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Robot-based play-drama intervention may improve the narrative abilities of Chinese-speaking preschoolers with autism spectrum disorder

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ABSTRACT

Background: Children with autism spectrum disorder (ASD) have deficits in their narrative skills and gestural communication. Very few intervention studies have been conducted with the aim of improving these skills.
Aims: We examined whether children with ASD who received the robot-based drama intervention had better narrative abilities and gestured more often than their peers who did not receive the intervention.
Methods and procedures: Preschool children were randomly assigned to the intervention group (N = 13) and waitlist control group (N = 13). Children in the intervention group watched three robot dramas and engaged in roleplays with both robots and human experimenters. Children in both groups took the pre-tests, immediate post-tests, and, two week later, delayed post-tests, in which they narrated three stories.
Outcomes and results: There were significant improvements in various narrative measures, including narrative length, syntactic complexity, narrative structure, and cognitive inferences, in the intervention group. There was also an improvement in the average number of overall gestures per clause in this condition. These learning outcomes were maintained in the delayed post-test. These patterns were not found in the waitlist control group.
Conclusions and implications: A robot-based play-drama intervention can enhance the narrative abilities and gestural communication of children with ASD.

What this paper adds

Individuals with ASD are found to have deficits in their narrative skills. Additionally, children with ASD also tend not to use gestures in their narrations. Previous narrative intervention research has mainly focused on children with language disorders and reading disabilities. Very few intervention studies have been conducted with the aim of improving the narrative abilities of children with ASD. Early interventions focusing on narrative abilities for preschoolers is crucial for the later development of language, literacy, communication, and socialization in children with ASD.

The present study adopted a play-drama intervention protocol. Instead of having human beings as the actors of the dramas, we deployed socially assistive robots. Socially assistive robots were programmed to act in the dramas. After watching the robot dramas,

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the children with ASD were given opportunities to communicate with the robots during roleplays in order to practice their narrative abilities. Finally, they were asked to generalize these abilities to communication with an adult actor who was not involved in the original dramas.

Clear changes in various narrative measures, including narrative length, syntactic complexity, narrative structure, and cognitive inferences, were documented in the intervention condition. There was also an improvement in the average number of overall gestures per clause in this condition. These learning outcomes were maintained in the delayed post-test. No improvement in narrative measures has been documented across time points in the waitlist control group. Our study is a pioneering work demonstrating that a robot-based play-drama intervention can enhance narrative abilities and gestural communication for children with ASD.

1. Introduction

Individuals with autism spectrum disorder (ASD) experience impairments in language discourse skills, including conversation and narrative (Lord & Paul, 1997; Tager-Flusberg, 2001; Tager-Flusberg, Paul, & Lord, 2005). Previous studies have found that they have difficulties initiating, maintaining, and repairing conversations (e.g., Loveland, McEvoy, Tunali, & Kelley, 1990; Capps, Kehres, & Sigman, 1998; Tager-Flusberg, 2007). They also find it challenging to respond appropriately in order to continue a conversation (Eigsti, Bennetto, & Young, 2007) and have preferences in regard to the preservation of topics that meet their own interests (Gerenser, 2009). There is also a lack of mental states and emotional terms in their conversations (Tager-Flusberg, 2007).

Besides conversation, individuals with ASD are also found to have deficits in their narrative skills. School-aged children with ASD have difficulties representing and retelling the gist of stories and situating the retellings as meaningful chains of events (Baron-Cohen, Leslie, & Frith, 1986). Additionally, they face challenges when portraying a story as a sequence of fictional events (Loveland & Tunali, 1993; Loveland et al., 1990). Previous research has established that individuals with ASD have a poor intuitive sense of time (Boucher, Pons, Lind, & Williams, 2007; Bowler, Gardiner, & Grice, 2000; Ozonoff, Pennington, & Rogers, 1991; Wimpory, Nicholas, & Nash, 2002) and, since they have difficulties representing and understanding changes that occur across time, their stories lack causal explanations (Diehl, Bennetto, & Young, 2006). Their narrations are also less syntactically complex (Capps, Losh, & Thurber, 2000) than those of children without ASD. They use fewer subordinate clauses involving characters' thoughts than typically-developing children (Baron-Cohen et al., 1986; Engberg-Pedersen & Christensen, 2017) and are less likely to make predictions based on a story character's behavior than children with specific language and pragmatic language impairments (Norbury & Bishop, 2003). Some of these problems continue until adolescence (Bruner & Feldman, 1993; Landa, Martin, Minshew, & Goldstein, 1995).

In addition to the challenges they face when narrating stories, children with ASD also tend not to use gestures in their narrations. When people speak, they gesture. Hand gestures are spontaneous hand movements produced for the sake of communication (e.g., waving a hand to say goodbye; swiping forehead with hand when feeling hot) (McNeill, 1992, 2005). In a study conducted by So, Wong, Lui, and Yip, 2015), six- to 12-year-old children with ASD were found to gesture less often and use fewer types of gestures, especially markers (gestures that express culturally specific meaning, such as nodding head for agreement), in their narratives, in comparison to their age-matched children with typical development.

Narrative discourse is a means for communicating perceptions, feelings, values, and attitudes within cultural contexts (Nelson, 1996). Not only is it an important communicative tool, but it is also an essential mechanism for making sense of experiences and relationships (Losh & Capps, 2003). Additionally, narrative abilities are a sensitive predictor of later language and literacy outcomes in children with language impairments (Botting, Faragher, Simkin, Knox, & Conti-Ramsden, 2001; Miller et al., 2006; Stothard, Snowling, Bishop, Chipchase, & Kaplan, 1998). They have been linked to competence in socialization (McCabe & Marshall, 2006), working memory (Duinmeijer, de Jong, & Scheper, 2012), and academic performance (Wellman et al., 2011). Considering these important functions and the fact that the majority of research on the topic has evidenced impairments in the narrative ability of children with ASD, it is necessary to design and implement an effective narrative intervention for children with ASD.

Previous narrative intervention research has mainly focused on children with language disorders (Hayward & Schneider, 2000; Klecan-Aker, 1993; Swanson, Fey, Mills, & Hood, 2005) and reading disabilities (Westerveld & Gillon, 2008). Very few intervention studies have been conducted with the aim of improving the narrative abilities of children with ASD. Of the few intervention studies on the narrative abilities, Petersen et al. (2014) provided an intervention focusing on personal narratives through verbal modeling and prompting for three six- to eight-year-old boys using a single-subject and multiple-baseline design. Up to 12 intervention sessions were offered. One child made a great improvement in his use of the specific grammar elements in the story, while the remaining two made moderate gains. However, none of the improvements were maintained after the intervention.

In another study, Dodd et al. provided a narrative intervention focusing on the use of mental state words and perspective-taking skills for nine- to 12-year-old children with ASD; 18 children took part (Dodd, Ocampo, & Kennedy, 2011). The intervention was conducted in small groups of five for 30-minute sessions three times a week for six weeks. Their findings showed that those who received explicit instructions in regard to perspective taking made greater improvement in this kind of skill than those who did not receive instructions. Specifically, these children could retell the story from the perspectives of different characters.

A recent study by Gillam et al. adopted a multiple-baseline across-participants design and taught eight- to 12-year-old children with ASD core story elements (character, setting, initiating event, internal response, plan, attempt, consequence, and reaction) in Phase I; linguistic structures, concepts, and vocabulary in Phase II; and creating and editing stories in Phase III (Gillam, Hartzheim, Studenka, Simonsmeier, & Gillam, 2015). The five participating children were asked to make up a story based on a picture before the intervention, after each phase, and four weeks after the intervention. Their results show improvements in overall story complexity, story grammar knowledge, and perspective taking for four out of five children and these learning outcomes were maintained after the intervention.

Although the aforementioned studies have reported some positive learning outcomes regarding narrative intervention, none of them focused on prechoolers children with ASD. Narrative production begins to emerge in the preschool years and continues to develop as children progress through school (e.g., Bamberg, 1987; Berman & Slobin, 1994; Peterson & McCabe, 1983). We propose that early interventions focusing on narrative abilities for preschoolers is crucial for the later development of language, literacy, communication, and socialization in children with ASD. While there is empirical support for the intervention program in Gillam et al.'s study, their training sessions may make large language demands of preschoolers. First, their participants were required to verbally identify story elements and create new stories with these elements during lessons. Second, the training materials across the three phases were increasingly difficulty in regard to the complexity of the vocabulary and syntax. Therefore, we design a new narrative intervention that caters for the learning needs of preschoolers with ASD.

The pilot present study adopted a play-drama intervention protocol. Previous research has provided empirical evidence showing that drama successfully addresses various aspects of social competence (de la Cruz, Lian, & Morreau, 1998; Goldstein & Winner, 2012; Lerner & Levine, 2007). One crucial ability in narrating a story is developing the temporal representation of events and how scenes are linked. Drama activities can help children with ASD to establish this kind of representation (Peter, 2003). Through acting out a drama, socially challenged children (e.g., those with ASD) can develop and explore pretending, thus leading to the discovery of implications of play behaviors and the potential impact of their behaviors on others' responses. Hence, children will gain a better understanding of patterns and sequences in life, which enable them to develop a coherent and meaningful framework in their narratives. Additionally, pretend play with others helps children to learn to recognize and appreciate others' intentions and mental well-being, as well as the consequences of others' thoughts in regard to their responses. It then strengthens children's understanding of causes and consequences and helps them to make cognitive and affective inferences in their narration. Finally, pretend play in drama activities involves body movements, including gestures. Thus, acting out a drama equips children with necessary gestural communication skills in narrations.

In this pilot study, preschoolers with ASD were presented with three dramas, each featuring two actors. They then engaged in roleplays with these actors and an adult who was not involved in the original dramas. All the dramas had prescribed narrative structures, which offered children repeated opportunities to learn to generate and sustain narrative abilities within secure and predictable boundaries (Peter, 1994; Taylor, 1984). Our intervention protocol examined whether or not children with ASD participated in the creation of a shared social narrative during roleplays, rather than their acting skills.

Instead of having human beings as the actors of the dramas, we deployed socially assistive robots (Feil-Seifer & Matarić, 2005; Matarić & Scassellati, 2016). According to the social motivation theory of autism, individuals with ASD show deficits in orienting themselves toward social stimuli, engaging with humans, and maintaining social relations (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012). Empirical evidence has supported this theory, showing that individuals with ASD tend to have low levels of interest in other humans and have a weaker understanding of the interpersonal world than of the object-related world (Klin & Jones, 2006; Klin, Lin, Gorrindo, Ramsay, & Jones, 2009). In addition, they find it challenging to pay attention to multiple cues during social interactions with humans (Koegel, Koegel, Harrower, & Carter, 1999). Thus, they are not sensitive to other people's behaviors (Lee, Takehashi, Nagai, Obinata, & Stefanov, 2012). Therefore, some studies have shown that individuals with ASD may find it difficult to learn social skills from human therapists. For example, Dewey, Cantell, and Crawford (2007) showed that five- to 18-year-old individuals with ASD (with a wide range of IQs) were less likely to imitate isolated gestures, demonstrated by a human experimenter, and produce gestures on command than children with other developmental disorders.

In contrast to human therapists, socially assistive robots may be more suitable for use in interventions with individuals with ASD. According to the Intense World Theory (Markram & Markram, 2010), individuals with ASD have excessive reactivity and rapidly form memories of experiences, due to a particular form of brain hypertrophy. The intensity of sensory processing becomes so overwhelming that autistic people may actively avoid surprises that cause sensory and emotional exposure, and instead focus on elementary features that are predictable. Robots are operated within predictable and lawful systems, thereby providing children with ASD with a highly structured learning environment and helping them to focus on the relevant stimuli.

The popularity of socially assistive robots as a treatment tool for individuals with ASD have risen over the past decade. (see reviews in Begum, Serna, & Yanco, 2016; Cabibihan, Javed, Ang, & Aljunied, 2013; Fong, Nourbakhsh, & Dautenhahn, 2003; Li, Cabibihan, & Tan, 2011). This rise in popularity is credited to various attributes of the robots that children with ASD find to be not only attractive, but also stimulating. (Kozima, Michalowski, & Nakagawa, 2009; Miyamoto, Lee, Fujii, & Okada, 2005). Scassellati, Admoni, and Matarić (2012) found that socially assistive robots were useful in the development of joint attention behaviors, self-initiated interactions, non-verbal communication skills, and an ability to make eye contact (Ricks & Colton, 2010; Werry, Dautenhahn, Ogden, & Harwin, 2001). More recently, So et al. (2016), 2018a, 2018b) reported that three- to 12-year-old children with ASD who received gestural training from socially assistive robots, were more likely to recognize and produce gestures, when compared to those who did not receive the training. Furthermore, Park, Grover, Spaulding, Gomez, and Breazeal (2019) found that young bilingual and English-language learners demonstrated improved literacy skills (including learning and retaining more target words as well as using more target syntax structures) when receiving a robot-based drama intervention.

Based on this evidence, we programmed socially assistive robots to act in the dramas. After watching the robot dramas, the children with ASD were given opportunities to communicate with the robots during roleplays in order to practice their narrative abilities. Finally, they were asked to generalize these abilities to communication with an adult actor who was not involved in the original dramas. This pilot study examined whether or not children with ASD who received the robot-based drama intervention had better narrative skills (in terms of number of clauses, syntactic complexity, story structure, and cognitive and affective inferences) and gestural communication than their peers in the waitlist control condition.

2. Method

2.1. Participants

A total of 26 Chinese-speaking (Cantonese-speaking) children aged four to six years old participated in this pilot study. The participants were randomly assigned to two groups: the intervention group and the waitlist control group. Children in the intervention group took robot drama classes, while those in the waitlist group received the intervention after the completion of the research. The mean age of the children in the intervention group ($N = 13$) was 5.62 (two females; $SD = 1.29$; range 4.66–6.40) and that of the waitlist control group ($N = 13$) was 5.49 (one female; $SD = 1.35$; range 4.45–6.38). The Mann-Whitney test showed that there was no significant difference in age between the two groups, $U = 21$, $p < .75$.

All children participating in the study had been diagnosed with autism between the ages of 18 and 48 months ($M = 32.35$; $SD = 14.56$) by pediatricians at the Child Assessment Center for the Department of Health in Hong Kong. Their ASD diagnoses were further confirmed by the research team using Autism Diagnostic Observation Schedule – Second Edition (ADOS-2; Lord et al., 2012) and by pediatricians from the Pamela Youde Child Assessment Center, Hong Kong, who followed the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; APA, 2013). All children met the ADOS-2 and DSM-5 criteria for ASD. They were attending various special care centers, which serve children with autism and other special needs, in various locations in Hong Kong.

All the procedures were approved by the institutional review board of the first author's university, in compliance with the Declaration of Helsinki (reference no. 14600817). We obtained the parents' informed consent prior to the start of the study. The children also gave their consent to participate in this study.

At the beginning of the experiment, all the children had their cognitive and motor abilities and theory of mind understanding assessed. Their cognitive and motor abilities were measured by the Mullen Scale of Early Learning (MSEL; Mullen, 1995). The MSEL was administered in the treatment rooms of the special care centers and videotaped for further analysis. The children's primary caregivers were also present during the assessment. Each time, the child was sat opposite the examiner, at a child-size testing table. Four cognitive domains were assessed: visual reception, fine motor skills, receptive language, and expressive language. Age equivalent scores are available for each subscale. There was no significant difference between the groups in each of the domains (visual reception: $U = 35.00$, $p < .07$; fine motor: $U = 38.50$, $p < .10$; receptive language: $U = 63.00$, $p < .92$; expressive language: $U = 52.50$, $p < .45$). As a result, both groups had comparable levels of cognitive and motor skills.

In addition to cognitive and motor abilities, we also measured the children's theory of mind understanding (ToM), which is children's understanding of persons' mental states. It was assessed by the Chinese version of six tasks: diverse desire, diverse belief, knowledge assessment, content false belief, explicit false belief, and hidden emotion. These tasks were developed by Wellman and Liu (2004) and Wellman, Fang, Liu, Zhu, and Liu (2006). The maximum possible score is six. There was no significant difference between the groups: $U = 64.00$, $p < .92$. Table 1 shows the chronological ages and descriptive statistics of the performance in each assessment for both groups of participants.

2.2. Stimuli

2.2.1. Prescribed dramas

We wrote three drama scripts: "Butterfly and Farmer", "Doctor and Patient", and "Tourist and Tour Guide" (see So et al., review under revision). These three dramas covered a wide range of topics. Each drama involved two characters. In "Butterfly and Farmer", the butterfly visits a farm and meets a farmer. She expects to taste honey there but is disappointed as the flowers have not grown yet. The farmer advises her to come back later. She comes back in a month and finally gets to taste the honey there. In "Doctor and Patient", the patient feels unwell and is anxious about it. He goes to a doctor, who comforts and examines him. In "Tourist and Tour Guide", a tourist visits Hong Kong from France. She experiences some turbulence on her flight and is afraid. She then meets a tour guide, who recommends some places to visit during her stay in Hong Kong.

The three dramas varied along the dimensions of reality and familiarity. Among the three dramas, the episodes of "Butterfly and

Table 1
Performance in various domains of the Mullen Scale of Early Learning and Theory of Mind understanding tasks in both groups of children.

Groups	Descriptive Statistics	Chronological Age	Age equivalent scores in VR In MESL	Age equivalent scores in FM In MESL	Age equivalent scores in RL In MESL	Age equivalent scores in EL In MESL	Score in ToM
Robot-based intervention (N = 13)	Mean	5.62	68.10	66.30	63.00	55.10	4.00
	SD	1.29	4.45	3.77	3.06	9.77	2.35
	Minimum	4.66	66.00	57.00	59.00	40.00	2.00
	Maximum	6.40	69.00	68.00	65.00	70.00	7.00
Wait-list control (N = 11)	Mean	5.49	66.72	64.37	62.82	52.15	4.15
	SD	1.35	3.71	6.32	7.35	10.11	152.00
	Minimum	4.45	58.00	49.00	51.00	42.00	1.00
	Maximum	6.38	69.00	68.00	69.00	70.00	6.00

Notes: VR: Visual Recognition; FM: Fine Motor; RL: Receptive Language; EL: Expressive Language; MESL: Mullen Scales of Early Learning (Mullen, 1995).

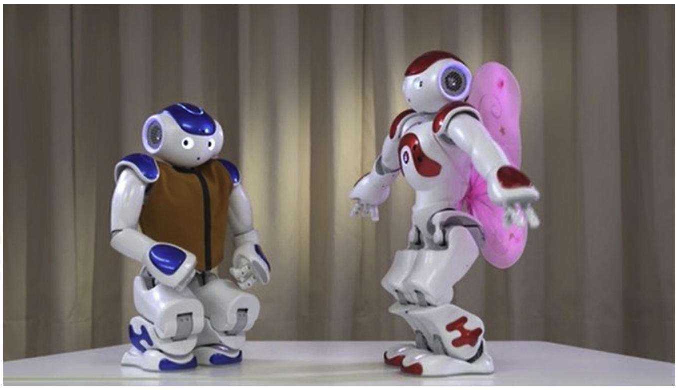

Fig. 1. The red NAO robot played the role of the butterfly while the blue NAO robot played the role of the farmer in "Farmer and Butterfly" Drama. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

Farmer" were relatively more imaginary than the other two dramas. In contrast, the episodes of the dramas, "Doctor and patient" and "Tourist and Tour Guide", were more realistic. Majority of the children with ASD participating in our study reported that they have visited doctors, but they have not joined any tours prior to our intervention. The episodes in "Butterfly and Farmer" were neither realistic nor familiar to the children. The episodes in "Doctor and Patient" were realistic and familiar to the children. The episodes in "Tourist and Tour Guide" were also realistic but not familiar to the children.

The gestures were then added to the scripts. These gestures commonly used in daily life and were taught in the previous intervention programs for three to twelve years old children with ASD (So et al., 2016; 2018a; 2018b). The findings of a study by Cabibihan, So, and Pramanik (2012) showed that many of these gestures are well recognized by speakers in Chinese society

Two NAO (Aldebaran Robotics Company) robots were programmed to speak and/or produce body movements (e.g., gestures) in the dramas. In "Butterfly and Farmer", one robot acted as the butterfly and another as the farmer (see Fig. 1). In "Doctor and Patient", one robot acted as the doctor and another as the patient. In "Tourist and Tour Guide", one robot acted as the tourist and another as the tour guide. Each drama lasted for between three and three and a half minutes. Appendix I shows the scripts of the three dramas and indications of the gestures the socially assistive robots produced in these dramas.

The NAO robot has been widely used in autism therapy. It is 50 cm tall and anthropomorphic. It was deployed in the present study because it might facilitate children with ASD in regard to generalizing the acquired imitation and social skills to human-to-human interactions (Cabibihan et al., 2013). Furthermore, unlike other robots, NAO robots can produce a wide range of body movements and gestures, which are commonly seen in dramas. The NAO robot contains 25 degrees of freedom (DOF) from 15 joints and actuators.

2.3. Procedures

The intervention and pre- and post-test assessments were conducted in the treatment rooms at various special care centers. The treatment rooms were often used by the children for school activities. The room was equipped with two NAO robots and a camera in front of the child. The camera recorded the speech and the hand movements the child produced during the sessions.

The robot-based drama intervention lasted for 12 weeks. The intervention consisted of a pre-test of narrative abilities, nine robot drama sessions (with three 45-minute sessions per drama, once per week), an immediate post-test (which was the same as the pre-test), and the same follow-up post-test after two weeks. The participants were accompanied by a caregiver in each training or assessment session. The training and assessment sessions were administered by a researcher, who was either the assistant or one of the authors. A small reward, by way of positive reinforcement (snacks or access to toys), was offered by the researcher at the end of each pre-test, post-test, and training session. All the sessions were videotaped. Details of the intervention program are provided below.

We conducted a narrative elicitation task in the pre-test. The researcher, who was blind to the study design and hypotheses, first greeted each child, then gave instructions and presented him or her with three sets of wordless pictures, with each set containing six snapshots of a story about Tweety Bird and Sylvester, one at a time. The story of Tweety Bird and Sylvester has been used in many prior studies on speech and gestures in regard to both typical and atypical development across different cultures. It is suitable for storytellers of different ages, different neurological conditions, and different language groups (McNeill, 1992, 2000). All three stories use little speech but have linear plot lines about the two characters: 1) Sylvester chases Tweety Bird, who hides in a toy house; 2) Sylvester climbs up a pipe to catch Tweety Bird; 3) Sylvester catches Tweety Bird and puts her in a sandwich.

The pictures were presented to each child in temporal order. The child was given two minutes to look at the pictures and was then invited to generate a story while looking at the pictures. The researcher was also allowed to interact with the child. In this way, the narrative elicitation approximated a natural setting. The researcher encouraged the child to produce a story that was as long and as complete as possible. When the child did not respond, or he or she seemed to lose attention, the experimenter gave prompts, such as, "What is happening?", "How does the story start?", and "Is that the end of your story?". The pictures were still present while the child was narrating, in order to reduce the demand on memory recall. In this narrative elicitation task, the child was not free to generate whatever story they liked, as they were given pictures that depicted the theme of the story. Thus, the child needed to extract a coherent narrative from pictures and to represent it linguistically (Botting, 2002). By generating a story from several pictures, we minimized the demand on language comprehension and recall of the materials (Demir, Levine, & Goldin-Meadow, 2010).

After the pre-test, the children in the robot-based intervention group proceeded to training. In the training sessions, one of the robots greeted each child, then gave the following instruction: “Today, we are going to perform a drama. Please sit back, relax, and watch our drama. After watching our drama twice, we will ask you to take part in a roleplay with us. Do you understand?” Training started when the child indicated that he or she understood. Otherwise, the robot repeated them. During training, two robots performed a drama twice (e.g., one robot played the role of a doctor while another placed the part of the patient). The child was then invited to act as the doctor and participate in a roleplay with the doctor robot. Next, the child swapped roles and acted as the patient, participating in a roleplay with the patient robot. Finally, the child was invited to take part in roleplays with a human researcher. He or she was prompted when he or she did not initiate a conversation or respond during a conversation for longer than three seconds. Each child received three training sessions for each drama, with each session lasting 45 min. Altogether, there were nine training sessions for three dramas. The children in the waitlist control group were cared as usual during this period.

All the children then completed the narrative elicitation tasks in the post-test immediately after the intervention and the delayed post-tests two weeks after the intervention. These narrative elicitation tasks were the same as those in the pre-test. The researcher administering the post-tests was the same as in the pre-tests. The procedures in both post-tests were the same as those in the pre-tests. The delayed post-tests examined whether or not the learning outcomes could be maintained, even when training was not provided. All the children were able to pay attention during the training and assessments. A short break was given to the participants if requested. None of the children were absent from the sessions.

2.4. Coding and scoring

We asked two research assistants, who did not know the objectives of the study and were unaware of the research questions, to watch the videos of the participants. The children’s narratives were videotaped, transcribed, and analyzed. The stream of speech was segmented into utterances, each of which consists of a clause that expresses a proposition (a noun phrase or its equivalent) and includes a predicate (a verb phrase and other accompanying elements, such as objects) (Crystal, 1980). Utterances containing more than one clause connected by a conjunction—for example, and (Cantonese *zung6 jau5*) or but (*daan6 hai6*)—were segmented into two utterances. Clauses that did not contain a predicate were not included in our analyses. We examined the number of clauses each child produced in three different stories in order to evaluate the narrative length.

Among the clauses included, we calculated the proportion of complex clauses, which was the total number of complex clauses for each story divided by the total number of clauses in that story. The proportion of complex clauses measured the syntactic complexity of the narrative. In Cantonese, a clause is complex if it contains two main verbs (e.g., “The cat climbed and moved up along the pipe”, “*zek3 maau1 paa4 soeng5 heoi3 seoi2 hau4*”; “The cat caught and ate the bird”, “*zek3 maau1 zuk1 zo2 zek3 zoek3 zai2 tung4 maai4 sik6 zo2 keoi5*”), and coverbs (e.g., “The bird was caught by the cat”, “*zek3 zoek3 zai2 bei2 zek3 maau1 zuk1 zyu6 zo2*”; “The bird let the cat defeat him”, “*zek3 zoek3 zai2 bei2 zek3 maau1 daa2 baai6 zo2*”; “The cat throws the bird into the sky”, “*zek3 maau1 zoeng3 zek3 zoek3 zai2 paau1 soeng5 tin1 hung1*”).

We also examined whether or not the stories contained goals. Goals are one of the four crucial features of narratives (Stein & Glenn, 1979). They can be either overtly stated with a mental state verb (e.g., “The cat wanted to eat the bird”; “The bird ran to escape the bird”) or inferred from the reported sequence of events (e.g., “The cat saw the bird and climbed up the pipe. He followed the cat and chased him”) (Demir et al., 2010). We calculated the proportion of goal-based stories, which was the total number of stories with goals divided by the total number of stories across all children.

Finally, we coded the number of stories with cognitive and affective inferences. Cognitive inferences were defined as references to a character’s intention (e.g., “The cat wants to eat the bird”), knowledge (e.g., “The bird knows the cat is nearby”), thoughts (e.g., “The cat is thinking about how to catch the bird”). Affective inferences were defined as references to emotional states (e.g., “The cat is very angry; the bird is very afraid of the cat”). We calculated the proportion of stories with cognitive (affective) inferences, which was the total number of stories with cognitive (affective) inferences divided by the total number of stories across all children.

In addition to examining speech in their narrations, we also investigated whether or not children with ASD gestured when they were narrating stories. We followed Goldin-Meadow and Mylander (1984); see also Iverson & Goldin-Meadow, 2005) and Özçalışkan and Goldin-Meadow (2005) in regard to coding gestures. Gestures consisted of four types. The definitions and examples of each type of gesture are as follows.

(1) Iconic gestures bear a resemblance to the objects they represent, or the actions associated with those objects (e.g., both hands forming fists moved up alternately, classified as an action of climbing up; right hand, opened palm, classified as a reference to bread; index and middle fingers moved forward while wriggling, classified as an action of walking).
(2) Deictic gestures serve to identify characters or objects (e.g., index finger pointing to the cat, classified as a reference to the cat).
(3) Markers express culturally specific meaning (e.g., head nod signifying agreement).
(4) Speech beats do not carry semantic content but follow the rhythm of the accompanying speech (e.g., index finger flips outward).

We counted the total number of gestures of all types produced by the children in both conditions. We also calculated the number of each type of gesture a child produced per utterance, which was the number of each type of gesture divided by the number of utterances he or she produced.

2.5. Reliability

We established the reliability of our measures by having a third individual transcribe 20% of the children's narratives. Agreement between coders was 93.52% for the number of clauses (N = 1200; Cohen's Kappa = .91, $p <$ .001); 90.87% for the identification of complex clauses (N = 1122; Cohen's Kappa = .89, $p <$ .001); 85.71% for the number of goal-based stories (N = 14; Cohen's Kappa = .84, $p <$ .05); 93.85% for the number of stories with cognitive inferences (N = 14; Cohen's Kappa = .91; $p <$ .01); 93.85% for the number of stories with affective inferences (N = 14; Cohen's Kappa = .91, $p <$ .01); and 92.28% for the identification of different types of gestures (N = 1122; Cohen's Kappa = .90, $p <$ .001).

3. Results

This pilot study examined whether or not a robot-based drama intervention was effective in improving the narrative abilities of children with ASD. We looked at the number of clauses, the proportion of complex clauses, the number of goal-based stories, and the number of stories with cognitive and affective inferences used by the children in the intervention group and compared them to those used by the children in the waitlist control group. We also examined the number and types of gestures both groups of children produced in their narratives. If a robot-based drama intervention was found to be effective, the narrative abilities of the children in the intervention group would improve and the children would produce more gestures after training, in comparison to their peers in the waitlist control group.

All the children completed all the training sessions related to the robot drama lessons. During training, each child watched a drama twice and then participated in roleplays with the socially assistive robots and a human experimenter. Most of the time, the children interacted with the socially assistive robots during the roleplays. They were prompted when they did not react during their turns for longer than three seconds. Our results show that on average these children were prompted 0.84 times (SD = .65) across all sessions. They were also able to interact with the human experimenter during the roleplays and were prompted only .50 times (SD = .50) across all sessions. We also examined whether or not the children were reacting and communicating appropriately in the exchanges with the socially assistive robots and adults in different roles. Their speech was considered appropriate if it matched the roles the children were acting and if it fit the context of the discourse. Their speech was appropriate 70.84% of the time (SD = .87) when interacting with socially assistive robots and 72.51% of the time (SD = .96) when interacting with the human experimenter. As a result, the children were successful in acting out the dramas with the socially assistive robots and the human experimenter over 70% of the time. The children were reminded of the scripts they should have followed during roleplays if they said something inappropriate. The children also gestured when participating in the roleplays. The majority of the gestures were demonstrated by the socially assistive robots. The children imitated the gestures 39.97% of the time (SD = .21) when interacting with robots and 43.94% of the time (SD = .23) when interacting with the human experimenter.

Table 2 depicts the results of the narrative measures in the pre-test and immediate and delayed post-tests of the narrative elicitation task in regard to the children with ASD in both conditions. We then examined whether or not children in the robot-based intervention group performed better in terms of number of clauses, the proportion of complex clauses, number of goal-based stories, and number of stories with cognitive and affective inferences after training than those in the waitlist control group. Separate linear mixed effects model analyses (LME model; Bates, Maechler, Bolker, & Walker, 2014) were conducted for various narrative measures using statistical analysis tools R (R Core Team, 2012).

The first LME model analysis examined whether or not the children in the robot-based intervention group showed significant differences in the total number of clauses across all time points (pre-test, immediate post-test, delayed post-test), in comparison to the children in the waitlist control group. An interaction between the time point and intervention was expected and, as such, an interaction term was included in the model as a fixed effect. Additionally, we entered chronological age, expressive language age equivalent score, and ToM as fixed effects. In regard to random effects, intercepts were created for individual children and stories, as were by-subject and by-story random slopes for the effects of both time point and intervention. The continuous dependent variable was the total number of clauses. After controlling for age, expressive language, and ToM, the time point x group interaction was found to be significant, β = 8.86, SE = 1.31; t = 6.76, $p <$ .001, *Cohen's* f^2 = *.36*[1] . Time point was found to affect the total number of clauses, β = 5.83, SE = 1.06; t = 5.50, $p <$ .001, Cohen's f^2 = .28, for the intervention group, but for not for the waitlist control group, β = .62, SE = 1.18; t = .53, $p <$ .89, Cohen's $f^2 <$ .01. Thus, there was a significant improvement in the total number of clauses in the immediate and delayed post-tests in regard to the children in the intervention group, but not those in the waitlist control group. Additionally, the learning outcomes were maintained in the delayed post-tests.

The second LME model analysis focused on the proportion of complex clauses. This model was similar to the first, with the proportion of complex clauses becoming the continuous dependent variable. After controlling for age, expressive language, and ToM, the time point x group interaction was found to be significant, β = .10, SE = .02; t = 5.60, $p <$ .001, Cohen's f^2 = .31. Time point was found to affect the proportion of complex clauses, β = .06, SE = .01; t = 4.70, $p <$ .001, Cohen's f^2 = .23, for the intervention group, but for not for the waitlist control group, β = .02, SE = .01; t = 1.55, $p <$ .12, Cohen's f^2 = .07. Again, children in the

[1] Cohen's f^2 is the effect size measure related to variance explained for the overall model (Cohen, 1992). Guidelines for interpretation of f2 indicate that 0.02 is a small effect, 0.15 is a medium effect, and 0.35 is a large effect.

Table 2
Results of the narrative measures in the pre-test and immediate and delayed post-tests of the narrative elicitation task.

Groups	Descriptive Statistics	Average total number of clauses			Average proportion of complex clauses			Average proportion of goal-based stories			Average proportion of stories with cognitive inferences			Average proportion of stories with affective inferences		
		Pre-test	Immediate Post-test	Delayed Post-test	Pre-test	Immediate Post-test	Delayed Post-test	Pre-test	Immediate Post-test	Delayed Post-test	Pre-test	Immediate Post-test	Delayed Post-test	Pre-test	Immediate Post-test	Delayed Post-test
Robot-based intervention (N = 13)	Mean	18.48	23.13	30.13	0.25	0.33	0.37	0.15	0.23	0.63	0.55	0.73	0.90	0.65	0.73	0.85
	SD	5.65	5.11	12.87	0.11	0.13	0.13	0.17	0.25	0.32	0.21	0.32	0.42	0.24	0.28	0.21
	Minimum	11.50	16.00	20.25	0.03	0.13	0.18	0.00	0.33	0.67	0.00	0.33	0.67	0.00	0.33	0.67
	Maximum	26.25	35.50	63.25	0.37	0.49	0.52	0.67	1.00	1.00	0.67	1.00	1.00	1.00	1.00	1.00
Waitlist control (N = 13)	Mean	24.38	19.48	18.31	0.30	0.23	0.22	0.22	0.17	0.25	0.46	0.50	0.46	0.58	0.48	0.43
	SD	10.37	9.15	7.28	0.09	0.07	0.12	0.26	0.25	0.16	0.25	0.23	0.34	0.24	0.25	0.32
	Minimum	8.00	14.00	14.00	0.14	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00
	Maximum	35.25	43.75	20.75	0.41	0.35	0.36	0.67	0.67	0.67	0.67	0.67	0.67	1.00	1.00	1.00

intervention group demonstrated a greater proportion of complex clauses in the immediate and delayed post-tests than those in the waitlist control group. Additionally, the learning outcomes were maintained in the delayed post-tests.

The third LME model analysis examined the effect of a robot-based intervention on the proportion of goal-based stories (the continuous dependent variable). After controlling for age, expressive language, and ToM, the time point x group interaction was found to be significant, $\beta = .22$, $SE = .05$; $t = 3.99$, $p < .001$, Cohen's $f^2 = .20$. Time point was found to affect the proportion of goal-based stories, $\beta = .24$, $SE = .04$; $t = 5.49$, $p < .001$, Cohen's $f^2 = .30$, for the intervention group, but not for the waitlist control group, $\beta = .02$, $SE = .03$; $t = .57$, $p < .52$, Cohen's $f^2 = .03$. The proportion of goal-based stories of the children in the intervention group improved in the immediate and delayed post-tests. Additionally, the learning outcomes were maintained in the delayed post-tests. This result was not found in regard to the children in the waitlist control group.

We then further examined whether or not our robot-based drama intervention would facilitate the children with ASD in regard to drawing cognitive and affective inferences in their narratives. The fourth LME model analysis focused on the proportion of stories with cognitive inference, which was the continuous dependent variable. After controlling for age, expressive language, and ToM, the time point x group interaction was found to be significant, $\beta = .18$, $SE = .06$; $t = 2.87$, $p < .004$, Cohen's $f^2 = .16$. Time point was found to affect the proportion of stories with cognitive inference, $\beta = .18$, $SE = .04$; $t = 4.06$, $p < .001$, Cohen's $f^2 = .21$, for the intervention group, but not for the waitlist control group, $\beta = .001$, $SE = .004$; $t = .00$, $p < 1.00$, Cohen's $f^2 < .01$. The proportion of stories with cognitive inference was greater in the immediate and delayed post-tests. Additionally, the learning outcomes were maintained in the delayed post-tests. This result was not found in regard to the children in the waitlist control group.

The fifth model examined the proportion of stories with affective inference. After controlling for age, expressive language, and ToM, the time point x group interaction was not significant, $\beta = .08$, $SE = .04$; $t = 1.79$, $p < .07$, Cohen's $f^2 = .06$. The time point and group fixed effects were also not significant (group: $\beta = .08$, $SE = .15$; $t = .51$, $p < .61$, Cohen's $f^2 < .01$; time point: $\beta = .08$, $SE = .08$; $t = 1.15$, $p < .26$, Cohen's $f^2 = .02$).

To summarize, our robot-based drama intervention yielded significant improvement in regard to various narrative measures, including narrative length, syntactic complexity, narrative structure, and cognitive inferences. The effect sizes, measured by Cohen's f^2, were medium to large. We next examined whether or not the children in the intervention condition gestured more often and produced more different types of gestures than those in the waitlist control group. Table 3 shows the overall average number of gestures per clause and the average number of different types of gestures in the pre-test and immediate and delayed post-tests of the narrative elicitation task in both conditions. Similar to the aforementioned analyses, separate linear mixed effects model analyses (LME model; Bates et al., 2014) were conducted for various gesture measures using statistical analysis tools R (R Core Team, 2012).

In the first LME model, we examined whether or not the children in the robot-based intervention group showed significant differences in gesture frequency across all time points (pre-test, immediate post-test, delayed post-test), in comparison to the children in the waitlist control group. As in the aforementioned models, we entered chronological age, expressive language age equivalent score, and ToM as fixed effects, and individual children and stories as random effects. The overall average number of gestures per clause was the continuous dependent variable. After controlling for age, expressive language, and ToM, the time point x group interaction was found to be significant, $\beta = .13$, $SE = .03$; $t = 3.85$, $p < .001$, Cohen's $f^2 = .19$. Time point was found to affect the overall average number of gestures per clause, $\beta = 0.08$, $SE = .02$, $t = 3.78$, $p < .001$, Cohen's $f^2 = .19$, for the intervention group, as well as for the waitlist control group, $\beta = -.04$, $SE = .02$; $t = -1.90$, $p < .05$, Cohen's $f^2 = .10$, in opposite patterns. Our results showed that there was a significant improvement in the overall average number of gestures per clause in the immediate and delayed post-tests in the intervention group. Additionally, the learning outcomes were maintained in the delayed post-tests. However, the average number of gestures per clause seemed to be declining across the three time points in regard to the children in the waitlist control group.

We then examined the average number of different types of gestures per clause in both groups of children across the three time points. We started with the average number of deictic gestures per clause. After controlling for age, expressive language, and ToM, the time point x group interaction was found to be significant, $\beta = .08$, $SE = .02$; $t = 3.85$, $p < .001$, Cohen's $f^2 = .19$. Time point was found to affect the average number of deictic gestures per clause, $\beta = 0.06$, $SE = .02$, $t = 3.29$, $p < .001$, Cohen's $f^2 = .16$, for the intervention group, but not for the waitlist control group, $\beta = -.01$, $SE = .01$; $t = -1.31$, $p < .19$, Cohen's $f^2 = .04$. We moved on to the average number of iconic gestures per clause. After controlling for age, expressive language, and ToM, the time point x group interaction was not significant, $\beta = .03$, $SE = .02$; $t = 1.36$, $p < .18$, Cohen's $f^2 = .04$. The time point effect was not significant either, $\beta = -.006$, $SE = .02$; $t = -.37$, $p < .71$, Cohen's $f^2 < .01$. These findings suggest that the average number of iconic gestures per clause did not increase across time points for either group of children. We then examined the average number of markers and speech beats per clause. For markers, the time point x group interaction was significant, $\beta = .01$, $SE = .006$; $t = 2.07$, $p < .03$, Cohen's $f^2 = .14$. Time point was found to affect the overall average number of markers per clause, $\beta = -.01$, $SE = .005$, $t = 3.34$, $p < .001$, Cohen's $f^2 = .19$, for the waitlist control group, but not for the intervention group, $\beta = .0004$, $SE = .003$; $t = .13$, $p < .89$, Cohen's $f^2 < .01$. The average number of markers per clause declined across time points in the waitlist control group. Finally, for speech beats, the time point x group interaction was not significant, $\beta = .009$, $SE = .005$; $t = 1.78$, $p < .07$, Cohen's $f^2 = .05$. The time point effect was not significant either, $\beta = -.005$, $SE = .003$; $t = -1.57$, $p < .11$, Cohen's $f^2 = .07$. Similar to iconic gestures, the average number of speech beats per clause did not increase across time points for either group of children.

To summarize, our robot-based drama intervention yielded significant improvements in the overall use of gestures, especially deictic gestures. The effect sizes were medium. However, there was no clear evidence of improvement in other types of gestures.

Table 3
Results of the number of different types of gestures in the pre-test and immediate and delayed post-tests of the narrative elicitation task.

Groups	Descriptive Statistics	Average number of gestures per clause	Average number of deictic gestures per clause			Average number of iconic gestures per clause			Average number of markers per clause			Average number of speech beats per clause		
		Pre-test Immediate Post-test Delayed Post-test	Pre-test	Immediate Post-test	Delayed Post-test	Pre-test	Immediate Post-test	Delayed Post-test	Pre-test	Immediate Post-test	Delayed Post-test	Pre-test	Immediate Post-test	Delayed Post-test
Robot-based intervention (N = 13)	Mean	0.48 0.59 0.66	0.17	0.23	0.28	0.28	0.31	0.33	0.02	0.02	0.02	0.01	0.02	0.02
	SD	0.21 0.28 0.34	0.14	0.16	0.17	0.17	0.18	0.17	0.02	0.02	0.02	0.01	0.03	0.02
	Minimum	0.10 0.00 0.07	0.00	0.00	0.01	0.10	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
	Maximum	0.85 1.00 0.96	0.49	0.49	0.41	0.73	0.57	0.57	0.06	0.05	0.03	0.04	0.10	0.05
Waitlist control (N = 13)	Mean	0.59 0.55 0.49	0.24	0.23	0.19	0.28	0.28	0.26	0.04	0.03	0.02	0.02	0.01	0.01
	SD	0.23 0.21 0.15	0.16	0.12	0.10	0.11	0.12	0.10	0.02	0.02	0.02	0.03	0.02	0.01
	Minimum	0.28 0.23 0.30	0.06	0.06	0.09	0.05	0.15	0.09	0.00	0.00	0.00	0.00	0.00	0.00
	Maximum	0.96 0.89 0.78	0.59	0.48	0.42	0.39	0.49	0.42	0.03	0.07	0.04	0.10	0.04	0.05

4. Discussion

This pilot study examined whether or not children with ASD who participated in a robot-based drama intervention could create better narrative abilities and gesture more often than their peers who did not receive training. We observed clear changes in various narrative measures, including narrative length, syntactic complexity, narrative structure, and cognitive inferences, in the intervention condition. There was also an improvement in the average number of overall gestures per clause in this condition. These learning outcomes were maintained in the delayed post-test. No improvement in narrative measures was documented across time points in the waitlist control group.

As shown in our findings, children with ASD in the intervention condition increased the number of clauses they used and their level of syntactic complexity after training; they were also able to incorporate characters' goals and make cognitive inferences regarding the characters in their narrations. Specifically, they could describe the causal and temporal structure of the narrative and identify the characters' goals and their attempts to achieve those goals. For example, in the narration of one of the stories about Tweety Bird and Sylvester during the pre-test, a child said, "One cat needed to eat the bird. Then he kept climbing up. Then the bird stood still. Then the cat extended his hand and caught the bird." During the post-test, the same child said, "The cat wanted to catch the bird. Therefore, he climbed up the pipe and walked along the cable. Then the bird pulled the cable and the cat fell down." The child was able to identify the mental state of the cat ("The cat wanted to catch the bird") and indicate the sequence of the events ("The bird pulled the cable and the cat fell down") in the post-test. Although the improvement in affective inference was not significant, children with ASD in the intervention condition tended to produce a greater proportion of stories with affective inference after training (from .65 in the pre-test to .73 in the immediate post-test and .85 in the delayed post-test; $p < .07$). Participating in the roleplays allowed the children with ASD to experience the characters' feelings toward other people, thereby enhancing their emotional understanding and enabling them to make affective inferences. Additionally, there was a significant increase in the average number of gestures used per clause, especially deictic gestures, by the children in the intervention condition, but this was not seen in regard to the children in the waitlist control condition. This might be related to the fact that the children with ASD in the intervention condition produced more clauses in their narratives in the post-tests. With an increase in narrative length, these children were more likely to produce deictic gestures to signify characters involved in their narratives and then elaborate on the characters' actions through speech.

These positive learning outcomes can be attributed to the combined effect of two factors: the adoption of the play-drama intervention protocol and the application of socially assistive robots in this protocol. The play-drama intervention protocol offered a structured approach that enabled the children to develop temporal representations of events and understand how the scenes were linked, which are critical skills in narration (Peter, 2003). For example, in the "Doctor and Patient" drama, the patient got sick, which led him to see a doctor, who then diagnosed him and gave him advice and medication. Finally, the patient left and felt relieved. This kind of drama demonstrates how events are linked as a result of human responses to situations. In this way, children with ASD are able to see patterns and sequences in life. Merely watching the demonstration may not be enough for these children to establish temporal representations. Through acting out a drama, which was part of our training, the participating children with ASD took the roles of the characters featured in the dramas and actively participated in them. Thus, they could practice the play behaviors and the potential impact of those behaviors on others' responses (Peter, 2003). Additionally, our dramas have a prescribed structure, thereby offering children with ASD a predictable sequence and secure framework in which to generate and sustain an understanding of narrative (Peter, 1994; Taylor, 1984). Through participating in our play-drama intervention protocol, the children were equipped with an understanding of patterns and sequences in life and were able to develop a coherent and meaningful framework within their own narratives.

By acting as characters in our play-drama intervention protocol, the children also imitated the gestures produced by the socially assistive robots and engaged in pretending. For example, in the "Farmer and Butterfly" drama, the social robot that took the role of the farmer pretended to plant seeds and made a gesture that indicated that he was doing so (right hand holding fist and moving down to the ground with fingers stretched), while the butterfly robot pretend to fly to the farm by making a flying gesture (both hands flapping). After watching the drama, the children were found to spontaneously produce these gestures approximately 40% of the time in their roleplays. They thereby developed an understanding of the meaning of those gestures and produced them in appropriate contexts. This motivated them to use their hands to convey meanings in their own narrations.

However, one might contend that the increase in the gesture rate mainly came from deictic gestures, rather than iconic and marker gestures, which were demonstrated by the socially assistive robots during the dramas. We acknowledge that the play-drama intervention protocol alone may not be sufficient to train children with ASD to use iconic and marker gestures. Previous research has shown that teaching children with ASD, aged three to 12 years, iconic and marker gestures, one at a time, through demonstrations by socially assistive robots, led to an improvement in gestural recognition and production (So et al., 2016, 2018a, 2018b). Specifically, the children recognized and imitated more gestures, as well as producing them in appropriate social contexts in both training and novel contexts after intervention (So et al., 2016; 2018b). They were even found to catch up to the level of gestural production found in children with typical development (So, Wong, Lam, Cheng et al., 2018). Therefore, we should provide this kind of gestural intervention protocol on top of the play-drama intervention protocol in order to achieve more successful gestural training. However, the current play-drama intervention protocol was still effective in enhancing the overall gesture rate.

Our second contributing factor was the application of socially assistive robots in promoting narrative abilities for children with ASD. Previous research has shown that individuals with ASD prefer corresponding with socially assistive robots, than with other human beings (Bird, Leighton, Press, & Heyes, 2007; Kim et al., 2013; Pierno, Mari, Lusher, & Castiello, 2008; So, Wong et al., 2019; Tapus et al., 2012; Vanderborght et al., 2012). This preference is in concurrence to the social motivation theory of autism, which states that individuals with ASD show deficits in engaging with humans (Chevallier et al., 2012). A recent study by So, Wong et al. (2019) established that children with ASD that were exposed to socially assistive robots demonstrated more instances of eye contact with their human instructors, when compared to the control group of children with ASD, who were provided with similar instruction without the socially assistive robots. The children in the present study were found to be engaged in the social robot dramas.

Not only were they more engaging, but the socially assistive robots used in this intervention were also programmed in the present study in order to provide a structured learning environment. According to the Intense World Theory (Markram & Markram, 2010), a highly structured learning environment leads to positive learning outcomes in children with ASD. From this perspective, children with ASD may learn effectively when they are placed in a highly structured learning environment in which the lessons are offered in a systematic and predictable manner (e.g., the new information is repeated a few times, each time sharing the same content, and the learning activity procedures are consistent across lessons). In the play-drama intervention protocol, socially assistive robots, but not human therapists, can ensure that the dramas are performed in a structured, repetitive, and predictable manner. It is unrealistic to expect human therapists to play the drama in exactly the same way each time. In addition, individuals with ASD find it challenging to pay attention to multiple cues during social interactions with humans (Koegel et al., 1999). Therefore, a prescribed drama played by socially assistive robots would enable children with ASD to focus on the relevant stimuli, which, in this case, was the narrative structure and gestures.

Our study is a pioneering work demonstrating that a robot-based play-drama intervention can enhance narrative abilities and gestural communication for children with ASD. Theoretically, our findings have extended existing research, which has posited that robot-based interventions can promote gestural communication skills. Based on the current findings, it can be said that robot-based interventions can also benefit narrative skills. This pilot study also has strong implications for the direction in which technology-based interventions for preschoolers with ASD should proceed. Our research team is investigating whether or not the robot-based play-drama intervention could facilitate symbolic play and joint attention skills. Practically, our research could promote the implementation of early robot-based interventions in preschool education, given that narrative production emerges in children's preschool years (e.g., Berman & Slobin, 1994; Peterson & McCabe, 1983). Our intervention is also suitable for children whose language and communication ages fall behind their chronological ages (i.e., children with language delay). After nine robot-based play-drama lessons, the narrative abilities of the participating children in this study improved. Our protocol may also be useful in promoting general social competence, such as in regard to joint attention, perspective taking, and understanding others' intentions. Nevertheless, the current design was not able to draw conclusions about the effectiveness of robot-based intervention in comparison to human-based intervention, which was not our objective. A previous study designed comparable robot- and human-based intervention programs and found that the learning outcomes for both programs were similar (So, Wong et al., 2019). Yet, children enrolled in the robot-intervention program were more likely to establish eye contact with their teachers (i.e., robots) than those in the human-intervention program whose teachers were human-beings.

That said, this pilot study has a few limitations. First, our sample size was relatively small. Impairments in narrative abilities are heterogeneous (Masi, DeMayo, Glozier, & Guastella, 2017). Thus, there may be individual variations in the learning outcomes of the robot-based play-drama intervention. One may question our choice of dramas and whether or not different kinds of dramas (e.g., dramas that depict real-life and familiar scenarios, such as "Doctor and Patient" vs. dramas that depict unrealistic or unfamiliar situations, such as "Farmer and Butterfly" and "Tour and Tour Guide") would influence the learning outcomes. A recent study has reported that children's responses (number of prompting times, number of gestures, and appropriateness of speech) during roleplays did not differ across these three dramas (So et al., review under revision). Yet, it is not clear whether different types of drama scenarios would affect the results of intervention, which was beyond the scope of the present study. Future study can address this issue by presenting different types of drama scenarios to different groups of children with ASD and examining the learning outcomes of each group. Finally, all participating children were from Hong Kong. We should further investigate whether the results may be generalized to other cultural contexts.

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Appendix I. The scripts of the three dramas with gestures (shown in the brackets)

< < The Farmer and the Butterfly > >		
1	Farmer	I have a seed. Let me plant it! [PLANT THE SEED]
2	Farmer	Good. Let me now get a watering can to water the flowers! [WATER]
3	Butterfly	La (x6, singing) ~ [FLY]
4	Butterfly	Hello, farmer! [WAVE] What are you doing here?
5	Farmer	Hello, [WAVE] butterfly!
6	Farmer	I am planting flowers here! Look! [LOOK]

7	Butterfly	Planting flowers? Let me smell it! [SMELL]
8	Butterfly	Why doesn't this flower have a scent? [WHY]
9	Farmer	It has not blossomed yet, [HEAD SHAKE] (so) of course it has no scent! Come back later!
10	Butterfly	Well, then! [HEAD NOD]
11	Butterfly	I shall go now. See you later! Goodbye! [BYE]
12	Farmer	Goodbye! [BYE]
	−1 month later-	
13	Farmer	Whoa! How come there are so many weeds? Let me get rid of them. [GRASP]
14	Butterfly	Farmer, here I come again! Today the sun is very bright! [HOT]
15	Farmer	Oh yes! Today it is very hot! Let me wipe my sweat! [SWIPE FOREHEAD]
16	Farmer	Butterfly, come here! [COME OVER] The flowers have finally blossomed!
17	Butterfly	Hurray! [POINT TO LEFT] The flowers have finally blossomed!
18	Farmer	Yes! This is so great! [BOTH HANDS CLAP]
19	Butterfly	Okay, let me try the nectar and see if it tastes good. [EAT]
20	Butterfly	Wow! The nectar is so delicious! [HEAD NOD]

< < The Doctor and the Patient > >		
1	Patient	This morning I'm not feeling very well. [TOUCH FOREHEAD] I may be sick.
2	Patient	Huh? There is a clinic over there. [POINT TO RIGHT]
3	Patient	Let me go there [WALK] and see the doctor.
4	Doctor	Hello, [WAVE] what's the matter?
5	Patient	Hello, doctor. [WAVE] I'm not feeling very well today.
6	Doctor	Oh? Please take a seat. [SHOW] Which part of you is not feeling well?
7	Patient	I feel dizzy [HEAD TURING AROUND] and I have a fever.
8	Doctor	Then let me take your temperature! [HOLD A THERMOETER]
9	Doctor	Don't worry! [SHAKING HEAD] It's only a mild fever!
10	Patient	I'm relieved to hear that! [TAPPING CHEST]
11	Doctor	Actually, to remain healthy, you may exercise more. [RAISING BOTH HANDS]
12	Patient	I love exercise. My favourite sport is swimming! [SWIM]
13	Doctor	Exercise alone is not enough! [SHAKING HEAD]
14	Doctor	Every day in general, you should also eat more fruit. [EAT]
15	Doctor	And drink more water. [DRINK]
16	Patient	Hmm, I see. [NODDING HEAD]
17	Doctor	I shall now give you some medicine. [GIVE] When you go home, remember to take your medicine!
18	Patient	Thank you, Doctor! [TAKE]
19	Doctor	Then please return next week for the follow-up appointment! Goodbye! [BYE]
20	Patient	Thank you! Goodbye! [BYE]

< < The Tourist and the Tour Guide > >		
1	Tourist	Hurray! [CLAPPING HANDS] Today I am travelling to Hong Kong. I am so happy!
2	Tour guide	Hello! I am your tour guide. [WAVE]
3	Tourist	Hello, [my] tour guide! [WAVE]
4	Tour guide	Welcome to Hong Kong (as a traveller)! [WELCOME] Where do you come from?
5	Tourist	I flew from France [AIRPLANE] to Hong Kong.
6	Tourist	Just now there was turbulence. The plane shook from side to side. I was so scared. [TAPPING CHEST]
7	Tour guide	Are you all right? How do you feel now? [HAND OPENING]
8	Tourist	I'm fine. Only a bit dizzy. [TURNING HEAD]
9	Tourist	Luckily, I had fastened my seat belt back then! [FASTEN]
10	Tour guide	That's good! [HEAD NODDING]
11	Tour guide	Oh? It's already noon! [LOOK AT THE WATCH]
12	Tour guide	Let's get something to eat! [EAT]
13	Tourist	Yes! I'm already very hungry! [HUNGRY]
	-After the meal-	
14	Tourist	Now that we've eaten, where shall we go? [WHERE]
15	Tour guide	In a moment, I will drive [DRIVE] you to the (Hong Kong) Wetland Park.
16	Tour guide	There, you can see many birds! [FLY]
17	Tourist	I love birds. In a moment, I am going to take more pictures with them! [PHOTOTAKING]
18	Tour guide	But remember, do not [HEAD SHAKING] feed them (without authorisation)!
19	Tourist	Hmm! I see! [HEAD NODDING]
20	Tour guide	Well, then let's begin the journey now! [POINT TO THE RIGHT]

References

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders (DSM-5)* (5th ed.). United States: American Psychiatric Publishing.
Bamberg, M. G. (1987). *The acquisition of narratives: Learning to use language*, *vol. 49*. Berlin: Walter de Gruyter.
Baron-Cohen, S., Leslie, A. M., & Frith, U. (1986). Mechanical, behavioural and intentional understanding of picture stories in autistic children. *The British Journal of Developmental Psychology, 4*(2), 113–125.
Bates, D., Maechler, M., Bolker, B., & Walker, S. (2014). Lm: Linear mixed-effects models using Eigen and S4. *R Package Version, 1*(7), e4.
Begum, M., Serna, R. W., & Yanco, H. A. (2016). Are robots ready to deliver autism interventions? A comprehensive review. *International Journal of Social Robotics, 8*(2), 157–181.
Berman, R. A., & Slobin, D. I. (1994). Narrative structure. *Relating Events in Narrative: A Crosslinguistic Developmental Study, 39*, 84.
Bird, G., Leighton, J., Press, C., & Heyes, C. (2007). Intact automatic imitation of human and robot actions in autism spectrum disorders. *Proceedings of the Royal Society of London B: Biological Sciences, 274*(1628), 3027–3031.
Botting, N. (2002). Narrative as a tool for the assessment of linguistic and pragmatic impairments. *Child Language Teaching and Therapy, 18*(1), 1–21.
Botting, N., Faragher, B., Simkin, Z., Knox, E., & Conti-Ramsden, G. (2001). Predicting pathways of specific language impairment: What differentiates good and poor outcome? *The Journal of Child Psychology and Psychiatry and Allied Disciplines, 42*(8), 1013–1020.
Boucher, J., Pons, F., Lind, S., & Williams, D. (2007). Temporal cognition in children with autistic spectrum disorders: Tests of diachronic thinking. *Journal of Autism and Developmental Disorders, 37*(8), 1413–1429.
Bowler, D. M., Gardiner, J. M., & Grice, S. J. (2000). Episodic memory and remembering in adults with Asperger syndrome. *Journal of Autism and Developmental Disorders, 30*(4), 295–304.
Bruner, J., & Feldman, C. (1993). Theories of mind and the problem of autism. In S. Baron-Cohen, H. Tager-Flusberg, & D. J. Cohen (Eds.). *Understanding other minds: Perspectives from autism*. Oxford, England: Oxford University Press.
Cabibihan, J. J., Javed, H., Ang, M., & Aljunied, S. M. (2013). Why robots? A survey on the roles and benefits of social robots in the therapy of children with autism. *International Journal of Social Robotics, 5*(4), 593–618.
Cabibihan, J.-J., So, W., & Pramanik, S. (2012). Human recognizable robotic gestures. *IEEE Transactions on Autonomous Mental Development, 4*, 305–314.
Capps, L., Kehres, J., & Sigman, M. (1998). Conversational abilities among children with autism and children with developmental delays. *Autism, 2*(4), 325–344.
Capps, L., Losh, M., & Thurber, C. (2000). "The frog ate the bug and made his mouth sad": Narrative competence in children with autism. *Journal of Abnormal Child Psychology, 28*(2), 193–204.
Chevallier, C., Kohls, G., Troiani, V., Brodkin, E. S., & Schultz, R. T. (2012). The social motivation theory of autism. *Trends in Cognitive Sciences, 16*(4), 231–239.
de la Cruz, R. E., Lian, M. C. J., & Morreau, L. E. (1998). The effects of creative drama on social and oral language skills of children with learning disabilities. *Youth Theatre Journal, 12*(1), 89–95.
Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*, 155–159.
Demir, Ö. E., Levine, S. C., & Goldin-Meadow, S. (2010). Narrative skill in children with early unilateral brain injury: A possible limit to functional plasticity. *Developmental Science, 13*(4), 636–647.
Dewey, D., Cantell, M., & Crawford, S. G. (2007). Motor and gestural performance in children with autism spectrum disorders, developmental coordination disorder, and/or attention deficit hyperactivity disorder. *Journal of the International Neuropsychological Society, 13*(2), 246–256.
Diehl, J. J., Bennetto, L., & Young, E. C. (2006). Story recall and narrative coherence of high-functioning children with autism spectrum disorders. *Journal of Abnormal Child Psychology, 34*(1), 83–98.
Dodd, J. L., Ocampo, A., & Kennedy, K. S. (2011). Perspective taking through narratives: An intervention for students with ASD. *Communication Disorders Quarterly, 33*(1), 23–33.
Duinmeijer, I., de Jong, J., & Scheper, A. (2012). Narrative abilities, memory and attention in children with a specific language impairment. *International Journal of Language & Communication Disorders, 47*(5), 542–555.
Eigsti, I. M., Bennetto, L., & Dadlani, M. B. (2007). Beyond pragmatics: Morphosyntactic development in autism. *Journal of Autism and Developmental Disorders, 37*, 1007–1023.
Engberg-Pedersen, E., & Christensen, R. V. (2017). Mental states and activities in Danish narratives: Children with autism and children with language impairment. *Journal of Child Language, 44*(5), 1192–1217.
Feil-Seifer, D., & Matarić, M. J. (2005). Defining socially assistive robotics. *Proceedings of the 2005 IEEE 9th International Conference on Rehabilitation Robotics* (pp. 465–468).
Fong, T., Nourbakhsh, I., & Dautenhahn, K. (2003). A survey of socially interactive robots. *Robotics and Autonomous Systems, 42*(3-4), 143–166.
Gerenser, J. (2009). There is no vowel at the end of D O G: Considerations for teaching speech production. *The Journal of Speech and Language Pathology: Applied Behavior Analysis, 4*(1), 180–189.
Gillam, S. L., Hartzheim, D., Studenka, B., Simonsmeier, V., & Gillam, R. (2015). Narrative intervention for children with autism spectrum disorder (ASD). *Journal of Speech, Language, and Hearing Research, 58*(3), 920–933.
Goldin-Meadow, S., & Mylander, C. (1984). Gestural communication in deaf children: The effects and noneffects of parental input on early language development. *Monographs of the Society for Research in Child Development, 49*(3–4), 1–121.
Goldstein, T. R., & Winner, E. (2012). Enhancing empathy and theory of mind. *Journal of Cognition and Development, 13*(1), 19–37.
Hayward, D., & Schneider, P. (2000). Effectiveness of teaching story grammar knowledge to pre-school children with language impairment: An exploratory study. *Child Language Teaching and Therapy, 16*(3), 255–284.
Iverson, J. M., & Goldin-Meadow, S. (2005). Gesture paves the way for language development. *Psychological Science, 16*(5), 367–371.
Kim, E. S., Berkovits, L. D., Bernier, E. P., Leyzberg, D., Shic, F., Paul, R., et al. (2013). Social robots as embedded reinforcers of social behavior in children with autism. *Journal of Autism and Developmental Disorders, 43*(5), 1038–1049.
Klecan-Aker, J. S. (1993). A treatment programme for improving story-telling ability: A case study. *Child Language Teaching and Therapy, 9*(2), 105–115.
Klin, A., & Jones, W. (2006). Attributing social and physical meaning to ambiguous visual displays in individuals with higher-functioning autism spectrum disorders. *Brain and Cognition, 61*(1), 40–53.
Klin, A., Lin, D. J., Gorrindo, P., Ramsay, G., & Jones, W. (2009). Two-year-olds with autism orient to non-social contingencies rather than biological motion. *Nature, 459*(7244), 257–261.
Koegel, L. K., Koegel, R. L., Harrower, J. K., & Carter, C. M. (1999). Pivotal response intervention I: Overview of approach. *Journal of the Association for Persons with Severe Handicaps, 24*(3), 174–185.
Kozima, H., Michalowski, M. P., & Nakagawa, C. (2009). Keepon. *International Journal of Social Robotics, 1*(1), 3–18.
Landa, R., Martin, M., Minshew, N., & Goldstein, G. (1995). Discourse and abstract language ability in non-retarded individuals with autism. *Paper Presented at the Society for Research in Child Development*.
Lee, J., Takehashi, H., Nagai, C., Obinata, G., & Stefanov, D. (2012). Which robot features can stimulate better responses from children with autism in robot-assisted therapy? *International Journal of Advanced Robotic Systems, 9*, 1–6.
Lerner, M. D., & Levine, K. (2007). The Spotlight Program: An integrative approach to teaching social pragmatics using dramatic principles and techniques. *The Journal of Developmental Processes, 2*, 91–102.
Li, H., Cabibihan, J. J., & Tan, Y. K. (2011). Towards an effective design of social robots. *International Journal of Social Robotics, 3*(4), 333–335.
Lord, C., & Paul, R. (1997). In D. J. Cohen, & F. R. Volkmar (Eds.). *Handbook of autism and pervasive developmental disorders* (pp. 195–225). (2nd ed.). New York, NY: John Wiley and Sons.
Lord, C., Rutter, M., DiLavore, P., Risi, S., Gotham, K., & Bishop, S. (2012). *Autism diagnostic observation schedule second edition (ADOS-2) manual (Part 1): Modules 1-4.* Torrance, CA: Western Psychological Services.

Losh, M., & Capps, L. (2003). Narrative ability in high-functioning children with autism or Asperger's syndrome. *Journal of Autism and Developmental Disorders, 33*(3), 239–251.
Loveland, K., & Tunali, B. (1993). Narrative language in autism and the theory of mind hypothesis: A wider perspective. In S. Baron-Cohen, H. Tager-Flusberg, & D. J. Cohen (Eds.). *Understanding other minds: Perspectives from autism*. Oxford, England: Oxford University Press.
Loveland, K. A., McEvoy, R. E., Tunali, B., & Kelley, M. L. (1990). Narrative story telling in autism and Down's syndrome. *The British Journal of Developmental Psychology, 8*(1), 9–23.
Markram, K., & Markram, H. (2010). The intense world theory: A unifying theory of the neurobiology of autism. *Frontiers in Human Neuroscience, 4*, 224.
Masi, A., DeMayo, M. M., Glozier, N., & Guastella, A. J. (2017). An overview of autism spectrum disorder, heterogeneity and treatment options. *Neuroscience Bulletin, 33*(2), 183–193.
Matarić, M. J., & Scassellati, B. (2016). *Socially assistive robotics. Springer handbook of robotics*. Cham: Springer1973–1994.
McCabe, P. C., & Marshall, D. J. (2006). Measuring the social competence of preschool children with specific language impairment: Correspondence among informant ratings and behavioral observations. *Topics in Early Childhood Special Education, 26*(4), 234–246.
McNeill, D. (1992). *Hand and mind: What gestures reveal about thought* (1st ed.). Chicago, IL: University of Chicago Press.
McNeill, D. (2000). *Language and gesture*, *vol. 2*. Cambridge University Press.
McNeill, D. (2005). *Gesture and thought* (1st ed.). Chicago, IL: University of Chicago Press.
Miller, C. A., Leonard, L. B., Kail, R. V., Zhang, X., Tomblin, J. B., & Francis, D. J. (2006). Response time in 14-year-olds with language impairment. *Journal of Speech, Language, and Hearing Research, 49*(4), 712–728.
Miyamoto, E., Lee, M., Fujii, H., & Okada, M. (2005). How can robots facilitate social interaction of children with autism? Possible implications for educational environments. *The 5th International Workshop on Epigenetic Robotics: Modeling Cognitive Development in Robotic Systems* (pp. 145–146).
Mullen, E. M. (1995). *Mullen scales of early learning.* Circle Pines, MN: AGS.
Nelson, K. (1996). *Language in cognitive development: The emergence of the mediated mind.* New York, NY: Cambridge University Press.
Norbury, C. F., & Bishop, D. V. (2003). Narrative skills of children with communication impairments. *International Journal of Language & Communication Disorders, 38*(3), 287–313.
Özçalışkan, Ş., & Goldin-Meadow, S. (2005). Gesture is at the cutting edge of early language development. *Cognition, 96*(3), 101–113.
Ozonoff, S., Pennington, B. F., & Rogers, S. J. (1991). Executive function deficits in high-functioning autistic individuals: Relationship to theory of mind. *Journal of Child Psychology and Psychiatry, 32*, 1081–1105.
Park, H. W., Grover, I., Spaulding, S., Gomez, L., & Breazeal, C. (2019). A model-free affective reinforcement learning approach to personalization of an autonomous social robot companion for early literacy education. *Proceedings of the Thirty Third AAAI Conference on Artificial Intelligence, AAAI,* 19.
Peter, M. (1994). *Drama for all.* London, England: David Fulton Publishers.
Peter, M. (2003). Drama, narrative and early learning. *British Journal of Special Education, 30*(1), 21–27.
Petersen, D. B., Brown, C. L., Ukrainetz, T. A., Wise, C., Spencer, T. D., & Zebre, J. (2014). Systematic individualized narrative language intervention on the personal narratives of children with autism. *Language, Speech, and Hearing Services in Schools, 45*(1), 67–86.
Peterson, C., & McCabe, A. (1983). *Developmental psycholinguistics: Three ways of looking at a child's narrative.* New York, NY: Plenum Press.
Pierno, A. C., Mari, M., Lusher, D., & Castiello, U. (2008). Robotic movement elicits visuomotor priming in children with autism. *Neuropsychologia, 46*(2), 448–454.
Ricks, D. J., & Colton, M. B. (2010). Trends and considerations in robot-assisted autism therapy. *Proceedings of the 2010 IEEE International Conference on Robotics and Automation,* 4354–4359.
Scassellati, B., Admoni, H., & Matarić, M. (2012). Robots for use in autism research. *Annual Review of Biomedical Engineering, 14*, 275–294.
So, W. C., Wong, M. K. Y., Lui, M., & Yip, V. (2015). The development of co-speech gesture and its semantic integration with speech in 6- to 12-year-old children with autism spectrum disorders. *Autism: International Journal of Research and Practice, 19*(8), 956–968.
So, W. C., Wong, M. Y., Cabibihan, J. J., Lam, C. Y., Chan, R. Y., & Qian, H. H. (2016). Using robot animation to promote gestural skills in children with autism spectrum disorders. *Journal of Computer Assisted Learning, 32*(6), 632–646.
So, W. C., Wong, M. K. Y., Lam, W. Y., Cheng, C. H., Yang, J. H., Huang, Y., et al. (2018). Robot-based intervention may reduce delay in the production of intransitive gestures in Chinese-speaking preschoolers with autism spectrum disorder. *Molecular Autism, 9*(1), 34.
So, W. C., Wong, M. K. Y., Lam, C. K. Y., Lam, W. Y., Chui, A. T. F., Lee, T. L., et al. (2018). Using a social robot to teach gestural recognition and production in children with autism spectrum disorders. *Disability and Rehabilitation: Assistive Technology, 13*(6), 527–539.
So, W. C., Wong, M. K. Y., Lam, W. Y., Cheng, C. H., Ku, S. Y., Lam, K. Y., et al. (2019). Who is a better teacher for children with autism? Comparison of learning outcomes between robot-based and human-based interventions in gestural production and recognition. *Research in Developmental Disabilities, 86*, 62–75.
Stein, N. L., & Glenn, C. G. (1979). An analysis of story comprehension in elementary school children. In R. Freedle (Vol. Ed.), *New directions in discourse processing: vol. 2*, (pp. 53–). Norwood, NJ: Ablex.
Stothard, S. E., Snowling, M. J., Bishop, D. V., Chipchase, B. B., & Kaplan, C. A. (1998). Language-impaired preschoolers: A follow-up into adolescence. *Journal of Speech, Language, and Hearing Research, 41*(2), 407–418.
Swanson, L. A., Fey, M. E., Mills, C. E., & Hood, L. S. (2005). Use of narrative-based language intervention with children who have specific language impairment. *American Journal of Speech-Language Pathology, 14*(2), 131–141.
Tager-Flusberg, H. (2001). A re-examination of the theory of mind hypothesis of autism. In J. Burack, T. Charman, N. Yirmiya, & P. R. Zelazo (Eds.). *Development in autism: Perspectives from theory and research* (pp. 173–193). Hillsdale, NJ: Erlbaum.
Tager-Flusberg, H. (2007). Evaluating the theory-of-mind hypothesis of autism. *Current Directions in Psychological Science, 16*(6), 311–315.
Tager-Flusberg, H., Paul, R., & Lord, C. (2005). Language and communication in autism. In F. R. Volkmar, R. Paul, A. Klin, & D. Cohen (Eds.). *Handbook of autism and pervasive developmental disorders: Diagnosis, development, neurobiology, and behavior* (pp. 335–364). Hoboken, NJ: John Wiley & Sons Inc.
Tapus, A., Peca, A., Aly, A., Pop, C., Jisa, L., Pintea, S., et al. (2012). Children with autism social engagement in interaction with Nao, an imitative robot: A series of single case experiments. *Interaction Studies, 13*(3), 315–347.
Taylor, J. (1984). *Steps to drama* (unpublished paper)London, England: ILEA.
R Core Team (2012). *R: A language and environment for statistical computing.* Vienna, Austria: R Foundation for Statistical Computing.
Vanderborght, B., Simut, R., Saldien, J., Pop, C., Rusu, A. S., Pintea, S., et al. (2012). Using the social robot probo as a social story telling agent for children with ASD. *Interaction Studies, 13*(3), 348–372.
Wellman, H. M., & Liu, D. (2004). Scaling of theory-of-mind tasks. *Child Development, 75*(2), 523–541.
Wellman, H. M., Fang, F., Liu, D., Zhu, L., & Liu, G. (2006). Scaling of theory-of-mind understandings in Chinese children. *Psychological Science, 17*(12), 1075–1081.
Wellman, R. L., Lewis, B. A., Freebairn, L. A., Avrich, A. A., Hansen, A. J., & Stein, C. M. (2011). Narrative ability of children with speech sound disorders and the prediction of later literacy skills. *Language, Speech, and Hearing Services in Schools, 42*(4), 561–579.
Werry, I., Dautenhahn, K., Ogden, B., & Harwin, W. (2001). *Can social interaction skills be taught by a social agent? The role of a robotic mediator in autism therapy. Cognitive technology: Instruments of mind.* Berlin, Heidelberg: Springer57–74.
Westerveld, M. F., & Gillon, G. T. (2008). Oral narrative intervention for children with mixed reading disability. *Child Language Teaching and Therapy, 24*(1), 31–54.
Wimpory, D., Nicholas, B., & Nash, S. (2002). Social timing, clock genes and autism: A new hypothesis. *Journal of Intellectual Disability, 46*, 352–363.