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Advantages of Indirect Conversation via a Desktop Humanoid Robot: Case Study on Daily Life Guidance for Adolescents with Autism Spectrum Disorders

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Abstract— **We conducted a pilot experiment to examine the potential of a communication robot for supporting verbal interaction among adolescents with autism spectrum disorders (ASD) and their caregivers. Three teenagers with ASD indirectly conversed with their teacher via a desktop humanoid robot for around 40 min on average per day. In this situation, they showed some positive tendencies such as non-echolalic responses and talk about problems related to human relationships; they had not shown such tendencies before when they directly talked with their teacher in their daily life. During the trials, they also showed changes in their attitudes toward their teachers and friends; this implies that individuals with ASD could use their experience of communication with a robot for communication with a human. A quantitative analysis of the utterances in the trials suggested that reduced utterances from a caregiver might positively influence individuals with ASD toward sharing more information.**

I. INTRODUCTION

Autism spectrum disorder (ASD) is a developmental disorder whose main features are deficits in social communication and tendencies of restrictive and repetitive interest or behavior [1]. Studies have reported that the number of individuals with ASD is increasing [2]. Therefore, there is an urgent need to recognize the necessity of providing treatment and education to such people. Various methods such as speech therapy, use of visual schedules, and sensory integration are employed for the treatment and education of individuals with ASD [3].

When individuals with ASD display its secondary mental problems, which sometimes manifest as anxiety and mood disorders [4] or as problems related to social maladaptation including bullying [5] and delinquent behavior [6], it is important for their caregivers to hear about their problems through conversations, namely, through counseling or daily life guidance. However, caregivers might find it difficult to converse with them owing to their conversational deficits [7] and their low attention to living things, which is partially evident by their insensitivity to social contingency and to biological visual stimuli [8].

Recent developments in information technology such as augmentative and alternative communication (AAC) devices [9] and virtual reality (VR) [10] are expected to support communication among individuals with ASD and their caregivers.

AAC devices are considered to help users to make received information understandable [11] as well as to express what needs to be conveyed [12]. For example, users can express their thoughts using an AAC device having a text-to-speech function. However, how to fill the gap between communication supported by AAC devices and natural communication remains an open question.

VR is also considered helpful [10]. Researchers have attempted to teach social skills to individuals with ASD in immersive virtual environments (IVEs) [13] or through interaction with an on-screen agent [14]. One positive aspect of virtual information in treatment and education for individuals with ASD is the possibility to simplify the world. In other words, VR is considered to appropriately suppress the level of reality in the stimuli compared to that in the real world, which might be more difficult for individuals with ASD to cope with because of their low attention to living things [8] and their poor capability to deal with a noisy environment [15]. However, it is necessary to consider how to connect experiences in such a suppressed environment to real ones. It is not always easy for caregivers to intervene in interactions conducted in IVEs. Even when caregivers intervene in an interaction between an individual with ASD and an on-screen agent, it is difficult to achieve triadic interaction owing to the limitations in projecting a three-dimensional image to a plane screen; in other words, it is difficult to draw images of the on-screen agent by which all participants can recognize the attention of this agent in the same way.

Robots can provide simplified stimuli in a manner similar to virtual agents, and they have a real-world body, unlike virtual agents. These features might contribute to the support of communication with individuals with ASD and let them naturally interact with their caregivers. The advantage of robots is partially supported by studies of the

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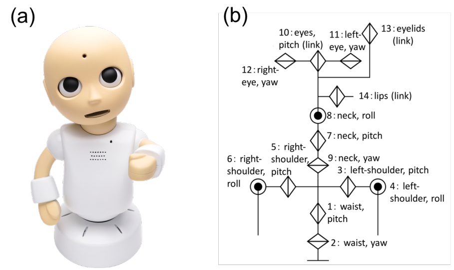

Fig. 1. The desktop humanoid CommU (a) and its motor axis arrangement (b)

non-verbal interaction between robots and individuals with ASD [16][17][18]. Kozima et al. reported that a yellow snowman-shaped robot called Keepon could elicit non-verbal social cues from children with ASD and promote sharing of their interests and feelings with their caregivers and among themselves [16].

These results motivate us to introduce a communication robot for treatment and education based on verbal interaction with individuals with ASD. If a robot can participate in a conversation to promote the verbal expression of individuals with ASD, therapeutic and educational verbal communication, that is, counseling or daily life guidance, could be performed more effectively. Shamsuddin et al. let a humanoid robot called Nao interact verbally with a 10-year-old child and showed a reduction in autistic traits during the interaction [19]. However, they did not focus on the supportiveness of the robot in a counseling-like situation.

This study aims to examine whether robots having an utterance function can assist in treatment and education based on verbal communication with individuals with ASD. As a first step, we examined the influence of conversation with a robot on individuals with ASD through pilot case studies for 2–4 days. We let three individuals with ASD experience an indirect conversation via a robot, in which they indirectly talked with their caregiver via a robot. Then, we qualitatively analyzed the changes in their behavior and quantitatively analyzed their utterances through a series of trials.

II. METHOD

A. System for indirect conversation via a robot

A small humanoid robot called CommU, which is 304 mm tall, was used as a platform for indirect conversation (Fig. 1). It 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 the rich DoFs dedicated for controlling where it is looking are expected to contribute to rich gaze expressions. At the same time, its small and cute appearance is expected to help avoid fearfulness among children.

Fig. 2 shows the framework in which a counselor conducted indirect counseling via a robot with the counselee. The robot utters a sentence that the counselor types with a keyboard interface installed on the counselor side. A commercial software, AITalk (AI Inc.), is used for Japanese

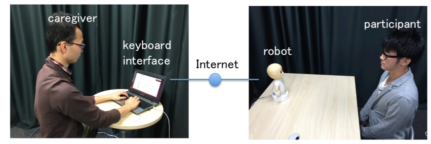

Fig. 2. Framework for indirect counseling via a robot

Fig. 3. Interface to control robot

text-to-speech synthesis, and a voice model called *yuuto* is chosen to match its childlike appearance. During utterances, the robot moves its lips to be easily identified as a speaker. Furthermore, it automatically shows some types of idling motions such as blinking and rolling the neck and shoulders so as to not look like an inanimate object.

Fig. 3 shows the interface that the counselor uses for producing a robot utterance. This interface is implemented in a laptop computer so that the counselor can arbitrarily place it inside or outside the room where the robot is placed. When operating from outside the robot room, the counselor uses video images captured by a video camera to observe the utterances and behavior of the counselee. The counselor basically types text in line editor A, and then the robot utters the typed text in the forward direction. If the counselor would like to make the robot utter the text in a different direction, for example, when more than two people are present in the robot room, the counselor uses line editor B to produce an utterance in a different pre-defined direction. Although the lower area of the interface is designed to produce pre-defined behaviors such as gestures and utterances, it was not used in this experiment.

There are two patterns of the arrangement of robots and other instruments in indirect conversation, which are shown as A1 and A2 in Fig. 4. A1 is for a dyadic interaction via a robot between a counselee and a counselor (operator). When it is easier for a counselee to type a sentence than to speak it, we choose the double indirect mode A2, in which one more robot is used for a counselee. In such a situation, a reduced version of the interface is used for the counselee. It automatically controls the complex behavior of multiple robots to manage turn taking and requires users to only type text.

B. Participants

We recruited six participants from students in a private school for special needs in Japan based on the opinions of

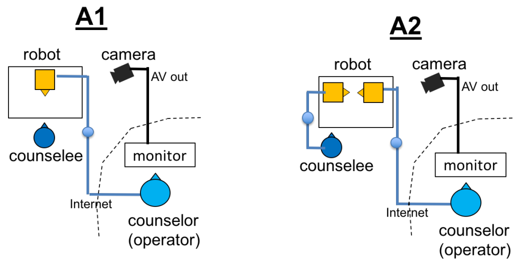

Fig. 4. Experimental arrangements

their teachers. Informed consent was obtained from all individual participants included in the study and their guardians.

To select the six participants, which was the maximum number that could be accommodated in the experimental trial during school hours, we first asked teachers to line up students with whom they would like to talk via a robot. Four students (A, B, C, and D) were lined up. A was chosen because the teacher sometimes faced difficulties in communication owing to his frequent echolalia. B, C, and D were chosen because they had difficulties with human relationships. Two more participants were chosen from among students who seemed interested in the robot. For this, we allowed five candidate students to perform a preliminary indirect conversation via a robot with the teacher after confirming that they hoped to do so. In the preliminary indirect conversation, which took 22±8 min on average, the teacher asked two types of questions: a daily question (e.g., "what is your name?", "how's the weather?", and "what did you eat today?") and a counseling-like question (e.g., "when and why were you scolded recently?", "why are you late for school?", and "who do you like/dislike?"). Four of the five students replied to both types of questions, whereas one student replied only to the daily question. Of these four, we asked the teacher to choose two (E and F) who had uttered more or showed different behavior from usual.

Although we selected six students by the procedure above, C, D, and F could not get more than two chances of daily life guidance via the robot owing to their absence from school during the experimental period. Therefore, we report the cases of the other three students (A, B, and E). Table I shows their personal details such as sex, age, and full scale intelligence quotient (FIQ) as estimated from the Wechsler Intelligence Scale for Children 3 [20] or 4 [21].

All of them were diagnosed through the consensus of a clinical team comprising experienced professionals (child psychiatrists and pediatric neurologists). The team assessments were performed following a detailed clinical examination on the first visit and follow-up observations and through an evaluation of the answers provided in response to a questionnaire related to the development and symptoms of participants as completed by guardians. Clinical psychologists collected information from the guardians concerning developmental milestones (including joint attention, social interaction, pretend play, and repetitive behaviors, with onset prior to 3 years of age) and episodes (e.g., how the individual with ASD behaved during kindergarten and school). Additional professionals, such as teachers, provided further background based on their detailed observations of interactions with people (especially non-family members), repetitive behaviors, obsessive/compulsive traits, and stereotyped behaviors. The fourth and seventh authors confirmed existing diagnoses by using diagnostic instruments and screening questionnaires, including the Pervasive Developmental Disorder-Autism Society Japan Rating Scale (PARS), a diagnostic interview scale for ASD developed in Japan (PARS Committee 2008) [22].

TABLE I
PARTICIPANTS

participant	sex	age	FIQ
A	Male	18 y	59
B	Female	15 y	80
E	Female	18 y	52

C. Procedure

The participants had an indirect conversation, in which they indirectly talked with their teacher via the robot, once a day. They continued it until they or the teacher decided to finish. They had a direct conversation, in which they talked with their teacher face to face, on the first and last day to compare their behavior in each type of conversation. Because they had two trials a day on the first and last days, we limited the time of direct conversation to 15 min to avoid making them too tired.

The appropriate experimental arrangement was chosen depending on the characteristics of the participants as well as the topic or purpose of each trial. The arrangement included factors such as how many robots were used, where the teacher operated the robot (same or different room from the robot), and whether another teacher different from the operator attended the conversation. The participants' utterances and behavior during the experiment were recorded by video cameras installed in the room where the conversation trials were conducted.

III. RESULT

Table II shows the conversation time. A, B, and E participated in the experimental trials for 4, 2, and 3 days, respectively. In the following subsections, we report suggestive examples of what happened to each participant. Instead of reporting the details of the utterances produced, we focus

TABLE II
TIME OF DIRECT AND INDIRECT CONVERSATIONS (MIN)

case	conversation	Day 1	Day 2	Day 3	Day 4
A	direct	7.1	-	-	13.0
	indirect	38.2	57.2	73.7	34.7
B	direct	2.3	6.3	-	-
	indirect	32.0	25.5	-	-
E	direct	8.3	-	5.1	-
	indirect	16.1	41.4	39.2	-

on describing the potential qualitative changes in social relationships as the effect of the proposed method since the utterances cannot be replicated in their details in any follow-up studies.

Case A

A was an 18-year-old male student with ASD. His teachers had difficulties in understanding his thoughts, tastes, and human relationships owing to his tendency of echolalia. Because we considered that typing might be easier for A than speaking, we introduced another robot for him. He let the robot utter what he typed. A was asked to attend to activities such as an association game, easy gymnastics, reading a poem, and a game of go in the trials because the teacher wanted to know what he was thinking in their daily school life. The teacher operated the robot in the same room where A was to support his trials.

Surprisingly, most of his messages produced by typing in the association game were not like echolalia. In the game, A and the teacher alternately uttered a word related to a specific topic such as "vehicle" or "food." A could respond to a request from the robot to change topics in the association game, while he never proposed a new topic by himself.

In other situations, the messages produced by him were like echolalia. Although the teacher asked him many questions such as whether he was satisfied with school life, A just typed the same text included in the teacher's questions. In other words, the teacher could not enrich his understanding on these questions through the trial.

Case B

B was a 15-year-old female student with ASD. She had some difficulties with her human relationships that could not be managed well by her teachers. In case B, the teacher operated the robot in a different room from B and the robot.

The teacher succeeded in talking with her via the robot about her excessive aggression toward particular classmates in daily life, which had been a difficult issue for the teacher to talk about directly. The teacher tried to suggest to her that she should inhibit her aggression and promised to allow her to use her favorite tablet PC as a reward. Because she accepted the offer, the teacher set up an opportunity for her to interact with one of the particular classmates. In this encounter, she did not show any aggressive behavior and got along with him, which seemed a positive experience to her according to the questionnaire. According to her teacher's later report, she had been able to control her aggression in front of the particular classmates for three weeks after her successful encounter.

Case E

E was an 18-year-old female student with ASD. She tended to avoid answering specific questions. One of them was about people she disliked. If the teacher directly asked her, "Do you have any person you dislike?" she usually answered with, "No, I don't." To let her participate in a triadic interaction with the robot, on Day 1 and Day 2 the teacher began to operate the robot in the same room where she was. Because E was disturbed by the teacher's presence and looked restless, the teacher decided to operate the robot from a different room on Day 3.

We observed a change in her answers to questions about the people she disliked. In the preliminary conversation to select participants, the teacher had asked her, "Do you have any person you dislike?" via the robot. She had responded with the name of a certain person (called X in this section), although she had tended to avoid talking about this topic. In a direct conversation on Day 1, the teacher asked her, "Who's a person you dislike?" She responded with, "No, I don't have." In an indirect conversation on Day 1, the teacher asked her, "Do you like or dislike X?" She responded with, "I dislike." It should be noted that the teacher was in the same room as she was during the conversation. On Day 2, the teacher asked her no questions related to the people she disliked. In a direct conversation on Day 3, the teacher asked her, "Who's a person you dislike?" She answered with two names, X and another person, called Y. This means that the teacher succeeded in directly talking with her about the people she disliked on Day 3, although he had failed to do so on Day 1.

IV. DISCUSSION

Each participant showed notable behavior in the indirect conversation: A responded with different words from those used by the teacher, which was not considered echolalia-like; B talked about her problems with human relationships; and E disclosed whom she disliked. These behaviors had not been shown in direct conversation with the teacher in their daily life. These successful changes in their behavior in conversation imply that a communication robot might assist caregivers to conduct counseling-like conversation with individuals with ASD.

Meanwhile, it has not been confirmed whether individuals with ASD can make use of such communication with robots for communication with a human. However, B and E showed changes in their attitude toward their friends or teacher after indirect conversation. B became able to keep calm in front of one of her classmates who had always irritated her after indirect conversation, in which she had promised to inhibit her aggression toward them. In this case, it is considered that the promise with the robot encouraged her to make efforts to solve her problem about human relationships. On the other hand, E did not make any promise with the robot through the trials. Nevertheless, E became able to disclose whom she disliked to her teacher directly on Day 3. In the three trials of indirect conversation conducted before Day 3, she had told the robot whom she disliked two times. In this case, it is considered that the experiences of disclosure in indirect conversation lowered her threshold to talk about the topic disclosed in it. Note that she avoided talking about whom she disliked in the direct conversation on Day 1, which was conducted between the first and the second disclosures to the robot. This failure on Day 1 and successful disclosure on Day 3 suggest that repeating the experience with the robot was effective for E to be able to directly disclose to the teacher about the topic she usually avoids. This suggestion motivates us to conduct a long-term experiment in the future. It should also be noted that two of her disclosures to the robot were performed under different situations. The first disclosure was performed in the situation in which only she and the robot existed in the room, whereas the second one was performed in the situation in which she, the robot, and the teacher existed in the room. In other words, it is considered that the situation of the second disclosure was a bit closer to the direct conversation than that of the first one. This closer situation might have contributed to the successful disclosure on Day 3, although we cannot distinguish its effect from the effect of repeating in this experiment. Considering the changes in B's and E's attitudes toward their friends or teacher after the indirect conversation, it is likely that individuals with ASD could be able to make use of communication with the robot for that with humans if they are counseled enough times in a properly designed manner.

To quantitatively evaluate the interaction, we calculated the length of utterance per minute (LoU) and the number of times of utterance per minute (NoU) of the participant and the teacher in each trial. Note that the period when the robot produced an utterance specified by the teacher was counted as an utterance of the teacher. The length of utterance was defined as the number of moras included in the utterance. It corresponds to the number of vowels and double consonants in Japanese, which was spoken in this experiment. The consecutive utterances of the same speaker were considered one utterance if the interval between the utterances was less than 1 s. To calculate the intervals, we used an annotation software that could import data for a recorded sound and display its waveform. The analyzed period was basically 3 min from the beginning of the conversation. If the conversation time was less than 3 min, we analyzed the entire conversation. The time of 3 min was arbitrarily defined from the time less than two times the shortest conversation so that the analyzed periods were not too different among the conversations. The analysis was conducted for only cases B and E. We did not analyze case A because A performed non-verbal interaction without utterances to become familiar with the robot at the beginning of each conversation. Tables III and IV show the calculated LoU and NoU. Note that the values on the tables are normalized per minute.

According to Tables III and IV, the LoU and NoU of the teacher in the indirect conversation were less than those in the direct one conducted on the same day, respectively. This indicates that the utterance of the teacher decreased in the indirect conversation. This is considered to be because in indirect conversation, the teacher uttered by typing, which generally consumes more time than simply speaking. Similarly, the LoU and NoU of E in indirect conversation were less than those in the direct one. This indicates that the utterance of E as well as that of the teacher decreased in the indirect conversation. This is considered to be because E's chances to utter were limited owing to the reduction in the utterance frequency of the teacher in the indirect conversation. On the other hand, the LoU and NoU of B in indirect conversation were more and less than that in the direct one, respectively. In other words, B had longer utterances per minute, even though her utterance frequency decreased in the indirect conversation. This is considered to be because the robot could strongly motivate her to produce long utterances so as to overcome the influence of the reduction in her chances to utter.

As reported in the results, the participants showed positive behavior that had not been seen in direct conversation in their daily life. This implies that the utterance reduction seen in Tables III and IV does not always have negative effects on counseling-like communication with individuals with ASD. The changes in moras per utterance shown in Fig. 5 might suggest the positive effects of the utterance reduction. A Wilcoxon rank sum test revealed that the medians of moras per utterance of the teacher in indirect conversation were less than those in the direct one ($p < .001, W = 2054$ for B and $p < .001, W = 3398$ for E). In contrast, the median of moras per utterance of B in the indirect conversation was more than that in the direct one ($p < .001, W = 1112$). Similarly, the median of moras per utterance of E was larger in the indirect one than in the direct one, although it was not significant ($n.s., W = 1654.5$). Although it is significant only in case B, the slow pace might cause longer utterances, which is considered to be an index related to good counseling for individuals with ASD. However, we did not control the contents and conversation among trials. It is desirable to conduct a more controlled experiment in the future. In addition, the validity of moras per utterance should be examined as an indicator to evaluate the quality of counseling.

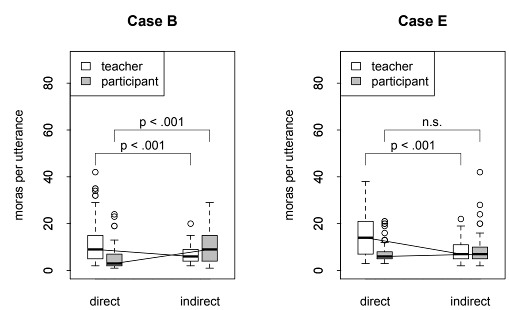

Fig. 5. Moras per utterance in the experiment between direct and indirect conversation

V. CONCLUSIONS

We performed a pilot experiment to examine the potential of indirect conversation via a robot for individuals with ASD. We reported three cases of indirect conversation via a robot between individuals with ASD and their teacher. The participants showed some positive tendencies, suggesting the advantage of a communication robot for supporting verbal interaction with individuals with ASD. Furthermore, the

TABLE III

LENGTH OF UTTERANCES PER MINUTE (LOU)

case	speaker	conversation	Day 1	Day 2	Day 3	Day 4
B	teacher	direct	200.9	198	-	-
		indirect	42.7	45.3	-	-
	participant	direct	78.2	62.3	-	-
		indirect	118.7	93.7	-	-
E	teacher	direct	221.7	-	250	-
		indirect	65.3	66.3	50.7	-
	participant	direct	91.3	-	96.7	-
		indirect	54.0	57.0	36.7	-

TABLE IV

NUMBER OF TIMES OF UTTERANCE PER MINUTE (NOU)

case	speaker	conversation	Day 1	Day 2	Day 3	Day 4
B	teacher	direct	19.3	15.3	-	-
		indirect	5.7	7.3	-	-
	participant	direct	14.5	11.7	-	-
		indirect	10.3	10.0	-	-
E	teacher	direct	17	-	15.3	-
		indirect	7.7	7.3	5.3	-
	participant	direct	13.7	-	12.0	-
		indirect	5.7	6.3	4.3	-

changes in the participants' behavior observed in a series of trials indicate that individuals with ASD might make use of an experience of communication with a robot for communication with a human. It is also pointed out that fewer utterances from a caregiver in an indirect conversation might be related to longer utterances, which are expected to improve mutual understanding in counseling. These results motivate us to introduce an indirect conversation system via a robot to the field of treatment and education for individuals with ASD. In future work, we will create a platform to perform repetitive and long interactions with robots and use them to conduct a controlled experiment with a larger sample size. In addition, the aspects of the robot's behavior and the symptoms of individuals with ASD that underlie the potential tendencies observed in indirect conversation that appeared in the current pilot experiment should be identified and examined.

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