International Journal of Social Robotics (2019) 11:171–184
https://doi.org/10.1007/s12369-018-0497-0

# Communication Support via a Tele-Operated Robot for Easier Talking: Case/Laboratory Study of Individuals with/Without Autism Spectrum Disorder

**Jiro Shimaya[1] · Yuichiro Yoshikawa[1] · Hirokazu Kumazaki[2] · Yoshio Matsumoto[3] · Masutomo Miyao[4] · Hiroshi Ishiguro[1]**

Accepted: 7 October 2018 / Published online: 16 October 2018


**Abstract**
The advantages of using a tele-operated robot to facilitate otherwise difficult verbal disclosure of thoughts and concerns was examined. In a field study, individuals with autism spectrum disorder, who often face obstacles in social interaction, were provided daily-life-guidance by a robot tele-operated by their caregiver. In cases in which the robot was operated remotely or from the same room, subjects were able to disclose concerns to the robot that they had not previously disclosed to their caregiver. Furthermore, under the latter case the improved communicability was maintained through subsequent conversation with the operator. In a separate laboratory experiment involving participants not judged to be on the autism spectrum, it was observed that the participants were silent longer during conversation via a robot than in face-to-face conversation. The enhanced length of silence in the first setting can be considered to be an index for good counseling of a subject. Furthermore, the enhanced length of silence was maintained in subsequent face-to-face conversation with a robot operator in the same room, which appears to be consistent with the results of the field experiment. The findings encourage future applications in therapeutic conversation approaches such as counseling for providing clients with environments that facilitate the disclosure of concerns.

**Keywords** Tele-operated robot · Human robot interaction · Ease of conversation · Side-by-side operation · Autism spectrum disorder

## 1 Introduction

### 1.1 Tele-Operated Robots and People with Autism Spectrum Disorder

Autism spectrum disorder (ASD) is a developmental disorder characterized primarily by deficits in social communication and tendencies toward restrictive and repetitive interests or behaviors [1]. Studies have reported that the number of individuals diagnosed as having ASD is increasing [2]. Various methods such as speech therapy, visual scheduling, and sen-

✉ Jiro Shimaya
shimaya.jiro@irl.sys.es.osaka-u.ac.jp

Yuichiro Yoshikawa
yoshikawa@irl.sys.es.osaka-u.ac.jp

Hirokazu Kumazaki
kumazaki@tiara.ocn.ne.jp

Yoshio Matsumoto
yoshio.matsumoto@aist.go.jp

Masutomo Miyao
miyaomncchd@gmail.com

Hiroshi Ishiguro
ishiguro@irl.sys.es.osaka-u.ac.jp

[1] Graduate School of Engineering Science, Osaka University/JST ERATO Ishiguro Symbiotic Human-Robot Interaction Project, 1-3 Machikane-yama, Toyonaka, Osaka 560-8531, Japan

[2] Research Center for Child Mental Development, Kanazawa University, 13-1 Takaramachi, Kanazawa, Ishikawa 920-8640, Japan

[3] AIST, 1-1-1 Umezono, Tsukuba, Ibaraki 305-8560, Japan

[4] Donguri Psycho Developmental Clinic for Developmental Disorder, 14-5, 4 Minami-Karasu-yama, Setagaya, Tokyo 157-0062, Japan

sory integration are used for the treatment and education of individuals with ASD [3]. Because individuals with ASD suffer from secondary mental problems such as social anxiety and mood problems [4] or issues related to social maladaptation such as bullying [5] and offending behaviors [6], it is important to use counseling or daily-life-guidance to discuss problems. However, conversational deficits [7] can make such conversations with caregivers difficult.

Recently, the use of tele-operated robots to effect smooth and active communication have been assessed via, for example, remote conferencing [8,9], consultation [10], and counseling [11]). One study reported that elderly individuals with moderate Alzheimer disease showed more positive reactions in conversation via a tele-operated robot than in face-to-face conversation [12]. Overall, such experiments indicate that tele-operated robots are often useful in enabling smooth communication for individuals who face difficulties in establishing face-to-face communication.

Computer-mediated communication (CMC) such as communication based on e-mail or video conferencing has inherent limitations relative to face-to-face communication in the conveyance of participants social cues such as gestures, facial expressions, and voice inflections(e.g., [13]). However, studies on CMC have reported that some participants have been able to disclose information more easily via CMC [14]. This can be interpreted to mean that the very limitations of CMC in conveying social cues can make conversation easier for participants who experience fear or pressure under face-to-face situations.

An onscreen human avatar, which is another medium with limited capabilities in conveying social cues, is also expected to be a less intimidating interviewer or counselor [15,16]. However, it has not been clear to what extent it is comparable to a human since Yokotani also reported that humans seem to still have an advantage as an interviewer whom clients disclosed to about their negative emotion [16]. On the other hand, the reduced tendency to obey orders given through a tele-operated robot instead of another person [17] suggests that many people can act more easily and spontaneously when interacting with robots than with humans. One outcome of this finding is the initiation of studies on the use of tele-operated robots in interviews with children [18,19] and in counseling [11].

The potential for the use of tele-operated robots as conversation partners has also been studied in the field of treatment and education of individuals with ASD. Previous field studies reported that different types of robots, including non-creature-like [20,21], animal-like [22,23], human-like [24–26] and very-human-like [27], were helpful in eliciting social behavior such as joint attention [22,25], vocalization [22], touching [24], and imitation [22,25] from individuals with ASD, whose diagnostic feature is manifested by absent, reduced, or atypical use of such social behaviors. These studies suggest that conducting conversations via a tele-operated robot might be effective in providing individuals with ASD environments in which they can disclose their concerns. However, it is unclear whether and how effectively verbal conversation can be established using tele-operated robots because previous studies have not focused on flexible, verbal counseling in actual treatment and education settings; correspondingly, in this study we developed a tele-operated robot for use in the field.

Tele-operated robots are typically used in situations in which the operator is in a remote location [9,12]. However, in using a tele-operated robot for counseling there is an ethical concern that the operator might hear information disclosed by a person who is addressing the robot alone under an assumption of confidentiality. In addition, there are further concerns that it might be difficult to bridge the experience of counseling via the robot to face-to-face conversation with the operator.

To address these concerns, we can consider an additional conversation format in which the counselor operates the robot from the same room. This would be expected to avoid ethical concerns as described above by making it clear to the participant that their conversation with the robot is being shared with the operator, who appears to be a side-participant. Furthermore, the experience of disclosing to the robot can be extended to disclosure to the counselor once the initial mental hurdle of interaction between the client and the counselor has been breached via robot-mediated communication. Thus, this study examined the advantages of counseling via a robot operated both remotely and from the same room.

### 1.2 Tele-Operated Robots and People with Typical Development

In the treatment and education field, increasing a sample size can be expensive owing to the necessity of strict and careful checking of the benefit of or at least lack of harm to participants of a potential experimental intervention. On the other hand, the spectrum nature of ASD implies the possibility that the effects of using a robot can be measured for and applicable to people with typical development (TD), i.e., those not diagnosed to be on the autism; hence, this paper also reports the results of laboratory experiments using only TD participants who were asked to perform simple self-disclosures in an environment in which the topic and stimuli were controlled and their behavior and subjective impressions were analyzed.

Several studies have compared human behavior under situations in which there was a tele-operated robot interlocutor and those with only a human interlocutor [9,18,19]. Bethel et al. reported on experiments with children with TD in which more participants answered "yes" to the question, "Do students at your school get teased about how they look?" to a

tele-operated robot than to human adults [19]. However, it is unclear whether this tendency indicated an enhanced ease of conversation, as there was a lack of reporting on consistent tendencies for answers to different questions or on an any behavioral measures. We use the word ease of conversation to describe the situation in which the communication can be performed well without stress. Although Wood et al. compared the number of words uttered by children with TD between cases in which they spoke to a robot and to human adults, no statistically significant difference was shown [18]. Tanaka et al. evaluated subject nervousness by focusing on the frequency of micro-pauses in utterances [9]. However, they found no significant difference between cases of talking to a tele-operated robot and talking to a human directly.

According to Gendlin, one of the pioneers of the client-centered approach in counseling, clients often insert silences when trying to focus on their feelings [28]. Nagaoka et al. found that Japanese clients in highly-evaluated counseling sessions were silent for longer periods than those in low-evaluated sessions [29]. Note that highly/low-evaluated mean adequate and inadequate therapeutic counseling, respectively, which were evaluated with a nine-point scale by the clinical psychotherapist. Thus, in this study on Japanese subjects, we adopted the length of silence of participants as the index of the ease of speaking.

The laboratory study compared the behavior of subjects who were asked to disclose information in semi-structured interviews following three conversational forms (see Fig. 1): talking face-to-face with another human (direct conversation); talking to a robot operated from the same room (semi-indirect conversation); and talking to the robot operated from a different room (indirect conversation). If the hypothesis that conversation via a robot is easier for participants is true, it would be expected that the lengths of silence would increase under semi-indirect and indirect conversation relative to direct communication. Furthermore, the length of silences under direct conversation would be expected to increase more following semi-indirect conversation than following direct conversation.

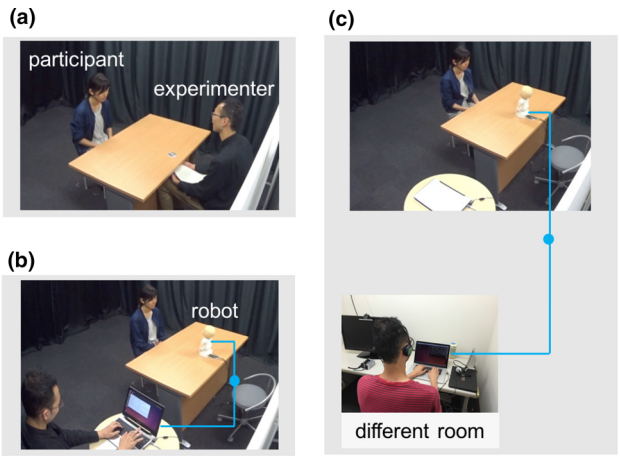


**Fig. 1** Scene of the laboratory experiment 1 **a** direct conversation, **b** semi-indirect conversation, **c** indirect conversation

This paper comprises five sections. Section 2 introduces two cases in which a tele-operated robot was used for providing daily-life-guidance to individuals with ASD. In this section, it is reported that the individuals with ASD disclosed concerns to the robot that had not previously been disclosed to their caregiver. Furthermore, an individual with ASD who engaged in semi-indirect conversation disclosed her concerns not only in indirect and semi-indirect conversations but also in direct conversations conducted following the semi-indirect conversations. Section 3 describes a laboratory experiment involving a simplistic self-disclosure situation that revealed behavioral tendencies that appeared to be consistent with those reported in Sect. 2. Finally, Sect. 4 concludes this study.

## 2 Field Experiment: Can Caregivers Better Address Concerns of Adolescents with ASD via a Desktop Humanoid Robot?

This section describes two case studies involving the daily life guidance of individuals with ASD, which were conducted in a Japanese school for special needs. The advantages of using a tele-operated robot in the treatment and education of individuals with ASD are discussed through the qualitative analysis of the behavior of the participants in the studies.

### 2.1 Method

#### 2.1.1 Communication Robot and Its Interface

A small humanoid robot called CommU, which is about 0.3 meters tall, was used as a tele-operated for indirect and semi-indirect conversation (Fig. 2).

CommU has 14 degrees of freedom (DoFs): waist (2), left shoulder (2), right shoulder (2), neck (3), eyes (3), eyelids (1), and lips (1). The careful design of the eyes and their rich

**Fig. 2** Desktop humanoid CommU

DoFs dedicated to controlling where the robot is looking are expected to contribute to rich gaze expressions. At the same time, its small, cute appearance is expected to help avoid fearfulness among children.

The robot utters sentences typed by a counselor using a keyboard interface installed on the counselor side. A commercial software application, AITalk (AI Inc.), is used for Japanese text-to-speech synthesis through a voice model, *yuuto*, which is chosen to match the robots childlike appearance. During utterances, the robot moves its lips for easy identification as a speaker. Furthermore, it automatically displays types of idling motions such as blinking and rolling of the neck and shoulders so as not to appear as an inanimate object. The interface is implemented on a mobile laptop computer so that it can be arbitrarily placed by the counselor inside or outside the room in which the robot is placed. When operating from outside the robot room, the counselor uses feed from a video camera to observe the utterances and behavior of the client.

### 2.1.2 Procedure

The participants took part in conversations in all or two of three conversational forms: direct, semi-indirect, and indirect conversation. They were instructed as follows:

- Please talk with the robot freely
- The conversations would last until you or the teacher decided to finish them.
- The conversation was recorded through the video camera

Direct conversation between the participants and the teacher was sometimes performed to examine the change in the participants behavior toward their teacher over the experimental period. The direct conversation time was limited to 15 min at maximum to avoid over-tiring of the participants. Note that P1 and P2 could have only two and four days of the experiment, respectively, owing to their absence from the experimental period. P1 did not perform semi-indirect conversation due to her absence.

We tried to obtain data for five days when the class schedules matched the use of the robot. However, P1 and P2 could have only one day and four days of the experiment, respectively, owing to their absence from the experimental period. P1 did not perform semi-indirect conversation because she showed a strong affinity for the robots appearance from the beginning; thus, it was considered better for her to concentrate on engaging in one-on-one conversation.

## 2.2 Result

The schedules of conversations taken part in by each participant are shown in Fig. 3. The red circles, orange rectangles, and blue triangles represent direct, semi-indirect, and indirect conversation, respectively. The black lines over the icons show on which days the conversations took place, while the numbers below the icon represent the duration of each conversation.

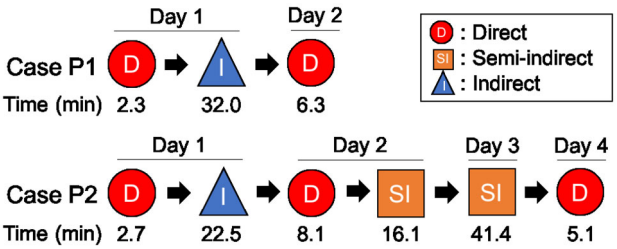


**Fig. 3** Conversation forms participated in by each participant and its duration time (min)

Direct conversations were maintained for 4.3 and 5.3 min on average in cases P1 and P2, respectively. In all instances, their teachers gave up the conversation before the maximum time set for direct conversation (15 min) had passed owing to the students negative responses. Conversation via the robot (i.e., indirect and semi-indirect) continued for an average of 32.0 and 26.6 min in cases P1 and P2, respectively. The teachers were able to maintain the conversations through the robot for longer times than in the direct case; the participants appeared to be more motivated to engage in conversation, and neither stopped until the teacher stopped.

The teacher tried to encourage participants to speak with richer body expression compared to the robot. We measured the FoN, which influences the participants perceptions, and found that the average FoN of the teacher during direct conversation was 16.1 (SD = 2.4) per minute while that of the robot was 0.

*Case P1*

P1 was a 15-year-old female student with ASD. Her full-scale intelligence quotient was 80 in WISC 4 [30]. The Childhood Autism Rating Scale total scores (34.5) indicated mild to moderate ASD. She had some difficulties with interpersonal relationships that could not be managed well by her teachers. In case of P1, the teacher operated the robot from a different room from the one in which P1 and the robot were located.

The teacher succeeded in speaking with her via the robot concerning her excessive aggression toward particular classmates in daily life, which had previously been a difficult issue for the teacher to address directly. Through the robot, it was suggested that she should inhibit her aggression in front of her classmates to obtain the right to play with her favorite tablet PC as a reward for her inhibition. Although she was not forced to do so, she accepted the offer and, although she said that she was merely giving up on refusing the robot's offer, she appeared to be pleased.

The teacher then set up an opportunity for her to interact with one of the classmates in question. In this encounter, she did not show any aggressive behavior and got along with him, which, from her self-report on the experience, seemed to her a positive experience. According to the teacher's later report, she had been able to control her aggression in front of the classmates in question for three weeks following this successful encounter.

*Case P2*

P2 was an 18-year-old female student with ASD. Her full-scale intelligence quotient was 52 in WISC 3 [31]. The Childhood Autism Rating Scale total scores (32.5) indicated mild to moderate ASD. She tended to avoid answering specific questions, including those concerning people she disliked. If the teacher directly asked her, "Do you have any person you dislike?" she usually answered with, "No, I don't."

As the study progressed, we observed a change in her answers to questions concerning people she disliked. In indirect conversation on Day 1, the teacher asked her, "Do you have any person you dislike?" via the robot. She responded with the name of an individual (called X in this section) even though she had previously avoided this topic with the teacher. In a direct conversation on Day 2, the teacher asked her, "Who's a person you dislike?" She responded with, "I don't have anyone." In a semi-indirect conversation on Day 2, the teacher asked her, "Do you like or dislike X?" She responded with, "I dislike." On Day 3, the teacher asked her no questions related to the people she disliked. In a direct conversation on Day 4, the teacher asked her, "Who's a person you dislike?" She answered with two names—X, and another individual, Y. This result indicates that, on Day 4, the teacher succeeded in directly talking to her about the people she disliked, although he had failed to do so on Day 2 and prior to the experiment.

### 2.3 Discussion

Each participant showed notably changed behaviors during indirect and semi-indirect conversation: P1 talked about her problems with human relationships, while P2 was able to disclose the identity of an individual she disliked. These behaviors had not previously occurred in direct conversation with the teacher in their daily lives. These successful changes in behavior in conversation and its beneficial outcome in human relationship imply that a communication robot might be useful in assisting caregivers in conducting counseling-type conversations with individuals with ASD.

We observed the successful change in the attitude of P1 toward her classmate through the counseling session. It is considered that the promise made through the robot encouraged her to change her attitude. It is worth noting that it was difficult for the teacher to even encourage her to promise to change her attitude during direct interactions in daily life.

By Day4, P2 was able to directly tell her teacher that she disliked. It should also be noted that the two disclosures were performed under different situations. The first disclosure took place when only the student and the robot were present in the room; the second took place when the student, robot, and teacher were all in the room. In other words, the conditions of the second disclosure can be considered to be somewhat closer to those of a direct conversation than those of the first discussion. This convergence of conditions might have contributed to the successful direct disclosure on Day 4, although we cannot distinguish their effects from the effect of repetition in the experiment. However, we believe that mere repetition of the opportunities to talk cannot be the sufficient cause for disclosure because the teachers repeated attempts to directly talk with P2 on this issue have failed so far.

The teacher tried to encourage participants to speak with richer body expression compared to the robot. We measured the FoN, which influences the participants perceptions, and found that the average FoN of the teacher during direct conversation was 16.1 (SD = 2.4) per minute while that of the robot was 0.

It is unclear how much intervention should be provided to participants and how long the effects of the robot will last. As an important future work, the system should be integrated into the daily lives of participants to provide useful, continuous opportunities for interaction with the robot by which we can examine influential factors for successful intervention.

## 3 Laboratory Experiment

The result of the field experiment imply two effects: one is that individuals with ASD can talk with a tele-operated robot easily and the other is that the tendency of ease to talk with the robot in semi-indirect conversation is maintained in a direct conversation with the operator after that. However, statistical significance was not analyzed due to the limitation of sample size and difficulty of controlling the topic in a real environment of daily-life-guidance. On the other hand, the spectrum nature of ASD implies the possibility that the useful effects of using the robot can also be observed in people with TD. Accordingly, some previous works have shown the possibility of the robot interacting with TD participants more actively, although it is not evident whether the ease of talking was promoted and maintained [11,12].

Therefore, we aim to examine whether the effect based on ease of the robot is observed in the laboratory experiment of a semi-structured interview in which university students with TD were asked to disclose themselves. This section describes two laboratory experiments to examine ease of conversation

which was felt by participants during or after the conversation with the robot.

### 3.1 Experiment 1

In this experiment, the three following conversational forms (see Fig. 1) were compared: (a) direct conversation; (b) semi-indirect conversation; and (c) indirect conversation. It was assumed that the duration of the period in which a participant remained silent increased when the conversation was easier for them. The hypotheses are stated as follows:

- The lengths of time during which a participant is silent are longer in indirect conversations than in direct conversations.
- The lengths of time during which a participant is silent are longer in semi-indirect conversations than that in a direct conversations.

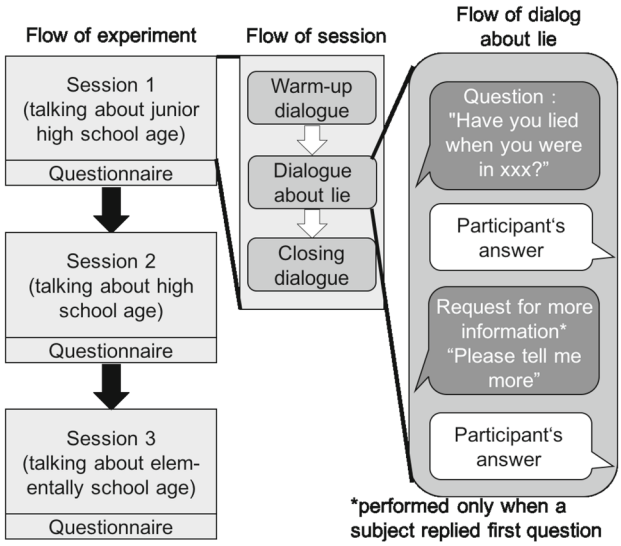


**Fig. 4** Flow of the laboratory experiment 1

#### 3.1.1 Method

*Participants* The participants included twelve university students (six males and six females) with TD ranging in age from 18 to 22 years.

*Apparatus* The conversation platform employed the CommU desktop humanoid robot (Fig. 2), which was also used in the field experiment.

The scene of the experiment is shown in Fig. 1. In direct conversations, the experimenter sat across a table from the participant. In semi-indirect and indirect conversations, the robot was placed on the table at a height of 70 cm and facing the participant. In semi-indirect conversations, the experimenter operating the robot sat where the participant could see him on the right edge of the field of view. In indirect conversation, the experimenter monitored participants' utterances and behavior using a feed from a video camera.

*Procedure* The direct, semi-indirect, and indirect conversations were compared using a within-subject design. Figure 4 shows the flow of the experiments. The participants attended three conversation sessions (sessions 1, 2, and 3) and answered questionnaires after each session. The participants discussed their junior high school, high school, and elementary school experiences in sessions 1, 2, and 3, respectively, taking part in direct, semi-indirect, and indirect conversations in a random, counter-balanced order in each session.

In each session, the participants were first asked to randomly draw from a set of topics for conversation. What the participants drew was controlled by preparing session-specific lotteries that included only topics relevant to the specific sessions. Thus, for all participants junior-high, elementary, and high school experiences for discussion were assigned for sessions 1, 2, and 3, respectively. This process was used to motivate participants to talk about topics based on a perception that they had selected the topics. Following the drawings, the conversations began.

The conversation in each session lasted for seven to ten minutes. At the beginning of the conversation, a warm-up question was inserted to habituate the participant to an interview-like conversational setting. Subsequently, the participants were asked to discuss an "experience of lying" while in junior high school, high school, and elementary school in sessions 1, 2, and 3, respectively. The topic of "lying" was selected because it was considered that the participants would be reticent to discuss it, which would be expected to clearly demonstrate the effect of using a robot.

To commence a discussion on lying, the interlocutor asked, "Have you lied when you were in junior high school (high school, elementary school)?" in Japanese, and then the participants answered the question. It should be noted that, in the direct conversation context, the interlocutor refers to the experimenter (human) while, in the semi-indirect and indirect conversation contexts, it refers to the robot operated by the experimenter. The interlocutor provided "neutral" responses such as simply nodding, or nodding using Japanese backchannels corresponding to "yeah" or "I see", while the participants answered the questions. The responses were inserted when the experimenter deemed it natural to do so. The interlocutor uttered the sentence, "Please tell me more about it," just once unless the participants provided negative answers such as "I don't remember" or "I don't want to talk about it." The interlocutor then completed the session by asking follow-up questions and thanking the participant.

The instructions to the participants are as follows:

- You will have three sessions.

- You will be asked about your school age experiences during each session.
- You can freely answer the questions. If you do not want to answer them, you can refuse to do so.
- The interviewer will either be the experimenter or the robot operated by the experimenter.
- Although the operator will be in the same room in one of the sessions, please direct your answer to the robot not to the operator. The operator will not speak to you directly.

*Mesurement* A questionnaire was used to evaluate the subjective feelings of the participants after each session. It included eight items related to ease and three items related to the turn-taking of the conversation, referred as E1-6 and T1-3, respectively. The items were:

E1 **Nervousness**: You were nervous during the conversation.
E2 **Calmness**: You could calmly think what you would say.
E3 **Fluency**: You could fluently speak what you thought
E4 **Embarrassment**: You felt embarrassed to answer.
E5 **Feeling of being hurried**: You felt as if you were being hurried to answer during the conversation.
E6 **Ease of eye contact**: You felt it was easy to make eye contact with the interlocutor
T1 **Slowness of pace**: The conversational pace was slow.
T2 **Unnaturalness of pace**: You felt that the conversation pace was not natural.
T3 **Naturalness of exchange**: The exchange during the conversation was natural.

To prepare indexes for the ease of conversation, we referred to the following items used in previous studies on human–robot interaction: nervousness [9], calmness [32], fluency [9], embarrassment [33] and eye contact [34]. Other items were chosen based on the observations in our field study. The feeling of being hurried and items on turn-taking (slowness/unnaturalness of conversational pace, and naturalness of conversational exchange) were included because the participants liked talking at their own pace in front of the robot, which was supposed to have a positive effect on the ease of conversation [35]. Note that we confirmed that participants correctly understood all concepts of questionnaire items through the interview after the experiment.

All items were answered using a seven-level Likert scale: 1. disagree strongly; 2. dis- agree moderately; 3. disagree slightly; 4. neutral; 5. agree slightly; 6. agree moderately; 7. agree strongly. In addition, questions unrelated to the research, which include seven items on the enjoyment of the conversation and four items for the general evaluation of conversational settings, were also asked to conceal the research purpose from participants. These questions were not analyzed, as they were not directly related to the hypothesis of the study.

Quantitative analysis of the conversations was conducted using videos of the experiment, with only those parts of the videos in which participants discussed experiences of lying analyzed. This involved transcribing what and when the participant uttered. Verbal fillers were included in the transcription. Subsequently, the following indices were calculated:

- **Conversation time (s)** This is the total amount of time passing from the moment the operator (or the robot) finished questioning to the moment the participant finished answering. It therefore does not include the time spent by the operator in typing.
- **Silent time (s)** This is calculated by subtracting the time spent in participant utterance, including verbal fillers, from the total conversation time. In other words, it represents the total amount of time that the participant remained silent during the conversation time.
- **Relative silent time** This is the ratio of the silent time to the conversation time.
- **Length of utterance** This is the number of moras (syllables) included in a participant's utterances, which corresponds to the number of Japanese vowels and double consonants used.

In addition, to check whether the interlocutor nonverbal behavior is controlled, we calculated frequency of nodding (FoN) of the human and robot interlocutors.

#### 3.1.2 Results

The results of the questionnaires with regard to ease and turn-taking of conversation are shown in Fig. 5. The scores of items E1-6 and T1-3 in each conversation form (direct, semi-indirect, and indirect conversation) were compared using the Wilcoxon signed rank test whose p-values were corrected using Shaffer's method. The score for E6 ("You feel that it is easy to make eye contact with the interlocutor") in indirect conversation significantly exceeds that in direct conversation ($p < .05,\ V = 40$). Note that V is the statistical value in Wilcoxon signed rank test. The score for T1 ("The conversation pace was slow") in indirect conversation significantly exceeds that in direct conversation ($p < .01,\ V = 62.5$); the score for T1 in semi-indirect conversation significantly exceeds the corresponding direct conversation score ($p < .01, V = 66$). The score for T2 ("You felt the conversation pace was not natural") in indirect conversation significantly exceeds that in direct conversation ($p < .05,\ V = 0$); the same question in semi-indirect conversation significantly exceeds that in direct conversation ($p < .05, V = 0$). The score for T3 ("The conversation was

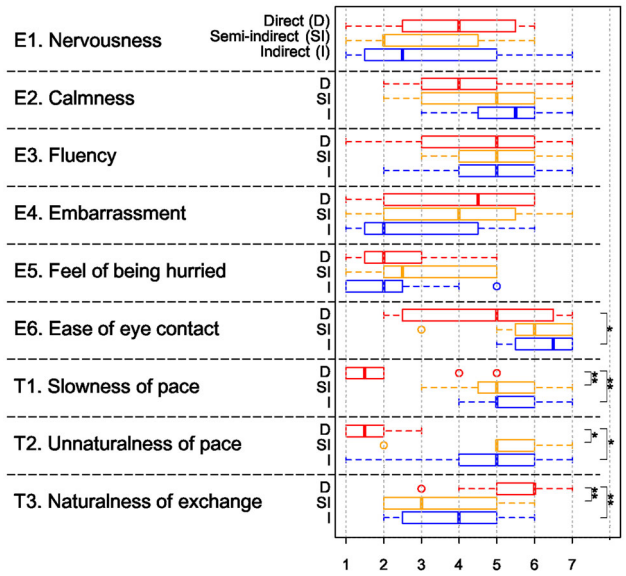


**Fig. 5** Subjective evaluation with respect to ease and turn-taking of conversation ($^{*}p < .05$; $^{**}p < .01$)

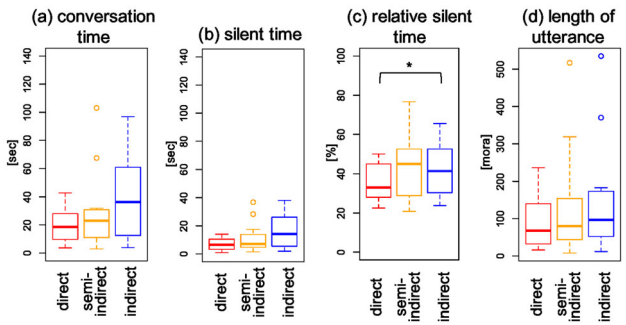


**Fig. 6** Quantitative evaluation of a conversation: ($^{*}p < .05$)

natural") in indirect conversation significantly exceeds that in direct conversation ($p < .01$, $V = 0$); the score for the same question in semi-indirect conversation significantly exceeds that in direct conversation ($p < .01$, $V = 0$). There are no significant differences for any other items.

The results of the quantitative analysis are shown in Fig. 6. The indices in each conversation form were compared using a Wilcoxon signed rank test in which the p-value was corrected using Shaffer's method. The relative silent time in indirect conversation significantly exceeds that in direct conversation ($p < .05$, $V = 7$). Note that there are no significant differences in length of utterances, as referred to in the discussion.

The average FoN of human was 21.1 (SD = 7.3) in the direct condition while one of the robot was 21.7(SD = 8.6) and 20.5(SD = 8.9) in the semi-indirect and indirect ones, respectively. The paired t-test with Shaffers p-adjustment method revealed no significant difference between each pair of the three conditions.

## 3.2 Experiment 2

The purpose of the second experiment is to show that robot-mediated conversation can replace direct conversation, which is the conventional method of counseling. We can consider both indirect and semi-indirect conversations as candidates for conversation via a tele-operated robot. However, we focused only on the semi-indirect condition for comparison with the direct condition because the semi-indirect condition is considered more practical than the indirect condition owing to the following potential merits. First, the field study implies that ease of talking in semi-indirect conversation can be maintained to the operator. Second, participants could stop disclosing if they do not want do so to the operator because it is apparent who is the operator in semi-indirect conversation.

In order to examine the effects of maintaining ease of talking in semi-indirect conversation, two conditions (the Direct-Direct (D-D) and Semi-indirect-Direct (S-D) conditions) were compared; in the D-D condition, participants carried out consecutive direct conversations; in the S-D condition, they participated in direct conversation following semi-indirect conversation. Silent time as an index of ease of talking was measured in the first and second conversations in each condition. At the same time, ease of semi-indirect conversation was rechecked because it was moderately observed but not significant in experiment 1. The hypotheses tested are as follows:

- The silent time in the second conversation in the S-D condition (direct conversation following semi-indirect conversation) is longer than that in the D-D condition (consecutive direct conversations).
- The silent time in the first conversation in the S-D condition (semi-indirect conversation) is longer than that in the D-D condition (direct conversation).

### 3.2.1 Methods

*Participants* The participants were twenty university students (ten males and ten females) with TD ranging in age from 18 to 24 years old.

*Apparatus* The system in which the experimenter communicated via robot with the participants was the same as in experiment 1.

The experimental environment is shown in Fig. 7. The experimenter, participant, and robot were placed in triangular configuration in a closed room with of size 2.2 [m] × 2.7 [m]. The distances between the experimenter and the participant, the participant and the robot, and the robot and the experimenter were 1.0, 1.1 and 1.1 [cm], respectively. The robot was placed on a round table with a height of 0.7 [cm] or, during direct conversation, was hidden from the partic-

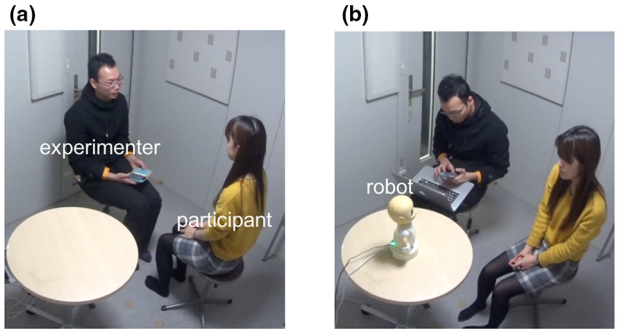


**Fig. 7** Scenes from laboratory experiment 2: **a** direct conversation; **b** semi-indirect conversation

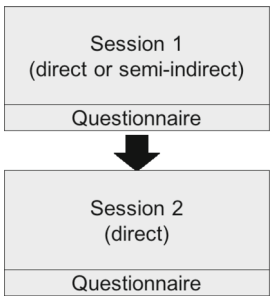


**Fig. 8** Flow of the laboratory experiment 2

ipant. During semi-indirect conversation, the experimenter operated the robot using a laptop PC placed on his lap.

*Procedure* The two conditions (D-D and S-D conditions) were compared using a between-subject design. The participants were split equally by gender between the D-D and S-D conditions. The flow of the experiment is illustrated in Fig. 8. Participants attended two conversation sessions (sessions 1 and 2) and answered questionnaires after each session. Participants in the D-D and S-D conditions participated in direct and semi-indirect conversation, respectively, in session 1. All participated in direct conversation in session 2. The roles of interlocutor in direct conversation and robot operator in semi-indirect conversation were assumed by the experimenter.

Self-promotion was chosen as a conversational task in each session because it was considered to not be generally easy to discuss. At the beginning of session 1, participants were instructed to imagine that the interlocutor was an interviewer whom they had met for the first time and for whom they would perform a self-promotion highlighting their attractiveness until the interlocutor told them to cease. Note that the experimenter who assumed the roles of robot operator and interlocutor was a stranger to all participants.

At the beginning of session 2, participants were instructed to perform self-promotion again but with an emphasis on characteristics differing from those in session 1. Directly following instruction, the interlocutor asked the participants to "please start," and the self-promotion commenced. During the self-promotion, the interlocutor silently nodded when they felt it appropriate to do so. When one minute had passed after commencement of the self-promotion, the interlocutor ended the process by telling participants to finish, regardless of whether they had completed.

The instructions given to participants were basically the same as those in laboratory experiment 1; only the number of sessions and interview situation had different instructions. Namely, the first and second bullet points in the instructions for laboratory experiment 1 were replaced with the following:

- You will have two sessions.
- You will be asked to convey your positive points to the interlocutor. Please assume that he/it is a job interviewer and that you do your best to emphasize all your best qualities.

*Measurements* A questionnaire was answered by the participants after each session. It included seven items related to ease of conversation, referred as E1-7. The items were:

E1 **Nervousness**: You were nervous during the conversation.
E2 **Calmness**: You could calmly think of what you would say.
E3 **Fluency**: You could fluently state what you wanted to say during the self-promotion.
E4 **Tiredness**: You felt tired during the conversation.
E5 **Achievement of eye contact**: You could make eye contact with the interlocutor.
E6 **Hesitation for eye contact**: You hesitated to make eye contact with the interlocutor.
E7 **Comparison of ease**: You promoted yourself more easily in session 2 than in session 1.

We changed some questionnaire items so as to be matched with the experimental setting. We divided an item about eye contact (ease of eye contact) into two ones (hesitation for eye contact and achievement of eye contact). Because we used the situation where strong pressure was placed on participants, it was assumed that most participants will have difficulty making eye contact. Thus, we asked about eye contact in two steps. We also chose opposite expressions in order to determine the degree of difficulty that causes participants to make less eye contact. Besides, we added an item "tiredness" as considered in previous work [36]. We set the situation that is considered more stressful for participants in experiment 2. Thus, we sought to estimate stress with the item because this factor could influence the ease of talking.

On the other hand, items to evaluate impression about turn taking (slowness/unnaturalness of conversational pace, naturalness of exchange) were removed because there were no turn-taking during the task in experiment 2. The feeling of being hurried was also removed because there were no turn-takings that were considered to cause such an impression. In addition, an item on embarrassment was removed for

the following reasons. The issue talked about in laboratory experiment 1, i.e., the experience of lying about their school age, was supposed to be an embarrassing topic because lying is usually interpreted as a negative experience. On the other hand, the task in laboratory experiment 2, i.e., self-promotion in the job interview, focused on the positive traits of participants. Thus, we did not ask about an item on embarrassment in laboratory experiment 2 although we did so in experiment 1.

All items were answered using the same seven-grade Likert scale as in experiment 1. E7 was answered only after session 2 because it involves a comparison between sessions 1 and 2. Questions unrelated to the research purpose, which are two items related to task evaluation and two items related to general evaluation of conversational settings were also included to conceal the research purpose, i.e., ease of conversation. These questions were not analyzed, as they were not directly related to the hypothesis of the study.

Quantitative analysis of the conversations was conducted using video clips of the experiment. Conversation time, silent time, relative silent time, and length of utterances during self-promotion were calculated in the same manner as in experiment 1.

### 3.2.2 Results

The questionnaire items and results are shown in Fig. 9. The scores of each item between the two conditions were compared using the Wilcoxon rank sum test. In session 1, no significant differences were seen between the scores of the items for the two conditions. In session 2, the score of E6, "You felt hesitant to make eye contact with the interlocutor" in the S-D condition was significantly higher than that in the direct condition ($p < .05,\ W = 20$). Note that W is the statistical value in Wilcoxon rank sum test. No significant differences between conditions were seen for any other items.

The results of the quantitative analysis of the conversation (conversation time, silent time, relative silent time, and length of utterances) are shown in Fig. 10. Note that the conversation time is defined here as the time from the moment at which the interlocutor finished saying "please start" through the moment at which the participant finished saying the last word of their self-promotion. Thus, it was generally calculated to be approximately 1 min, as the requested time for self-promotion was 1 min. However, as some participants could not talk for this length of time, the conversational time of a few participants was calculated to be shorter than 1 min, as shown in Fig. 10 (1-a) and (2-a). Each index was compared between the D-D and S-D conditions using the Wilcoxon rank sum test. In session 1, silent time and relative silent time in the S-D condition were significantly larger than in the D-D condition ($p < .01,\ W = 10$ for silent time and $p < .01,\ W = 10$ for relative silent time). Length of utterance in session 1 in the S-D condition was significantly smaller than that in the D-D condition ($p < .01,\ W = 90$). In session 2, silent time and relative silent time in the S-D condition were significantly larger than in the D-D condition ($p < .05,\ W = 20$ for silent time and $p < .05,\ W = 20$ for relative silent time). Length of utterance in session 2 in the S-D condition was significantly smaller than in the D-D condition ($p < .05,\ W = 80$). No significant differences were seen in the other indexes.

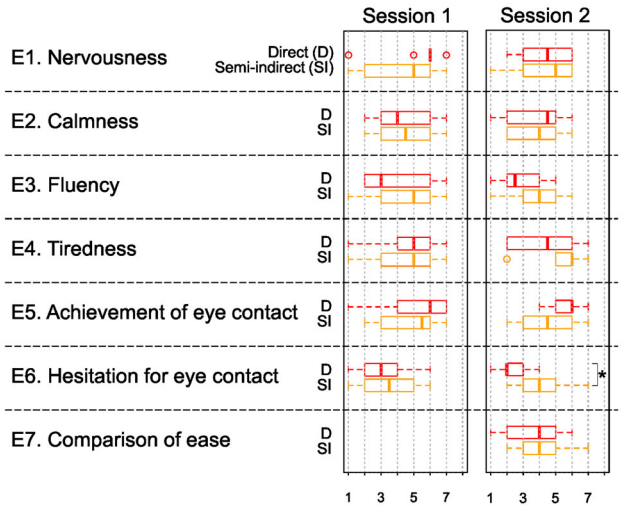


**Fig. 9** Subjective evaluation for ease of conversation ($^{*}p < .05$)

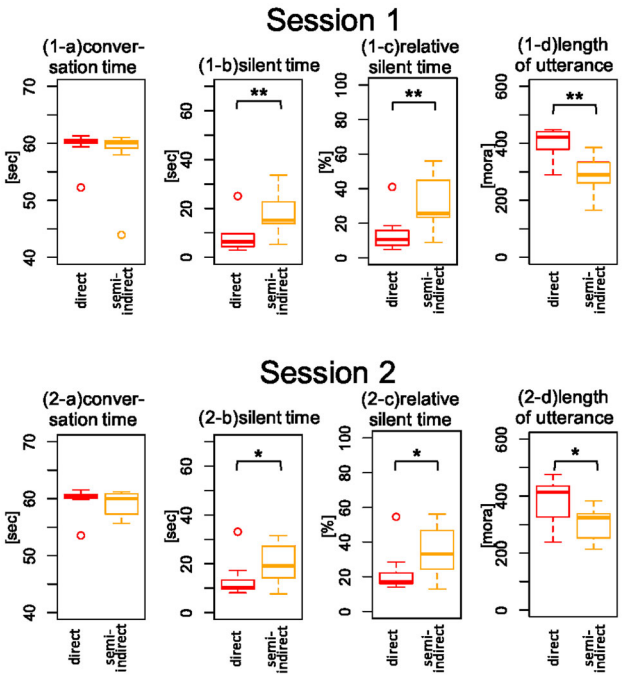


**Fig. 10** Quantitative evaluation of conversation ($^{*}p < .05$; $^{**}p < .01$)

The average FoN values in session 1 under D-D and S-D conditions were 15.2 (SD = 7.0) and 12.5 (SD = 3.7), respectively, whereas that of session 2 under D-D and S-D conditions were 14.3 (SD = 5.3) and 11.2 (SD = 3.1), respectively. There were also no significant differences between each pair according to the t-test results.

### 3.3 Discussion

There was no significant difference between the subjective impressions on the ease of conversation between conditions (see Fig. 5). On the other hand, the relative silent times significantly increased in indirect conversation than in direct conversation. One possible interpretation of these inconsistent results is that the effect of using the robot on the ease of conversation might be limited to the subconscious level.

The participants felt that it was easier to make eye contact with the robot than with the experimenter (E6 in Fig. 5). As gaze pressure, which tends to be avoided by people who feel threatened or anxious (e.g., [37,38]), was considered to be reduced in conversation via the robot, these participants could be considered to be calmer than those engaged in direct conversation. On the other hand, the verbal response of the robot was often delayed because the operator operated its utterances using a keyboard interface, which usually takes more time than speaking verbally. This delay in terms of response is considered to have made participants feel that the conversational pace was slow (T1 in Fig. 5). Another interpretation of this is that the slow pace calmed them by providing thinking time.

To determine whether this slow pace should be mitigated or maintained in future implementations, it is worth checking which aspects of robot-mediated conversation contribute to an increase in conversational calmness. In addition, the above results appear to be consistent with the results of the field study. In other words, it can be hypothesized that the reported increase in self-disclosure in the field study were caused by an increase in calmness during conversation via robot in individuals with ASD.

Another possible interpretation of the results on amount of silent time is that the index represents the degree of difficulty for a participant in speaking with the interlocutor. Unnaturalness in terms of the pace and exchange of conversation (T2, T3 in Fig. 5) might represent or cause such difficulty. However, there was no significant difference in the length of utterance—which is considered to decrease if the participant experiences difficulty in talking with the interlocutor—among conditions. Therefore, it is likely that the amount of silent time in a conversation via robot does not represent difficulty but rather ease of talking.

The increased relative silent time during semi-indirect conversation reported in Sect. 3.2.2 indicates the effect of the robot in encouraging longer silences, even when the robot operator was in the same room as the participant.

The increased relative silent time during direct conversation following the semi-indirect conversation reported in Sect. 3.2.2 indicates that the ease of talking was maintained during consecutive direct conversations with the operator. The maintained effect between two consecutive sessions seems consistent with the results in the field study. The conversational topic remained the same between consecutive sessions in the field study, while it changed in the laboratory study, which suggests that this effect can be observed regardless of whether a single topic is focused on. It is possible that the experience of talking easily with a robot sitting beside its operator might have been conflated in the participants minds with the experience of speaking directly to the same person. To test this, it is worth determining whether the current effect occurs with several participants who might be silent at first in the S-D condition.

No significant differences were found in any items in the subjective evaluation of session 1 of experiment 2. It is hypothesized that the variance in ease of self-promotion among the participants made it difficult to observe the hypothesized effects because the variance could not be controlled for in the between-subject design.

The impression of improved eye contact under the D-D condition reported in Sect. 3.2.2 implies that the first session of direct conversation worked as habituation. This habituation could be another cause of enhanced ease of speaking; however, the results show that the increased silence through the experience of semi-indirect conversation exceeded the increase due to this habituation.

It should be noted that the increased length of utterance in experiment 2 reported in Sect. 3.2.2 should be carefully interpreted. The length of utterance was treated as a kind of behavioral measure of the active attitude of the participant to mention something in experiment 1. However, because it was fixed to one minute and consists of the length of utterance and silent time, the length of the utterance should be treated as an artifact representing the silent time and ignored in experiment 2.

Although we found that Japanese clients can be more silent in front of the robot, cultural factors were not examined. Considering that the attitude toward the robot can vary depending on culture [39], the tendency for long silences might not be observed in clients in other cultures. In addition, although we considered silence as positive sign, it is unclear whether the same is true for subjects in the USA or Western Europe, which is considered to have more extraverted culture [40]. In order to clarify whether this system is effective in other countries, it is important future work to conduct cross-cultural studies.

## 4 Conclusion

This study examined the advantages of using a tele-operated robot to talk to individuals with ASD and TD in various situations. The results of the field experiment suggest that daily-life-guidance via a tele-operated robot can enable individuals with ASD to establish conversational focus on topics that they had not previously disclosed to their caregiver. In addition, the use of tele-operated robots was found to be potentially beneficial for treatment and education, as it was shown that human relationship issues of subjects with ASD could be relieved or at least disclosed. The enhancement of discussion was observed when the robot was operated both remotely and from the same room. A further finding was that conversation with a robot whose operator is in the same room can make it easier for an ASD individual to share information with their teacher after they have done so in semi-indirect conversation. These results suggest the potential applications of tele-operated robots to improve counseling in the treatment and education of ASD individuals.

A subsequent laboratory experiment then examined the ease with which TD individuals conversed in three formats: direct, semi-indirect, and indirect conversation. The results of this experiment suggest that participation was easier in both semi-indirect and indirect conversation than in direct conversation in terms of increased silent times, which is considered to be an index of how long an individual takes to compose an utterance and, thus, of their comfort level. Going back to the results of the field experiment, it can be argued that the effect of increased length of silence might have contributed to creating an easier environment for the individuals with ASD to formulate and disclose their thoughts and concerns.

In addition, it was conjectured that the tendency toward increased ease during the semi-indirect situations was maintained even in consecutive direct conversation with the operator. In the field study, such effects were observed for a fixed subject of conversation; in the laboratory experiment, the maintenance of ease seemed to occur regardless of whether the topic of conversation changed. We hypothesize that this effect arises from the subjects experiences of speaking easily via the robot while in the presence of the operator. Through this experience, a participant could adopt a calmer attitude through the robot toward the operator. This argument suggests the potential of applications using semi-indirect forms of communication for establishing smoother interpersonal relationships. For applications involving treatment and education, it is worth clarifying whether and how the customization of the design of robot appearance and interfaces might be considered.

**Acknowledgements** We are deeply grateful to the participants and their guardians for their kind cooperation. We also appreciate the beneficial support and feedback provided by the schoolteachers. This work was supported by the Japan Science and Technology Agency (JST), the Exploratory Research for Advanced Technology (ERATO) the ISHIGURO symbiotic human–robot interaction project, and Japan Society for the Promotion of Science (JSPS) KAKENHI Grant Numbers 25220004, 24680022, and 15K12117.

### Compliance with Ethical Standards

**Conflict of interest** Y. Yoshikawa and H. Ishiguro serve as consultants of Vstone Co. Ltd.

**Ethical Statement** In this study, ethical approval was received from Graduate School of Engineering Science, Osaka University and Research Center for Child Mental Development, Kanazawa University.

## References

1. Carpenter Laura (2013) American Psychiatric Association. Diagnostic and statistical manual of mental disorders fifth edition (dsm-5)
2. Baio J, Eds, (2010) National Center on Birth Defects and Developmental Disabilities, and CDC. Prevalence of autism spectrum disorder among children aged 8 years autism and developmental disabilities monitoring network, 11 sites, united states
3. Green VA, Pituch KA, Itchon J, Choi A, OReilly M, Sigafoos J (2006) Internet survey of treatments used by parents of children with autism. Res Dev Disabil 27(1):70–84
4. Kim JA, Szatmari P, Bryson SE, Streiner DL, Wilson FJ (2000) The prevalence of anxiety and mood problems among children with autism and asperger syndrome. Autism 4(2):117–132
5. Carter S (2009) Bullying of students with asperger syndrome. Issues Compr Pediatric Nurs 32(3):145–154
6. Allen D, Evans C, Hider A, Hawkins S, Peckett H, Morgan H (2008) Offending behaviour in adults with asperger syndrome. J Autism Dev Disord 38(4):748–758
7. Paul R, Orlovski SM, Marcinko HC, Volkmar F (2009) Conversational behaviors in youth with high-functioning asd and asperger syndrome. J Autism Dev Disord 39(1):115–125
8. Choi JJ, Kwak SS (2016) Can you feel me?: How embodiment levels of telepresence systems affect presence. In: 2016 25th IEEE international symposium on robot and human interactive communication (RO-MAN). IEEE, pp 606–611
9. Tanaka K, Nakanishi H, Ishiguro H (2014) Robot conferencing: physically embodied motions enhance social telepresence. In: Proceedings of the extended abstracts of the 32nd annual ACM conference on Human factors in computing systems. ACM, pp 1591–1596
10. Stollnberger G, Giuliani M, Mirnig N, Tscheligi M, Arent K, Kreczmer B, Grzeszczak F, Szczesniak-Stanczyk D, Zarczuk R, Wysokinski A (2016) Designing user interfaces for different user groups: a three-way teleconference system for doctors, patients and assistants using a remote medical robot. In: 2016 25th IEEE international symposium on robot and human interactive communication (RO-MAN). IEEE, pp 612–617
11. Uchida T, Takahashi H, Ban M, Yoshikawa Y, Ishiguro H (2017) A robot counseling system -what kinds of topics do we prefer to disclose to robots? In: 2017 26th IEEE international symposium on robot and human interactive communication (RO-MAN). IEEE, pp 207–212
12. Kuwamura K, Nishio S, Sato S (2016) Can we talk through a robot as if face-to-face? long-term fieldwork using teleoperated robot for seniors with Alzheimer's disease. Front Psychol 7

13. Sproull L, Kiesler S (1986) Reducing social context cues: electronic mail in organizational communication. Manag Sci 32(11):1492–1512
14. Joinson AN (2001) Self-disclosure in computer-mediated communication: the role of self-awareness and visual anonymity. Eur J Soc Psychol 31(2):177–192
15. DeVault D, Artstein R, Benn G, Dey T, Fast E, Gainer A, Georgila K, Gratch J, Hartholt A, Lhommet M et al (2014) Simsensei kiosk: a virtual human interviewer for healthcare decision support. In: Proceedings of the 2014 international conference on Autonomous agents and multi-agent systems. International Foundation for Autonomous Agents and Multiagent Systems, pp 1061–1068
16. Yokotani K, Takagi G, Wakashima K (2018) Advantages of virtual agents over clinical psychologists during comprehensive mental health interviews using a mixed methods design. In: Computers in human behavior
17. Geiskkovitch DY, Cormier D, Seo SH, Young JE (2015) Please continue, we need more data: an exploration of obedience to robots. J Hum Robot Interact 5(1):82–99
18. Wood LJ, Dautenhahn K, Rainer A, Robins B, Lehmann H, Syrdal DS (2013) Robot-mediated interviews-how effective is a humanoid robot as a tool for interviewing young children? PloS ONE 8(3):e59448
19. Bethel CL, Henkel Z, Stives K, May DC, Eakin DK, Pilkinton M, Jones A, Stubbs-Richardson M (2016) Using robots to interview children about bullying: lessons learned from an exploratory study. In: 2016 25th IEEE international symposium on robot and human interactive communication (RO-MAN). IEEE, pp 712–717
20. Weir S, Emanuel R (1976) Using LOGO to catalyse communication in an autistic child. University of Edinburgh, Edinburgh
21. Salter T, Davey N, Michaud F (2014) Designing & developing queball, a robotic device for autism therapy. In: 2014 RO-MAN: the 23rd IEEE international symposium on robot and human interactive communication. IEEE, pp 574–579
22. Hideki K, Michalowski MP, Nakagawa C (2009) Keepon. Int J Soc Robot 1(1):3–18
23. Kim ES, Berkovits LD, Bernier EP, Leyzberg D, Shic F, Paul R, Scassellati B (2013) Social robots as embedded reinforcers of social behavior in children with autism. J Autism Dev Disord 43(5):1038–1049
24. Robins B, Amirabdollahian F, Ji Z, Dautenhahn K (2010) Tactile interaction with a humanoid robot for children with autism: a case study analysis involving user requirements and results of an initial implementation. In: RO-MAN, 2010 IEEE. IEEE, pp 704–711
25. Robins B, Dautenhahn K, Dickerson P (2009) From isolation to communication: a case study evaluation of robot assisted play for children with autism with a minimally expressive humanoid robot. In: Second international conferences on advances in computer-human interactions, 2009. ACHI'09. IEEE, pp 205–211
26. Shamsuddin S, Yussof H, Ismail LI, Mohamed S, Hanapiah FA, Zahari NI (2012) Initial response in HRI-a case study on evaluation of child with autism spectrum disorders interacting with a humanoid robot nao. Procedia Eng 41:1448–1455
27. Yoshikawa Y, Matsumoto Y, Kumazaki H, Wakita Y, Nemoto S, Ishiguro H, Mimura M, Miyao M (2015) Positive bias of gaze-following to android robot in adolescents with autism spectrum disorders. In: JSAI international symposium on artificial intelligence. Springer, pp 447–453
28. Gendlin ET (1982) Focusing. Bantam, New York
29. Nagaoka C, Kuwabara T, Yoshikawa S, Watabe M, Komori M, Oyama Y, Hatanaka C (2013) Implication of silence in a Japanese psychotherapy context: a preliminary study using quantitative analysis of silence and utterance of a therapist and a client. Asia Pacific J Couns Psychother 4(2):147–152
30. Wechsler D (1991) WISC-III: wechsler intelligence scale for children: manual. Psychological Corporation, Agra
31. Wechsler D (2003) WISC-IV wechsler intelligence scale for children: technical and interpretative: manual. Pearson, London
32. Sumioka H, Nakae A, Kanai R, Ishiguro H (2013) Huggable communication medium decreases cortisol levels. Sci Rep 3:3034
33. Bartneck C, Bleeker T, Bun J, Fens P, Riet L (2010) The influence of robot anthropomorphism on the feelings of embarrassment when interacting with robots. Paladyn J Behav Robot 1(2):109–115
34. Yoshikawa Y, Shinozawa K, Ishiguro H, Hagita N, Miyamoto T (2006)The effects of responsive eye movement and blinking behavior in a communication robot. In: 2006 IEEE/RSJ international conference on intelligent robots and systems. IEEE, pp 4564–4569
35. Shimaya J, Yoshikawa Y, Matsumoto Y, Kumazaki H, Ishiguro H, Mimura M, Miyao M (2016) Advantages of indirect conversation via a desktop humanoid robot: case study on daily life guidance for adolescents with autism spectrum disorders. In: 2016 25th IEEE international symposium on robot and human interactive communication (RO-MAN). IEEE, pp 831–836
36. Wada K, Shibata T, Saito T, Tanie K (2004) Effects of robot-assisted activity for elderly people and nurses at a day service center. Proc IEEE 92(11):1780–1788
37. Modigliani A (1971) Embarrassment, facework, and eye contact: testing a theory of embarrassment. J Pers Soc Psychol 17(1):15
38. Adams RB, Gordon HL, Baird AA, Ambady N, Kleck RE (2003) Effects of gaze on amygdala sensitivity to anger and fear faces. Science 300(5625):1536–1536
39. Bartneck C, Nomura T, Kanda T, Suzuki T, Kato K (2005) Cultural differences in attitudes towards robots. In: Proceedings of symposium on robot companions (SSAISB 2005 convention), pp 1–4
40. Nishimura S, Nevgi A, Tella S (2008) Communication style and cultural features in high/low context communication cultures: a case study of Finland, Japan and India. Teoksessa A. Kallioniemi (toim.), Uudistuva ja kehittyvä ainedidaktiikka. Ainedidaktinen symposiumi 8 (2008): 783–796



**Jiro Shimaya** received the master degree in engineering from Osaka University, Osaka, Japan, in 2017. He is a Ph.D. student at Graduate School of Engineering Science, Osaka University. His research interests include human–robot interaction and education.

**Yuichiro Yoshikawa** received the Ph.D. degree in engineering from Osaka University, Japan, in 2005. From 2010, He has been an Associate Professor in the Graduate School of Engineering Science, Osaka University. From 2014, he has been a project coordinator of JST ERATO Ishiguro Symbiotic Human–Robot Interaction Project. His research interests include interactive robotics, therapeutic robots for individual with developmental disorders, and cognitive developmental robotics.

**Hirokazu Kumazaki** received the M.D. from Keio University School of Medicine in 2004, and Ph.D from Keio University School of Medicine in 2015. He has been conducting research for intervention for children with autism spectrum disorders using robots. He is currently an associate professor in Research Center for Child Mental Development, Kanazawa University.

**Yoshio Matsumoto** is currently a team leader of Service Robotics Research Team, Robot Innovation Research Center, National Institute of Advanced Industrial Science and Technology (AIST). He received

Ph.D degree in information engineering from the University in 1998. Then he joined the Australian National University in 1998, Nara Institute of Science and Technology in 1999, Osaka University in 2007, and AIST in 2009. His research interests include assistive service robots, human–robot interaction, android robotics, and real-time vision.

**Masutomo Miyao** received the M.D. and Ph.D. of medicine from Tokushima University of Medicine in 1975. Then he joined the Department of Pediatrics, The University of Tokyo Hospital in 1975, Jichi Medical University Dept. of Pediatrics in 1980, Dept. of Neurobiology, Harvard University in 1986, and Dept. of Psychosocial Medicine, National Center for Child Health and Development in 2002. From 2014, he has been the director of Donguri Psycho Developmental Clinic for Developmental Disorder. His research interests includes child psychiatry and therapeutic intervention for children with developmental disorders using robots.

**Hiroshi Ishiguro** received the Ph.D. degree in engineering from the Osaka University, Japan in 1991. He is currently Professor of Department of Systems Innovation in the Graduate School of Engineering Science at Osaka University (2009–) and Distinguished Professor of Osaka University (2017–). He is also visiting Director (2014–) (group leader: 2002–2013) of Hiroshi Ishiguro Laboratories at the Advanced Telecommunications Research Institute and an ATR fellow. His research interests include sensor networks, interactive robotics, and android science. He received the Osaka Cultural Award in 2011. In 2015, he received the Prize for Science and Technology (Research Category) by the Minister of Education, Culture, Sports, Science and Technology (MEXT).

# Terms and Conditions

Springer Nature journal content, brought to you courtesy of Springer Nature Customer Service Center GmbH (“Springer Nature”).
Springer Nature supports a reasonable amount of sharing of research papers by authors, subscribers and authorised users (“Users”), for small-scale personal, non-commercial use provided that all copyright, trade and service marks and other proprietary notices are maintained. By accessing, sharing, receiving or otherwise using the Springer Nature journal content you agree to these terms of use (“Terms”). For these purposes, Springer Nature considers academic use (by researchers and students) to be non-commercial.
These Terms are supplementary and will apply in addition to any applicable website terms and conditions, a relevant site licence or a personal subscription. These Terms will prevail over any conflict or ambiguity with regards to the relevant terms, a site licence or a personal subscription (to the extent of the conflict or ambiguity only). For Creative Commons-licensed articles, the terms of the Creative Commons license used will apply.
We collect and use personal data to provide access to the Springer Nature journal content. We may also use these personal data internally within ResearchGate and Springer Nature and as agreed share it, in an anonymised way, for purposes of tracking, analysis and reporting. We will not otherwise disclose your personal data outside the ResearchGate or the Springer Nature group of companies unless we have your permission as detailed in the Privacy Policy.
While Users may use the Springer Nature journal content for small scale, personal non-commercial use, it is important to note that Users may not:

1. use such content for the purpose of providing other users with access on a regular or large scale basis or as a means to circumvent access control;
2. use such content where to do so would be considered a criminal or statutory offence in any jurisdiction, or gives rise to civil liability, or is otherwise unlawful;
3. falsely or misleadingly imply or suggest endorsement, approval , sponsorship, or association unless explicitly agreed to by Springer Nature in writing;
4. use bots or other automated methods to access the content or redirect messages
5. override any security feature or exclusionary protocol; or
6. share the content in order to create substitute for Springer Nature products or services or a systematic database of Springer Nature journal content.

In line with the restriction against commercial use, Springer Nature does not permit the creation of a product or service that creates revenue, royalties, rent or income from our content or its inclusion as part of a paid for service or for other commercial gain. Springer Nature journal content cannot be used for inter-library loans and librarians may not upload Springer Nature journal content on a large scale into their, or any other, institutional repository.
These terms of use are reviewed regularly and may be amended at any time. Springer Nature is not obligated to publish any information or content on this website and may remove it or features or functionality at our sole discretion, at any time with or without notice. Springer Nature may revoke this licence to you at any time and remove access to any copies of the Springer Nature journal content which have been saved.
To the fullest extent permitted by law, Springer Nature makes no warranties, representations or guarantees to Users, either express or implied with respect to the Springer nature journal content and all parties disclaim and waive any implied warranties or warranties imposed by law, including merchantability or fitness for any particular purpose.
Please note that these rights do not automatically extend to content, data or other material published by Springer Nature that may be licensed from third parties.
If you would like to use or distribute our Springer Nature journal content to a wider audience or on a regular basis or in any other manner not expressly permitted by these Terms, please contact Springer Nature at

onlineservice@springernature.com