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Social and Communication Skills Predict Imitation Abilities in Children with Autism

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This study examined whether social and communicative skills would predict the ability to imitate conventional-interactive gestures (e.g., HAND WAVING for saying goodbye) in children with autism spectrum disorders (ASD). Twenty 6- to 11-year-old Chinese-speaking children with ASD were participated. Their social and communicative skills were assessed based on their caregivers' ratings on their social and communication impairments and the observation of their gesture production in spontaneous interactions with the caregivers 3 months prior to the administration of the gesture imitation task. After controlling for gesture recognition and visual–motor coordination skills, the results of the partial correlation analyses have shown that there was significant association among the number of conventional-interactive gestures imitated accurately, the caregivers' ratings, and the number of conventional-interactive gestures produced during interactions. Four regression analyses were thus conducted. We found the severity of social and communication impairments predicted the imitation of communicative gestures, with such relation mediated by the production of conventional-interactive gestures during the interactions. Overall, the results suggest that social and communication skills may play a causal role in imitation abilities in children with autism.

Keywords: autism, imitation, gesture, social and communication skills

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INTRODUCTION

Imitation normally emerges in early infancy [Meltzoff and Moore (1977), Heimann (1989); see review in Jones (2009)]. Not only does it help infants acquire new skills but it also helps them to engage in social interaction with others. Previous research has found a significant association between the social use of imitation in infancy and the development of social communication skills [e.g., Halliday and Leslie (1986), Charman et al. (2000), Paukner et al. (2014), Simpson et al. (2016), and Trevarthen et al. (1999)].

However, children with autism spectrum disorders (ASD), regardless of severity, have difficulties with imitating [see reviews in Smith and Bryson (1994) and Williams et al. (2004)]. Previous research has found that children with ASD show an imitation deficit, compared to children with developmental delay (matched for chronological and mental ages, and expressive language; Rogers et al., 1996) and typically developing children (matched for mental ages; Stone et al., 1997). Such deficit is found in spontaneous imitation as well as elicited imitation of gestures and actions in relation to objects [e.g., Smith and Bryson (2007), Rogers et al. (2008), Vivanti et al. (2008), and Gizzonio et al. (2015)]. As in other aspects of ASD, the severity of impairment in imitation can vary widely [e.g., Ingersoll and Gergans (2007), Ingersoll and Lalonde (2010), and Ingersoll and Meyer (2011)]. Some children with ASD may have better imitation abilities than others.

Past studies have shown that deficits in imitation are associated with the impairments in social communication skills in children with ASD (Rogers and Pennington, 1991; Meltzoff and Gopnik, 1994). A few studies have found a significant correlation between imitation and joint attention in children with ASD (Carpenter et al., 2002; Rogers et al., 2003). Children with ASD who are found to have imitation deficits also display similar deficits in their spontaneous play (Jarrold et al., 1993; Libby et al., 1997). Imitation skills can even predict the development of a child's social and communication skills (Rogers, 1999). One early study has shown that gesture imitation performance can influence the production of communicative gestures (Curcio, 1978). A longitudinal study by Stone et al. (1997) found that imitation of actions with objects at the age of 2 was highly correlated with the development of play skills a year later. Likewise, Rogers et al. (2003) found that early imitation abilities predicted language development, IQ, and social skills (Rogers et al., 2003). In a training study, Ingersoll and Schreibman (2006) reported that training imitation skills promoted the use of spontaneous pretend play.

While abundant empirical evidence has supported the directionality of the effects of imitation on social engagement in individuals with ASD, very few studies have explored whether social communication and interaction skills would predict imitation abilities in individuals with ASD. We addressed this issue in this study. Children with ASD who have poorer social and communication functioning might have greater deficits in imitation than those who have better social and communication functioning. Imitation requires individuals to develop a sense of social connectedness with the people being imitated (Hobson and Lee, 1999). After achieving interpersonal connectedness, individuals engage in a social exchange with those people through imitation. Thus, in addition to serving as a learning tool, imitation is a kind of social strategy for communicating and interacting with others (Ingersoll, 2008). In this sense, having poorer social and communicative skills would result in a greater difficulty in imitation (Hobson, 1989).

Of different aspects of imitation abilities, we focused on here the ability to imitate gestures, particularly meaningful gestures, in children with ASD. Previous research has shown that individuals with ASD are found to have difficulties imitating non-meaningful gestures (i.e., actions that do not carry semantic meaning, e.g., both hands raised; Rogers et al., 1996; Vivanti et al., 2008; Gizzonio et al., 2015) and meaningful gestures (i.e., actions that carry semantic meaning, e.g., both hands flap to indicate a bird or an action of flying; Dewey et al., 2007; Smith and Bryson, 2007). However, imitating meaningful actions increases children's natural motivation to complete the actions (Ingersoll, 2008). Previous findings have also shown that individuals with ASD imitate meaningful gestures better than non-meaningful ones [e.g., Cossu et al. (2012) and Wild et al. (2012)]. Of the different kinds of meaningful gestures, we focused on conventional-interactive gestures (e.g., hand waves for saying goodbye). These gestures are conventionally or culturally defined and are used for regulating interaction (McNeill, 1992, 2000).

In this study, we aimed to examine whether social and communication skills would predict imitation abilities in children with ASD. Social and communication skills were assessed in two ways: (1) caregivers' ratings on the severity of social and communication impairments of their children with ASD and (2) children's production of conventional-interactive gestures during their interactions with the caregivers. Our study had two objectives. The first objective was to examine whether the severity of social and communication impairments would predict the ability to imitate conventional-interactive gestures in children with ASD. Three months prior to testing the children's ability to imitate conventional-interactive gestures, we asked their caregivers to rate the children's social and communication skills. We hypothesized that children with ASD who were rated as having overall more severe social and communication impairments were less likely to imitate conventional-interactive gestures than those who were rated as having less severe social and communication impairments.

The second objective was to examine whether the earlier production of conventional-interactive gestures would influence the ability to imitate the same kind of gestures. Ingersoll (2008) argued that engagement in particular social communicative behaviors would influence the development of imitation skills. However, this issue has yet to be empirically studied. Thus, 3 months prior to testing the children's ability to imitate conventional-interactive gestures, we asked the children to interact with their caregivers in order to examine their production of the same kind of gestures. We hypothesized that the children who produced more conventional-interactive gestures when interacting with caregivers would be more able to imitate conventional-interactive gestures that they had not previously produced.

MATERIALS AND METHODS

Participants

A total of 20 Chinese-speaking (specifically, Cantonese-speaking) children aged 6–11 years were participated in this study (5 were female; mean age 9.12 years, ±1.32 SD; age range 6.94–11.73 years). They had all been diagnosed with autism or another autistic disorder between the ages of 18 and 60 months (M = 32.40; SD = 13.26) by pediatricians at the Child Assessment Centers for the Department of Health in Hong Kong. All of the children were attending Hong Chi Morninghill School, Tsui Lam, Tseung Kwan O; this is a special school in Hong Kong for children with ASD and mild to moderate intellectual disabilities. Their ASD diagnoses were further confirmed by clinical psychologists and pediatricians from the Pamela Youde Child Assessment Center, Hong Kong, through standard clinical interviews with their parents and on the basis of the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV, American Psychiatric Association, 2000). The study was approved by the Survey and Behavioral Research Ethics Committee at the university of the first author and was conducted according to the Declaration of Helsinki. We obtained the parents' informed consent prior to the study.

The children's IQs were assessed by qualified clinical psychologists from the Pamela Youde Child Assessment Center. Of the 20 children, 12 had their IQs assessed by the Wechsler Intelligence Scale for Children®, Fourth Edition (Hong Kong; WISC IV-HK); their IQs ranged from 51 to 72 (M = 61.52; SD = 7.87). The other eight children had their IQs assessed by with the Stanford Binet Intelligence Scale (Fourth Edition; SB: FE) because they were not capable of completing the subtests in the WISC IV-Hong Kong; their IQs ranged from 49 to 62 (M = 51.18; SD = 4.42).

Procedures

The experiment was conducted at Hong Chi Morninghill School, Tsui Lam, Tseung Kwan O. All children were recruited through this special school and were tested individually. The assessments were separated into several sessions. In the first session, the children interacted with their caregivers for 15 min. After this time, the caregivers were invited to complete the Chinese version of the Social Communication Questionnaire (SCQ; Rutter et al., 2003). Three months later, the children took neuropsychological tests, as our assessments of the use of gestures required visual–motor coordination, which might influence their ability to imitate gestures. In addition to this, the children were administered a gesture recognition task in order to understand whether they could identify the meaning of the conventional-interactive gestures before taking the imitation task. In the final session, they were asked to imitate gestures demonstrated by an actor.

Tasks

Social and Communication Skills

Social and communication skills were measured by the caregivers' reports on the severity of social and communication impairments of their children with ASD and by the observation of the children's production of conventional-interactive gestures during interactions with their caregivers.

Caregivers were invited to complete the SCQ (lifetime), which measured the severity of autism symptoms in regard to the children's communication and social functioning. The SCQ consists of 40 items (e.g., "Is he/she able to produce short phrases or sentences?"). We scored the SCQ based on the established manual. Higher scores represent more severe communication and social skill impairment. The total score is 40.

In order to capture the production of conventional-interactive gestures produced by the children with ASD, caregivers were instructed to interact naturally with their children for 15 min. Of the 20 caregivers, 15 were the children's mothers, 4 were fathers, and 1 was a grandmother. Of the 20 caregivers, 15 were the children's main caregivers. A farm block play set of 36 brightly painted wooden blocks was provided to facilitate communication. This set allowed the children to build a barn and play with animals together with their caregivers. Caregivers and children were not instructed or prompted to gesture. Previous research has found that this kind of play set can elicit speech and gestures among participants with ASD (So et al., 2015). The session was videotaped.

Visual–Motor Coordination

Two tests, the Beery Visual–Motor Integration Test (VMI) and the Beery Visual Perceptual Subtest (VP), were administered to assess the children's visual–motor coordination. The children were asked to reproduce the geometric shapes in the VMI and to recognize the patterns they had seen earlier in the VP (Beery and Beery, 2004). We evaluated the children's visual–motor coordination skills in accordance with the scoring manuals of the VMI and the VP (Martin, 2006). The maximum possible scores are 78 and 16 for the VMI and the VP, respectively.

Gesture Recognition

All of the children were asked to recognize six conventional-interactive gestures that are commonly used in daily life (**Table 1**). Of the six gestures, three involved movements of one hand and the remaining involved movements of both hands. The children did not produce any of these gestures during their interactions with their caregivers (see Results). However, it is possible that some children might have understood the meaning of these gestures but did not produce them. Thus, we administered a recognition task to test whether or not the children could recognize the gestures, even if they had not produced them themselves.

The model demonstrated the six gestures (e.g., right hand waves) to the children (one at a time, in a randomized order) and then asked the children to indicate the meaning of the gestures. The model verbally provided three predetermined choices in Cantonese ["*Baai Baai*" (goodbye), "*Bin Dou*" (where), and "*Foon Ying*" (welcome)] that were also visually displayed in separate buttons on the computer screen. The children were given 10 s to respond, either by pointing to the correct answer on the screen (e.g., "goodbye") or by verbally responding to the researcher. The model prompted the children if they gave no response and then gave the children 10 more seconds to respond. Upon receiving each child's response, the model proceeded to the next gesture. This test was completed after all six gestures had been covered. A small reward by way of positive reinforcement was provided after the test. We counted the total number of gestures each child correctly recognized.

Gesture Imitation Task

This model produced the same six conventional-interactive gestures twice, one at a time, in a randomized order, and then asked the child to imitate the gesture (e.g., "now it is your turn to do this"). Words that represented the gestures' meanings

TABLE 1 | List of the six gestures in the gesture imitation and gesture recognition tasks.

Form	Meaning
Right palm waves	GOODBYE
Right arm crooks with right palm moving outward from the chest	WELCOME
Right hand with open palm is held up	WAIT
Both arms crook and form a cross at the chest level	WRONG
Right arm extends and left arm crooks with palm facing self, moving back and forth	COME
Both palms face upward and are placed at their own side	WHERE

(e.g., "*Baai Baai*") were also displayed on the computer screen. The children were given 10 s to imitate the gesture. The model prompted the children if they gave no response and then gave the children 10 more seconds to respond. The model then proceeded to the next gesture. This test was completed after all six gestures had been tested. A small reward by way of positive reinforcement was provided after the test. A camera located behind the computer captured each child's gestures for coding. We counted the total number of gestures each child correctly imitated (see Coding and Scoring below).

Coding and Scoring

For the spontaneous interaction task, all conversations between the children and their caregivers were transcribed by research assistants who were native Cantonese speakers. All transcripts were then checked by the second coder, who was also a native Cantonese speaker. The stream of speech was segmented into utterances, each consisting of a clause that expressed a proposition and included a predicate (Pei and Gaynor, 1954; Hartmann and Stork, 1972; Crystal, 1980). Utterances containing more than one clause connected by a conjunction, for example, "and" (*zung jau*) or "but" (*daan hai*), were segmented into two utterances.

In terms of coding communicative gestures, we followed Goldin-Meadow and Mylander (1984) [see also Iverson and Goldin-Meadow (2005) and Özçalişkan and Goldin-Meadow (2005)] in excluding hand movements that involved the direct manipulation of an object (e.g., placing a block on the table) or were part of a ritualized game (e.g., putting a puzzle piece into a slot). The communicative gestures were of four types. Iconic gestures bear a resemblance to the objects they represent or the actions associated with these objects (e.g., index finger and thumb forming a rectangle, classified as a reference to a small block; index finger and thumb turned counterclockwise, classified as an action of rotation). Deictic gestures serve to pick out objects (e.g., index finger pointing to a block or holding it up, classified as a reference to a block). Conventional-interactive gestures (also called markers) express culturally specific meaning (e.g., a nod of the head signifying agreement). Speech beats do not carry semantic content but follow the rhythm of the accompanying speech (e.g., index finger flips outward). Each gesture was then assigned a meaning. The meaning was determined by its form in conjunction with the speech with which the utterance occurred. For each child, we calculated the number of each type of gesture per utterance, which was the number of that type of gesture divided by the number of utterances.

For the imitation task, we watched the videos of the children and counted the number of times they produced conventional-interactive gestures correctly according to four parameters: use of hand/hands (e.g., placing right/left hand against the head vs. using both hands), hand shape (e.g., open palm vs. curled palm vs. fist), direction of movement (e.g., head nods vs. head shakes; moving hand from left to right vs. moving it up and down), and placement (e.g., hand placed at the head vs. at the chest). A description of the gestures can be seen in **Table 1**. The following gestures were considered incorrect: using the left hand only to produce the "where" gesture (reason: incorrect use of hands); waving with a fist when producing the "goodbye" gesture (reason: incorrect hand shape with the left or right hand); moving the right hand upward when producing the "come" gesture (reason: incorrect direction of movement); and placing both hands on the thighs when producing the "wrong" gesture (reason: incorrect placement).

Reliability

To assess the inter-coder reliability of the gesture coding in the spontaneous interaction task, we randomly selected 4 of the 20 videos for independent transcription and coding by the second trained coder, who was also a native Cantonese speaker. The inter-rater agreement was 0.90 ($N = 342$; Cohen's Kappa = 0.88, $p < 0.001$) for the identification of the same number of gestures, and 0.97 ($N = 138$; Cohen's Kappa = 0.95, $p < 0.001$) for the determination of gesture types. The inter-observer agreement for evaluating the gesture production in the imitation task was 0.94 ($N = 80$; Cohen's Kappa = 0.87, $p < 0.001$).

RESULTS

Table 2 shows the descriptive statistics for the gesture imitation, social and communication skills, gesture recognition, and the visual–motor coordination. The mean score of gesture imitation task was 3.10 (SD = 1.33), suggesting that on average only half of the gestures were imitated by the children. As expected, there were individual variations in the children's ability to imitate conventional-interactive gestures. Their scores ranged from 1 to 5 in the gesture imitation task. Children's social and communication skills were measured by the SCQ and their production of conventional-interactive gestures during spontaneous interactions with the caregivers. The mean score of SCQ was 22.80. All children but one had an SCQ score of 15 or above. The exceptional child, however, only scored 6 points in her SCQ, but had been previously diagnosed with autism by a psychiatrist.[1] During interactions with their caregivers, children on average produced 116.50 speech utterances, with each containing 0.21 gestures. Majority of the gestures were deictic gestures. It was not surprising given that children were playing with farm blocks that were easily referred to by pointing gestures (So et al., 2015). All of the children gestured when interacting with their caregivers but hardly produced any iconic gestures and speech beats. The most dominant type of gesture was deictic, followed by conventional-interactive gestures. Of the 20 children, 15 produced conventional-interactive gestures. However, they only produced two different conventional-interactive gestures, which were head nodding (showing agreement or saying yes) and head shaking (showing disagreement or saying no).

The mean scores of VMI and VP (measuring visual–motor coordination) were 53.05 (SD = 13.39) and 7.05 (SD = 3.63), respectively. Note that the mean score of gesture recognition task was almost 5 (the maximum score was 6), suggesting that most of the gestures were able to be recognized by the children. Sixteen out of the 20 children successfully recognized more than half of the conventional-interactive gestures in the gesture recognition

[1]The results were the same, even after excluding this child from the analyses.

TABLE 2 | Descriptive statistics for the gesture imitation, social and communication skills, visual–motor coordination, and gesture recognition.

			Mean	SD	Range
Gesture imitation task			3.10	1.33	1–5
Social and communication skills					
	Spontaneous interaction task				
		Number of speech utterances	116.85	54.95	31–235
		Number of gestures per utterance	0.21	0.12	0.09–0.41
		Number of iconic gestures per utterance	0	0	0–0.01
		Number of markers per utterance	0.05	0.05	0–0.12
		Number of deictic gestures per utterance	0.16	0.12	0.01–0.44
		Number of speech beats per utterance	0	0	0
	SCQ		22.8	7.16	6–34
Visual–motor coordination					
	VMI		53.05	13.39	22–72
	VP		7.05	3.63	3–13
Gesture recognition task			4.95	1.36	3–6

SCQ, Social Communication Questionnaire; VMI, Beery Visual–Motor Integration Test; VP, Beery Visual Perceptual Subtest.

test. As for the remaining children, three of them recognized half of the gestures, while one child only recognized two gestures.

Table 3 shows the correlations among the number of conventional-interactive gestures the children imitated accurately, their SCQ scores, social communicative skills before and after controlling for performance in the VMI, the VP, and the gesture recognition tasks. Visual–motor coordination, but not gesture recognition, was significantly associated with the number of conventional-interactive gestures the children imitated accurately. Although it was not significant, the correlation between gesture recognition and gesture imitation was 0.36. After controlling for visual–motor coordination and gesture recognition, we found that the number of conventional-interactive gestures the children imitated accurately was negatively correlated with their SCQ scores, and positively correlated with the number of conventional-interactive gestures produced during interactions. The SCQ scores were also negatively correlated with the children's production of conventional-interactive gestures during interactions.

We then conducted regression analyses to investigate whether social and communication skills (as measured by the SCQ score and the production of conventional-interactive gestures during interactions) predicted the children's ability to imitate new conventional-interactive gestures. However, based on the results of the partial correlation analyses, which have shown that there was significant association among the number of conventional-interactive gestures imitated accurately, the SCQ score, and the number of conventional-interactive gestures produced during interactions, we expected to find that either SCQ score or gesture production in interactions was a mediator variable, which influenced the number of conventional-interactive gestures accurately imitated by the children. Therefore, we ran a series of regression analyses in order to examine how SCQ score and gesture production influenced the imitation of conventional-interactive gestures across the children with ASD.

We established mediation using four regression analyses (Judd and Kenny, 1981; James and Brett, 1984; Baron and Kenny, 1986). Twenty participants are sufficient for multiple regression analyses with two predictor variables (Tabachnick and Fidell, 1983). **Table 4** shows the statistics. In the first regression analysis, we entered the SCQ score as the predictor and the number of conventional-interactive gestures accurately imitated as the dependent variable. We found a significant effect of the severity of social and communication impairments on the imitation of conventional-interactive gestures. In the second regression analysis, we entered the SCQ score as the predictor and the number of conventional-interactive gestures produced during interactions as the dependent variable and found a significant effect of the severity of social and communication impairments on the production of conventional-interactive gestures during the interactions. In the third regression analysis, we entered the SCQ score and the number of conventional-interactive gestures produced as the predictors in Step 1 and Step 2, respectively, and the number of conventional-interactive gestures accurately imitated as the dependent variable. We found a significant effect of the production of conventional-interactive gestures on the imitation of conventional-interactive gestures, even after controlling for the SCQ score. However, in the fourth regression analysis, while we entered the number of conventional-interactive gestures produced and the SCQ score as the predictors in Step 1 and Step 2, respectively, and the number of conventional-interactive gestures accurately imitated as the dependent variable, we did not find a significant effect of the severity of social and communication impairments on the imitation of conventional-interactive gestures after controlling for the production of conventional-interactive gestures during the interactions. These findings suggest that the production of conventional-interactive gestures during the interactions completely mediated the relation between the severity of social and communication impairments and the imitation of communicative gestures.

DISCUSSION

While past studies have shown that imitation skills can predict social and communication skills in children with ASD (Stone et al., 1997; Ingersoll and Schreibman, 2006), this pilot study provided empirical evidence for the reverse directionality. Specifically, the severity of social and communication impairments in children with ASD predicted their ability to imitate conventional-interactive gestures, with such relation mediated

TABLE 3 | Correlations among gesture imitation, SCQ score, and the production of conventional-interactive gestures during interactions, before and after controlling for performance in the VMI and the VP.

	Gesture imitation	SCQ	Gesture Production	VMI	VP	Gesture recognition
Gesture imitation	–	−0.52*	0.74**	–	–	–
SCQ	−0.46*	–	−0.62**	–	–	–
Gesture production	0.45*	−0.51*	–	–	–	–
VMI	0.58**	−0.52*	−0.36	–	–	–
VP	0.71**	−0.17	−0.16	0.69**	–	–
Gesture recognition	0.36	−0.27	−0.12	0.33	0.04	–

**p* < 0.05.
***p* < 0.01.
Numbers above the diagonal are the correlations after controlling for performance in the VMI and the VP; numbers below the diagonal are the correlations before controlling for performance in the VMI and the VP.

TABLE 4 | Statistics of four regression analyses showing the effects of the SCQ score and the production of conventional-interactive gestures in interactions on the imitation of conventional-interactive gestures.

Regression analysis	β	*t*	sr²	*R*	*R*²	DR²	*F*
1. SCQ score	−0.46	−2.20*	0.21	0.46	0.21	0.21*	4.86*
2. SCQ score	−0.40	−2.11*	0.18	0.40	0.16	0.16*	4.59*
3.							
Step 1: SCQ score	−0.46	−2.20*	0.21	0.46	0.21	0.21*	4.86*
Step 2: The number of conventional-interactive gestures produced during interactions	0.510	2.71*	0.32	0.62	0.38	0.19*	6.34**
4.							
Step 1: The number of conventional-interactive gestures produced during interactions	0.52	2.93*	0.38	0.75	0.56	0.56*	8.38**
Step 2: SCQ score	−0.08	−0.41	0.01	0.76	0.58	0.02	8.48**

**p* < 0.05.
***p* < 0.01.

by the number of conventional-interactive gestures produced during interactions.

Social and communication skills can play important roles in helping individuals imitate others. In particular, they help an individual to identify with another person and to establish interpersonal correspondences with the person in regard to actions and attitudes (Hobson and Lee, 1999). They also help the individual to be responsive to the actions, gestures, body movements, and vocalizations of the person with whom they are interacting, as well as to engage in social exchange when it is the individual's turn. The individual can thereby choose to convey messages, thoughts, and feelings to the other person, both verbally and non-verbally. Imitation, including gesture imitation, as a communicative act and an effective social strategy by which to express interests and establish connectedness with others (Ingersoll, 2008). Therefore, having better social and communication skills increases the likelihood of an imitative response in the children with ASD (Hobson, 1989). However, we do not argue against the directionality of the effect of imitation abilities on the development of social and communication skills. On the contrary, we propose that the possession of some social and communication skills is necessary for the occurrence of imitation, which in turn further develops advanced social and communication skills.

In this study, we assessed the children's social and communication skills based on their caregivers' ratings on their severity of social and communication impairments and our observation of their gesture production during interactions with the caregivers. We found that the severity of social and communication impairments was negatively correlated with the ability to imitate conventional-interactive gestures and to the ability to produce this kind of gestures in spontaneous interactions. Thus, poorer social and communication skills would make a child with ASD difficult to communicate with others using gestures [see also So et al. (2015)]. We further established that social and communication impairments would influence the children's ability to imitate conventional-interactive gestures, with such relation mediated by the production of the same kind of gestures in day-to-day interactions. While the severity of social and communication impairment is important for imitation in the first place, being able to produce some conventional-interactive gestures in day-to-day interactions is critical for the imitation of the same kind of gestures. Some children with ASD produced conventional-interactive gestures more often than others in such day-to-day interactions. More importantly, children with ASD who were more likely to produce conventional-interactive gestures were also more likely to imitate conventional-interactive gestures than those who produced fewer conventional-interactive gestures in the first place. This is possibly because children with ASD who frequently used conventional-interactive gestures might be familiar with using this kind of gestures for engaging in social exchange with others (Ingersoll, 2008). Therefore, they were more likely to imitate the conventional-interactive gestures in the gesture imitation task. Future study should be conducted to examine the mechanisms possibly operated in the causal relationship between social and communication skills and imitation abilities.

Similar to conventional-interactive gestures, iconic gestures carry semantic meaning. However, none of the children with ASD in this study produced iconic gestures. Previous research has shown that young children with ASD have delayed production of other types of gesture, such as iconic gestures and speech beats (Charman et al., 2003; Wetherby et al., 2004; Luyster et al., 2007). Yet, recent findings have not shown this pattern in school-aged children with high-functioning ASD (So et al., 2015). In fact, the absence of iconic gestures might be attributed to the fact that the children with ASD were playing with blocks, which were easily referred to by deictic gestures. Deictic gesture was also a dominant type of gesture in the present study [see also So et al. (2015)]. Based on the findings in this study, we expect that the production of iconic gestures during interactions may predict children's ability to imitate iconic gestures. Future study should be conducted to address this issue.

It is also worth noting that imitation relies on different processes in multiple domains. In addition to social and communication skills and the ability to produce gestures during interactions, we found that both visual–motor coordination was significantly associated with the number of conventional-interactive gestures imitated by the children. Imitation requires visual–motor processing, in which visual inputs are translated into motor outputs (Cisek and Kalaska, 2010). Previous research has found concurrent correlations between imitation and different measures of visual–spatial information processing and motor abilities (Smith and Bryson, 1998; Mostofsky et al., 2006; Vanvuchelen et al., 2007; Salowitz et al., 2013). Past research has also reported both concurrent and predictive correlations between imitation and language skills in children with ASD [e.g., Stone and Yoder (2001), Toth et al. (2007), and Ingersoll and Meyer (2011)]. Further studies can be conducted to replicate the directionality of the effect of social and communication skills on gestural imitation, after controlling for the visual–motor coordination and language skills of children with ASD.

To conclude, our results suggest that social and communication skills may play a causal role in imitation abilities in children with autism. However, the findings should be interpreted with caution because of the small sample of children with ASD in this study. Future studies should be conducted to test these preliminary findings in a larger sample of children with ASD. An increase in the number of children with ASD would also help us to investigate the heterogeneity within ASD and the factors that could account for the individual variations in different kinds of impairments [e.g., see reviews in Lenroot and Yeung (2013)]. We observed that there were individual variations in the ability to imitate conventional-interactive gestures in children with ASD. With a large sample size, we can examine the possible factors, such as language skills, social and communication skills, and visual–motor coordination, which may explain these variations.

ETHICAL APPROVAL

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

INFORMED CONSENT

Informed consent was obtained from all individual participants included in the study.

AUTHOR CONTRIBUTIONS

W-CS designed the study, analyzed the data, and wrote the paper. MK-YW analyzed the data. K-YL collected the data.

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