang, 2010).

The "Intense World Theory" (Markram, 2007) states that individuals with ASD might perceive their surroundings not only as overwhelmingly intense owing to the hyper-reactivity of primary sensory areas but also as aversive and highly stressful owing to an overly reactive amygdala. Therefore, they attempt to cope with intense and aversive worlds through avoidance. "The Social Motivation Theory of Autism" (Chevallier et al., 2012) states that individuals with ASD can be construed as extreme cases of diminished social motivation. Social motivation is a powerful force that guides human behavior. It is a set of psychological dispositions and biological mechanisms that bias individuals to preferentially orient themselves toward the social world (social orienting), seek and take pleasure in social interactions (social rewards), and work to foster and maintain social bonds (social maintenance). Social motivation enables individuals with ASD to foster smooth relationships and promotes coordination. Social communication intervention approaches are effective for motivational activities and settings (Warren et al., 2015). Thus, programs that decrease social anxiety and promote social motivation may address the challenges of social participation and communication in the population with ASD.

Interventions employing artificial intelligence (AI) technologies, such as virtual reality and robots, have the potential to enhance social interactions and communication skills in individuals with ASD (Sun et al., 2023; Thornton et al., 2023; Wankhede et al., 2024). Interventions using virtual reality present certain merits: 1) active participation instead of passive observation and 2) a unique training experience with each simulation. A previous study using virtual reality for collaborative work demonstrated improvements in verbal communication and collaboration (Amat et al., 2023; Zhang et al., 2020); however, no improvements were observed in nonverbal communication. One concern regarding generalization for interventions using virtual reality is that users cannot extend their abilities to the real world. Thus, learning environments in which individuals interact with others in the real world potentially represent more powerful avenues by which to enhance nonverbal communication skills and promote their generalization to real-world settings.

Robots enable the control and replication of scenes involving smooth and accurate conversations, regardless of reactions. Thus, robots contribute to more structured and standardized interventions. Unlike humans, robots operate within predictable and rule-based systems, providing a highly structured learning environment for individuals with ASD and facilitating their focus on relevant stimuli. Structured interactions with humanoid robots are likely to create standardized social situations in which certain social behaviors can emerge (Kumazaki et al., 2020). Individuals with ASD focus more on humanoid robots than on humans (Diehl et al., 2012; Doğan and Çolak, 2024; Kumazaki et al., 2020; Pennisi et al., 2016; Ricks and Colton, 2010; Scassellati et al., 2012). Previous studies focused on actual robot operations (Kumazaki et al., 2017, 2019b, 2019c). The motivation of individuals with ASD improved and their anxiety decreased when they engaged with these robots (Kumazaki et al., 2021, 2019b, 2019a; Yoshida et al., 2022).

Therefore, we developed a collaborative work training program using a single humanoid robot designed for individuals with ASD who experience challenges in collaborative activities. By utilizing the robot, the program aims to reduce social anxiety and foster social motivation. Furthermore, by engaging in real-world collaborative tasks, this intervention specifically seeks to enhance nonverbal communication skills. A single small humanoid robot was operated by two individuals with ASD during training, with each operating different parts of the robot: one person moved the right half of the body while the other moved the left. This separation of the roles of each pair promoted cooperative behavior. Furthermore, three-dimensional learning environments that operate real humanoid robots evoke stress and anxiety levels, which may be helpful in generalizing performance to real-world settings and promoting the use of nonverbal communication, such as gestures and eye contact, to promote engagement in cooperative behavior.

This study aimed to assess the feasibility of the proposed intervention for both verbal and nonverbal communication. We hypothesized that our intervention would promote both verbal and nonverbal communication among individuals with ASD.

2. Methods

2.1. Participants

This non-controlled interventional study was approved by the Ethics Committee of Kanazawa (University ethical approval number 2015–229), and the authors declare no conflicts of interest. Fourteen participants were recruited by providing flyers explaining the nature of the experiment. All the participants and their guardians agreed to participate after receiving a complete explanation of the study. Written informed consent was obtained from the legal guardians of the individuals and/or minors for the publication of any potentially identifiable images or data. All the participants provided written informed consent. The inclusion criteria were as follows: 1) ASD diagnosis based on the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) (American Psychiatric Association, 2013) by a supervising psychiatrist; 2) age 18–27 years old, 3) ability to understand teachers' instructions; 4) ability to operate an electrical device, including a gamepad; and 5) inability to show improvement in communication skills despite various interventions, including social skills training, for years. The participation criteria in this study were set to (2) and (5) to target individuals who particularly require support for social participation, particularly those who were unable to show improvement despite various interventions. Criteria (3) and (4) were established based on the abilities of the participants to participate in the experiment. During enrollment, the diagnoses of all participants were confirmed by a psychiatrist with more than 15 years of experience in ASD diagnosis. Standardized criteria obtained from the Diagnostic Interview for Social and Communication Disorders (DISCO) (Wing et al., 2002), which have good psychometric properties (Wing et al., 2002), were used for the evaluation. In this study, we did not set a cutoff based on the Japanese version of the Autism Spectrum Quotient (AQ-J) score and relied solely on the DSM-5 and DISCO for diagnosing ASD and determining participant inclusion.

All participants completed the Japanese version of the Autism Spectrum Quotient (AQ-J) (Wakabayashi et al., 2004), which was used to evaluate ASD-specific behaviors and symptoms. The AQ-J is a short questionnaire with five subscales (social skills, attention-switching, attention-to-detail, imagination, and communication). Previous studies using the AQ-J were replicated across cultures (Wakabayashi et al., 2007) and at different ages (Auyeung et al., 2008). The AQ is sensitive to broader autism phenotypes (Wheelwright et al., 2010). We did not set the cutoff according to the AQ-J score, which takes approximately 10 min to assess; we only used the DSM-5 and DICSO to diagnose ASD and assess participant inclusion.

Full-scale IQ scores were obtained using the Japanese Adult Reading Test (JART) (Hirata-Mogi et al., 2016). The JART IQ measurements are valid (Hirata-Mogi et al., 2016). The JART results, which required approximately 10 min to assess, were compared with those of the WAIS-III.

2.2. Procedures

A humanoid robot (KHR-3HV Ver2; Kondo Kagaku; height: 40.1 cm, weight: 1.5 kg) was used for training, and the participants practiced communication by operating the robot in pairs to complete the tasks described below (Fig. 1). The selected robot was lightweight (1.5 kg) and designed to prevent injury to the participants, even if they fell and made contact with them. The operating positions of the participants were selected to avoid potential contact during the fall of the robot. The participants were paired according to the compatibility of their hobbies. Each participant operated different parts of the robot using a game controller (switch controller, BebonCool) (Fig. 2). The robot and two game controllers, each controlled by one participant in each pair, were connected to a computer. The operating program was created using Microsoft Visual Studio based on the Rcb4 library (Kondo Kagaku).

The participants were trained once a week for a maximum of 7 sessions over 2 mo. In a previous study (Watanabe et al., 2020) using the same humanoid robot (KHR-3HV), the maximum operation time while maintaining concentration was set to 30 min (Table 1). The session duration was determined based on these results. According to another study (Yoshida et al., 2022), communication improvements were observed even with sessions conducted once every two weeks. Although a higher session frequency would have been preferable, considering these findings and the fact that the experiment took place during the pandemic, the number of sessions per week was set to one. As some participants could not attend the training because of COVID-19, the number of training sessions varied for each individual. Two participants and one facilitator participated in the training. Table 1 summarizes the training flow for each session. First, the facilitator explained the tasks to be performed. The participants were instructed on how to operate the robot using the controller, after which they practiced operating the robot. Fig. 3 shows the training task. The first task was designed by the authors, whereas the others were modified based on the task designed by the authors and according to the opinions of the participants. Their opinions were obtained at the end of each training session, as shown in the row labeled “Brief feedback and goodness” (Table 1). If the task is too difficult or easy, the participants may lose interest. A task that is too easy can be completed with minimal communication. To maintain interest and ensure some level of communication, the task difficulty was set sufficiently high to encourage collaboration. We initially set the task difficulty to a low level and then gradually increased it. Because the level of difficulty that keeps participants engaged varies from person to person, we adjusted the task difficulty to a challenging level based on feedback from each participant to keep them unsure of whether they could complete the task. This approach established a process for collaborative tasks that sustained the interest of the participants and increased their communication frequency. During the experiment, we confirmed that participants did not receive any specific therapy, such as speech therapy, occupational therapy, or ABA therapy. We thoroughly explained the experimental procedure before the study; however, we did not conduct introductory sessions.

The participants manipulated the robot to assume a specified pose during the first and second sessions (Fig. 3). The difference between the sessions was the difficulty of the poses (the first session was easier in its specified poses, and the second session was more complex). The difference in difficulty was owing to the challenges in maintaining the center of gravity balance and the complexity of limb postures. The command button on each controller was assigned to the movement of each joint motor of the robot and was set such that one participant rotated the joint only in the positive direction and the other rotated the joint only in the negative direction. During the third and fourth sessions, participants manipulated the robot to walk along designated obstacle-free and obstacle-covered courses, respectively. The difficulty level of the course was controlled by varying the sizes and numbers of obstacles. In the third to seventh sessions, the command button on each controller was assigned to the movements of the robot such that one controller could only control the left part of the robot, whereas the other controller could only control the right part. The task in the fifth session involved operating the robot to kick a ball at a designated point. It is necessary to generate a balanced movement on one leg to kick the ball while positioning the other foot at the location of the ball. Because kicking a ball itself has a certain level of difficulty, Session 5 was designated as a task focused solely on kicking the ball. The sixth and seventh sessions involved manipulating the robot to dribble a ball to a designated point along the course. Difficulty was controlled by varying the sizes and numbers of obstacles during the course. The training continued until either 30 min had elapsed or the participants requested to stop. When completing the task before 30 min had elapsed, participants repeated the task. Before each task repetition, the participants were asked if they wanted to change their task difficulty. If so, it was changed accordingly (e.g., more obstacles and corners on the course).

On the last day of training, the participants were asked to complete a

Fig. 2. System design.

Table 1
Training flow for each session.

Duration	Content
5 min	Greetings and instructions on the task in the session
5 min	Practice
30 min	Training (Repeat the task until 30 min have elapsed.)
5 min	Brief feedback and goodbye

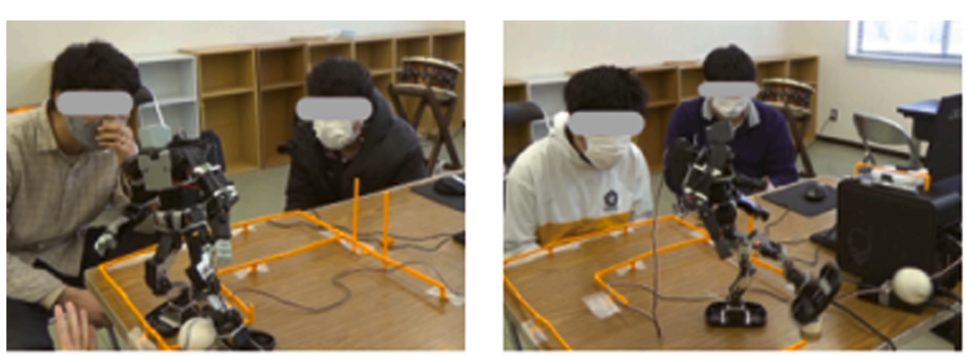

Fig. 1. Training overview.

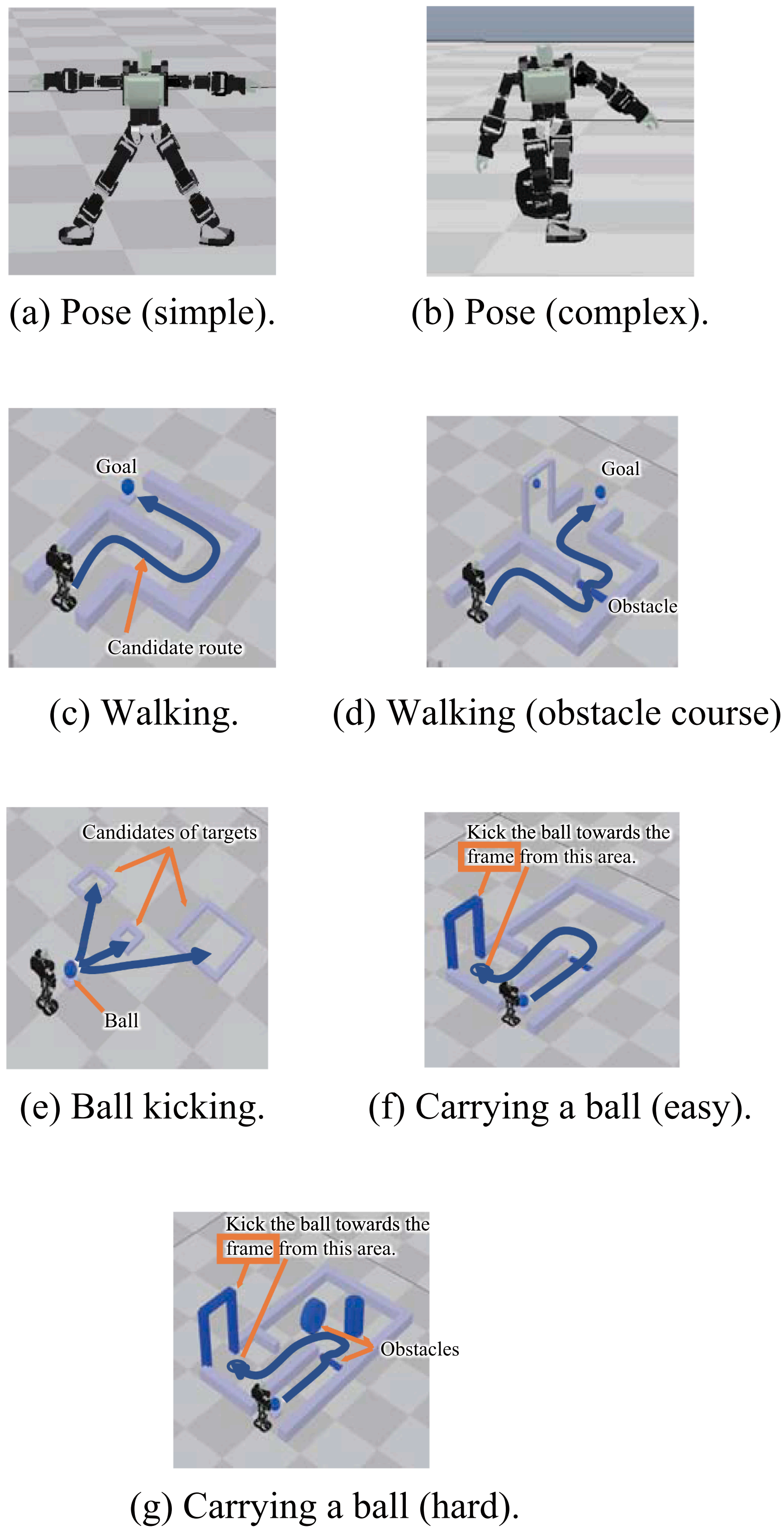

Fig. 3. Training tasks. (a) Pose (simple). (b) Pose (complex). (c) Walking. (d) Walking (obstacle course). (e) Ball kicking. (f) Carrying a ball (easy). (g) Carrying a ball (hard).

questionnaire consisting of 23 items regarding their characteristics, impressions of the training, and subjective effects of training. Characteristic items included the experiences of the participant with robot-based games and their preferences regarding collaboration and communication to assess the traits relevant to this training. To measure training acceptance, impression items included factors such as preferences, enjoyment of communication, and collaboration induced by the training. The subjective evaluation items captured changes in the attitudes of participants toward communication and collaboration owing to the training. A 7-point Likert scale was used to score the questionnaire.

2.3. Data analysis

A video camera was used to record the training sessions and evaluate the communication between the two participants. Two types of communication indices were evaluated. Verbal communication was defined as the amount of speech per minute uttered by a participant during training. The amount of speech was scored on the basis of the number of characters per minute. The number of characters in Japanese corresponds to the number of words used in English. Therefore, the scored verbal communication is referred to as the number of words per minute. Because the two pairs included individuals with mutism, their speech data were not evaluated. The other communication index was nonverbal communication, which was defined as the number of times per minute participants made eye contact or gestures during training, such as nodding and hand gestures.

Statistical analyses were performed using the IBM SPSS software (ver. 29). We studied changes in the amount of communication between the first and last training sessions for each pair. Because the data were unidirectional with values that increased but did not decrease, differences between comparisons were analyzed using the Wilcoxon signed-rank test. Statistical significance was set at $p < 0.05$.

3. Results

Table 2 shows the characteristics of the participants. Fourteen Japanese individuals (12 males and 2 females) with ASD participated in the training. Their mean age, IQ score, and AQ-J score were 21.57 ± 2.09 years, 82.0 ± 17.2, and 29.1 ± 5.42, respectively (Table 2).

Training significantly increased verbal ($z = -2.02$, $p = 0.044$, $r = 0.60$) and nonverbal communication ($z = -2.26$, $p = 0.024$, $r = 0.64$). The number of words (per minute) uttered by participants increased from the first session (13.6 [8.83–34.9]) to the final session (37.6 [22.2–42.8]). Similarly, the number of times (per minute) participants made eye contact and gestures increased from the first session (0.35 [0.00–1.28]) to the final session (1.14 [0.45–2.55]). The details of the communication metrics are presented in Table 3 as well as Figs. 4 and 5. The data for each participant are plotted as circles, and the corresponding data are connected by lines. The amount of verbal communication increased for 80 % of the participants (Fig. 4), and the amount of nonverbal communication increased for 79 % of the participants (Fig. 5).

Table 4 presents the questionnaire responses. Q1 revealed that the training was unfamiliar to the participants (2.7 ± 2.1). Q2–Q6 showed that the participants did not consider communication unskilled. Q7–Q13 indicated that participants had a positive impression of training and were highly motivated to participate; high scores were obtained for Q7–Q9, whereas low scores were obtained for Q10 (2.2 ± 1.6) and Q11 (3.3 ± 1.9). The scores for Q12 (5.6 ± 1.0) and Q13 (5.1 ± 1.4) indicated that participants could operate the robot to a certain extent. Q14–Q23 indicated that participants recognized the importance of cooperation and conversation with others through training, with scores greater than 5.8 for Q16, Q18, and Q22. Moreover, the scores suggested that the training made them enjoy cooperating with others (5.5 ± 1.3) and enabled them to converse with others (5.5 ± 1.4).

Table 2
Characteristics of participants.

	Age	IQ	AQ-J
Mean	21.57	82.0	29.1
SD	2.09	17.2	5.42

4. Discussion

This study aimed to assess the feasibility of the proposed intervention for enhancing both verbal and nonverbal communication. We investigated whether the collaborative operation of a humanoid robot by a pair of individuals with ASD increases communication. Both verbal and nonverbal communication skills increased during the training, demonstrating the feasibility of collaborative humanoid robot operations in promoting nonverbal communication in individuals with ASD. The improvement in this nonverbal communication skill is supported not only by statistical significance but also by a large effect size.

Numerous studies have suggested that robot-based interventions are effective in eliciting social behaviors in individuals with ASD (Wainer et al., 2014). This finding also holds true in our study, in which robot-induced communicative behavior was observed. As shown in Fig. 5, participants who did not exhibit any eye contact or gestures during the first session demonstrated these behaviors in the final session. When individuals with ASD interact with a robot, they are initially interested only in the robot and shift their interest over time to the person operating the robot rather than the robot itself (Robins and Dautenhahn, 2006). Verbal communication increased after they became aware of the presence of their partners during collaborative tasks (Zhao et al., 2018). Thus, our robotic system improved active verbal communication between partners. Nonverbal skills are abstract and context-dependent and are often acquired through experience rather than direct instruction (Dubreucq et al., 2022; Otero et al., 2015). Individuals with ASD struggle with abstract concepts and context-dependent situations (Gambra et al., 2024; Skoyles, 2011). Therefore, interventions that account for these challenges in understanding abstractions and contexts are necessary. The intervention in this study was designed to be accessible to individuals who have difficulty with abstract concepts and context-dependent situations. This accessibility may help improve the nonverbal communication skills of individuals with ASD. Interventions using humanoid robots are more powerful in promoting verbal and nonverbal communication than are those using virtual agents (Berland and Wilensky, 2015; Kamide et al., 2014). These results may be linked to the findings of the present study; our approach increased both verbal and nonverbal communication.

Some participants with ASD stopped participating because of stress or decreased motivation (Golan and Baron-Cohen, 2006; Miller et al., 2020). In this study, none of the participants dropped out of the training, indicating that it was well-accepted by the participants. Positive responses to questionnaires related to motivation for training (for example 7. Did you enjoy operating the robot? 8. Did you enjoy cooperating with your partner? 9. Would you like to participate in this training again? 22. Has the training made you recognize the greater importance of conversing with others?) indicated that the participants had a highly favorable impression of the training. The collaborative work was designed to require input from both members, ensuring that work could not be completed through the actions of only one member. Frequently observed conversations included, “I cannot move it, please move it.” and “It is your right leg, so it is your turn.” Thus, the setting that forced the two paired participants to operate the robot together effectively promoted communication between them. However, such forced communication may also reduce motivation in individuals with ASD. The enjoyment derived from interacting with a game or tangible robot likely mitigates the feeling of being forced (Kumazaki et al., 2021, 2019b, 2019a; Yoshida et al., 2022) and thereby enables increased

Table 3
Amount of verbal and nonverbal communication.

	First training			Final training			Wilcoxon signed-rank test		Effect size
	Q_1[a]	Median	Q_3[b]	Q_1	Median	Q_3	z	p	r
Number of words	8.83	13.6	34.9	22.2	37.6	42.8	−2.02	0.044	0.64
Number of instances of nonverbal communication	0.00	0.35	1.28	0.45	1.14	2.55	−2.26	0.024	0.60

[a] First quartile.
[b] Third quartile.

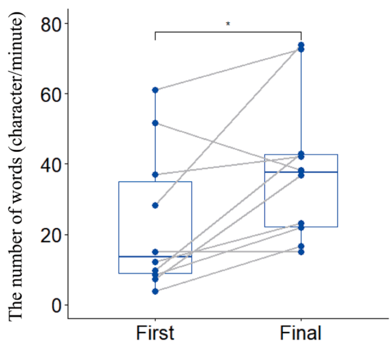

Fig. 4. Number of words per minute uttered by participants during training.

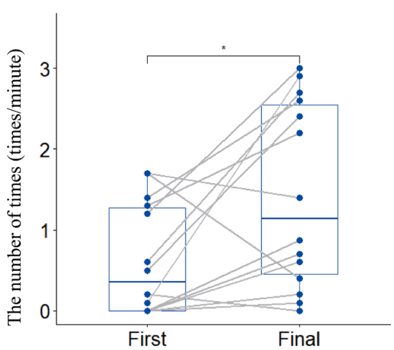

Fig. 5. Number of times per minute that participants made eye contact or made gestures during training.

communication while maintaining motivation.

It is advisable to introduce tailored social skills training programs for individuals with ASD (Frye, 2022). In this study, we adjusted the difficulty level of the course based on each individual's accomplishments, which helped maintain motivation while also enhancing communication.

Tangible interfaces and robot programming tasks have been shown to be effective for providing cognitive training to individuals with memory dysfunctions (Demetriadis et al., 2015). Collaborative training programs may also be beneficial for improving communication skills in various conditions, such as mild cognitive impairment (MCI), where interpersonal interaction and teamwork are essential, in addition to ASD. The interventions used in this study may also be useful for such individuals. Further research is needed to explore the potential applicability of this approach in other contexts.

To effectively implement interventions aimed at improving communication skills, it is essential to conduct comprehensive assessments tailored to the unique needs of each individual and formulate intervention strategies based on these assessments (Tragantzopoulou and Giannouli, 2024). Therefore, a multidisciplinary approach to ASD management is crucial. This approach emphasizes collaboration among various stakeholders, including clinicians, healthcare professionals, researchers, educators, parents, and policymakers, to address the diverse needs of individuals with ASD across medical, psychological, educational, and social domains. A collaborative effort ensures holistic care and support, optimizing the well-being and quality of life of individuals with ASD. Our intervention may serve as a valuable component of this comprehensive approach.

Table 4
Questionnaire for the participants (responses were collected using a 7-point Likert scale).

Question	Mean (SD)
Characteristics	
1. Have you ever played games similar to those in this training	2.7 (2.1)
before?	4.8 (1.8)
2. Do you like having a conversation with others?	5.3 (1.5)
3. Do you like cooperating with others?	4.7 (1.3)
4. Do you tend to follow others when you disagree with their	5.1 (1.6)
opinions?	5.1 (1.3)
5. Do you like listening to others while being a listener?	
6. Do you like following the pace of others?	
Impression of the training	
7. Did you enjoy operating the robot?	6.7 (0.5)
8. Did you enjoy cooperating with your partner?	6.1 (1.0)
9. Would you like to participate in this training again?	5.9 (1.3)
10. Did you want to stop participating in the training halfway	2.2 (1.6)
through?	3.3 (1.9)
11. Do you think this training is more fun when played only by	
one person than in a pair?	
12. Did you operate the robot to perform what you wanted it to	5.6 (1.0)5.1 (1.4)
do?	
13. Did you feel as if the robot became part of your body?	
Subjective effects of training	
14. Has the training made you enjoy more cooperating with	5.5 (1.3)
others?	5.3 (1.3)
15. Has the training made you feel more comfortable	
conversing with others?	
16. Has the training led you to see the value of cooperating with	5.8 (0.9)
others?	
17. Has the training improved your ability to cooperate with	5.4 (1.4)
others?	6.0 (1.0)
18. Has the training led you to see the value of conversing	4.7 (1.5)
with others?	
19. Has the training made you feel more inclined to follow the	
other person's opinion?	
20. Has the training made you like listening to others more?	5.2 (1.5)
21. Has the training improved your ability to converse with	5.5 (1.4)
others?	5.9 (1.0)
22. Has the training made you recognize the greater	
importance of conversing with others?	
23. Has the training made you more comfortable with the pace	4.8 (1.4)
of others?	

4.1. Limitations

Based on Noether (1987), with a significance level of 0.05, the effect size presented in Table 3, and the number of participants, the estimated statistical power ranges from 0.40 to 0.60, suggesting that the sample size is relatively small. Future studies with larger sample sizes could provide more meaningful data regarding the potential use of the proposed system. Second, we did not include a control group. It remains unclear whether the observed improvement in communication was solely attributable to the training itself or to the combined effects of training and daily life activities. However, the participants did not show improved communication skills despite different interventions, including social skills training over the years. Verbal communication was minimal, and nonverbal communication was nearly nonexistent, suggesting a limited impact of daily activities on communication improvement. Third, we could not assess the generalizability of our training to daily life. Future studies with long-term longitudinal designs, including assessments of the generalizability of our training to daily life, are required to examine whether our program can achieve this goal.

5. Conclusion

We assessed the feasibility of collaborative work training for individuals with ASD using a single humanoid robot. The training was well-accepted and enjoyed by all the participants. Moreover, the training facilitated both verbal and nonverbal communication (e.g., spontaneous conversations, gestures, and eye contact) between participants and their partners. In the future, we plan to establish evidence to support the generalizability of the acquired skills to daily life activities by considering a longitudinal design.

CRediT authorship contribution statement

Nishida Kihei: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Kumazaki Hirokazu:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization. **Watanabe Tetsuyou:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors confirm that they do not have any conflicts of interest.

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