The Role of Theory of Mind in Scalar Implicatures: Evidence from Mandarin-speaking Preschoolers with Autism Spectrum Disorder

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ABSTRACT:

According to the traditional Pragmatic account, Theory of Mind (ToM) abilities are involved in the derivation of scalar inferences. ToM abilities have been found to be impaired in individuals with Autistic Spectrum Disorders (ASD). Despite this, a series of studies have produced the puzzling finding that people with ASD derive scalar inferences as readily as their Typically Developing (TD) peers. Notably, in most of this previous work the ToM abilities of the ASD or TD participants were not directly measured. The current study addressed this by directly measuring the ToM abilities of Mandarin-speaking preschool children with ASD and their typically developing (TD) peers and testing whether there was a relationship between this measure and scalar implicature derivation. In line with previous work, we found no correlation between ToM abilities and scalar implicature derivation for Mandarin-speaking preschoolers with ASD or their TD peers. We propose two ways in which this unexpected pattern of results might be accounted for and discuss their implications for theory and methodology.

Keywords: Theory of Mind; East Asian Languages, Pragmatics, Semantics, Language Delay

1. Introduction

According to the latest edition of Diagnosis and Statistical Manual of Mental Disorders (DSM-5; American Psychological Association 2013), one of the diagnostic criteria of Autism

Spectrum Disorder (ASD) is that an individual displays “persistent deficits in social communication and social interaction”. The extent to which these deficits affect the understanding that people with ASD have of specific linguistic phenomena has been explored by a series of studies. These studies have found impairments in this population’s comprehension of a variety of linguistic phenomena that rely on social/pragmatic processes, including: jokes, figurative language, irony, metaphor, and indirect requests (Emerich et al. 2003; Happé 1993; Martin & McDonald 2004; Norbury 2005; Ozonoff & Miller 1996; Tager-Flusberg 1996, 1999, among many others).

There are several proposals regarding the cause of these social communication impairments. For example, it has been suggested that they might be caused by recorded deficits in the Theory of Mind abilities of people with ASD (ToM; Baron-Cohen et al. 1985; Baron-Cohen 1989, 1991, 1993, 2000; Frith 1994; Happé & Frith 1995; Jolliffe & Baron-Cohen 1999; Tager-Flusberg 1992; Yirmiya et al. 1998, among many others). ToM refers to the cognitive ability to attribute mental states to other people. It involves an understanding of oneself and others as mental beings who have beliefs, desires, emotions and intentions, as well as understanding that behaviors are motivated by these mental states (Flavell & Miller 1998).

Alternatively, it has been proposed that the noted social communication difficulties might be a result of the difficulties people with ASD have integrating and processing information (Happé & Frith 2006), or a result of their noted executive function limitations (Hill 2004). While it is possible that each of these impairments contribute to the noted difficulties with pragmatic and social aspects of language, the role that ToM deficits plays has been investigated

to a greater extent than the others. That is, a series of studies have investigated the relationship between various pragmatic impairments and ToM abilities in the ASD population and have consistently found that such impairments are associated with ToM deficits (Baron-Cohen 1989; Capps et al. 1998; Hale & Tager-Flusberg 2005; Happé 1993; Loveland & Tunali 1993; Martin & McDonald 2004; Tager-Flusberg 1993, 1996, 1999). In other words, there is evidence that the difficulties ASD individuals experience in making inferences about the mental states and communicative intentions of others is at least somewhat responsible for their difficulties in understanding various social/pragmatic linguistic phenomena.

Scalar implicatures are one kind of linguistic meaning that traditionally have been analyzed as being derived through pragmatic processes (see Grice 1975; Horn 2004). Specifically, according to this "Pragmatic" account, scalar implicatures are derived from a provided utterance as a result of a hearer considering alternative utterances the speaker could have used instead, and reasoning about why she did not. We will present this process in more detail later, however, it is clear from even this short description, that such a process clearly involves ToM abilities. Therefore, according to this Pragmatic account, there should be a positive relationship between ToM abilities and the ability to derive scalar implicatures.

2. Research background

2.1. ToM deficits and pragmatic impairments in ASD individuals

The acquisition of ToM abilities is a crucial part of a child's developments and is required to achieve adult-like competence in a variety of domains, including in accurately understanding

certain aspects of linguistic meaning. For a typically developing (TD) child, the development of ToM abilities proceeds through two identifiable stages (de Villers 2007; Wellman & Liu 2004). The first is the acquisition of first-order mental states, which enable a child to make inferences about what someone else believes about the world (Wimmer & Perner 1983). Later, a child acquires second-order mental states, which enable them to make inferences about what someone else believes about the beliefs of others (Perner & Wimmer 1985). TD children first experience success on first-order mental state tasks around the age of 4 to 5 years old (Wellman & Liu 2004; Wellman et al. 2001, 2006). Second-order mental state attribution appears between 5 to 8 years of age and continues developing through adolescence (Apperly 2012; Bosco et al. 2017; Dumontheil et al. 2010; Miller 2009).

While TD children acquire ToM skills as a natural part of their development, this is not the case for children with ASD. That is, limitations in ToM skills have been identified as a core deficit in children with ASD. This is revealed in the fact that children with ASD have been reported to be impaired in ToM development across different IQ ability ranges and age groups (Baron-Cohen et al. 1985, 1997; Happé & Frith 1995; Leslie & Frith 1988; Perner et al. 1989; Steele et al. 2003; Tager-Flusberg 1992, 2001, 2007; White et al. 2009; Yirmiya et al. 1996). In fact, it has been suggested that people with ASD may never achieve the same endpoint as TD people as far as ToM skills are concerned (Hale & Tager-Flusberg 2005).

As already mentioned, parallel to ToM deficits, ASD individuals experience difficulties in understanding and using pragmatic aspects of language, that is, aspects of language that rely on contextual/social processes or knowledge (see Cummings 2013a, 2013b; Pijnacker et al.

2009; Tager-Flusberg 1999 for relevant reviews). To list a few examples, the ASD population has been reported to be impaired in accurately understanding humour (Emerich et al. 2003; Ozonoff & Miller 1996), metaphors (Dennis et al. 2001; Happé 1995; Rundblad & Annaz 2010), irony (Martin & McDonald 2004) and conversational inferences (Dennis et al. 2001; Jolliffe & Baron-Cohen 1999, 2000). Moreover, it has been found that they sometimes do not follow the conventional rules of conversation, like "be informative" (Surian et al. 1996), and do not make use of contextual information when answering questions (Loukusa et al. 2007a, 2007b).

In addition to the combined presence of pragmatic impairments and ToM deficits in people with ASD, empirical studies have consistently reported associations between them in ASD populations (Baixauli-Fortea et al. 2019; Bosco & Gabbatore 2017; Capps et al. 2000; Hale & Tager-Flusberg 2005; Happé 1993; Losh & Capps 2003; Martin & McDonald 2004; Norbury 2005; Tager-Flusberg & Sullivan 1995; White et al. 2009; Winner & Leekman 1991). For instance, Happé (1993) found that ToM skills were a good predictor of metaphor and irony comprehension for ASD participants. To be more specific, the study included three groups of ASD participants, who differed with regard to their ToM abilities. There was a "No-ToM" group (10-28 years old, M=17.6), who failed tasks designed to test for first-order ToM abilities, a "1st-ToM" group (9-25 years old, M=15.8), who passed the first-order ToM tasks, but failed those designed to detect second-order ToM abilities, and finally a "2nd-ToM" group (11-26 years old, M=17.5), who passed both the first and the second-order ToM tasks. Happé (1993) compared the figurative language comprehension of these different groups and found that the No-ToM group had some understanding of similes (e.g. *he was like a tree*), but displayed poor

understanding of metaphors (e.g. *he was a tree*) and of irony (e.g. *well that's very clever, isn't it!* = 'that's not very clever'). Moreover, they found that the 1st-ToM group displayed an understanding of similes and metaphors, but struggled with irony, and that the 2nd-ToM group displayed a good understanding of all three types of figurative language. In sum, Happé (1993) found a clear relationship between ToM ability and figurative language comprehension in individuals with ASD.

In a similar fashion, ToM skills have been reported to be correlated with narrative abilities in children with ASD (M=12.6 years old) (Capps et al. 2000). Moreover, Martin & McDonald (2004) found that ToM reasoning was associated with the ability to interpret ironic jokes in young adults with ASD (18-24 years old, M=19.64). And finally, Hale & Tager-Flusberg (2005) examined ToM abilities and discourse skills in ASD children over a one-year time span, testing at two time points (time 1, 4;00-13;11, M=7.40; time 2, 5;00-14;90, M=8.42), and found associations between ToM skills and performances on discourse comprehension at both time points.

To recap, previous work has demonstrated a clear and consistent positive relationship between ToM abilities and pragmatic competence. We turn now to consider the role that ToM is proposed to have in the derivation of another linguistic phenomenon, that of "scalar implicatures".

2.2. The role of ToM in scalar implicature derivation

In communication, language users often derive inferences that extend beyond the literal content

of what is said. For example, the sentence in (1) literally conveys that "at least one of the apples are red". That is, such a sentence is consistent with a situation in which "all of the apples are red". Despite this, in conversation, language users are likely to interpret a sentence like (1) as inferring (2). Evidence that (2) is an inference, rather than part of the literal meaning of (1) comes from the fact that (2) can be canceled, as in (3), without generating a contradiction. Note that a similar inference is associated with sentences containing the quantifier 'most' (i.e. (4) implies (2)).

(1) *Some* of the apples are red.

(2) *Not all* of the apples are red.

(3) *Some* of the apples are red…in fact, all of the apples are red.

(4) *Most* of the apples are red.

According to the traditional "Pragmatic account", scalar implicatures have been thought to be derived from a combination of general reasoning, certain norms of conversation, and lexical scales (Grice 1975; Horn 2004). The lexical scales are proposed to be made up of multiple lexical items ordered by informational strength (e.g., *some*, *many*, *most*, *all*). Grice (1975) proposes that when people engage in conversation, they (by default) assume that all participants are following the Principle of Cooperation which, among other things, dictates that people should make their contributions as informative as possible (part of the "Maxim of quantity"). As a result, when a speaker utters a sentence like (1), a hearer will usually reason that the speaker must not have been in the position to utter a more informative sentence, in

which, for example, the quantifier "some" was replaced with one of its more informative scale-mates (e.g., "all"). The hearer reasons that, if the speaker could have uttered a more informative sentence like (5), then they would have. If the speaker is assumed to be knowledgeable regarding the relevant content, then the fact that the they did not say a more informative sentence leads the hearer to conclude that the speaker believes such a sentence to be false. That is, the hearer includes the negation of certain more informative alternative sentences in their final interpretation of sentences like (1).

(5) *All* of the apples are red.

Crucially, according to this Pragmatic account, the computation of scalar implicatures clearly requires the hearers to use ToM abilities, i.e., attribute intentions and beliefs to others (Pijnacker et al. 2009). That is, in order to derive a scalar implicature in the manner just outlined, a hearer must be able to attribute mental states to the speaker of an utterance. As a result, this account clearly expects for the derivation of scalar implicatures to be positively correlated with ToM skills.

2.3 Relationship between ToM and scalar implicature derivation in typical and atypical populations

A series of previous studies have explored the relationship between ToM abilities and scalar implicature derivation. These studies have been conducted with participants from both typical and atypical populations.

In the case of the TD population, as far as we know, the only previous study that has

directly examined the relationship between ToM and scalar implicature derivation is Foppolo et al. (2020). Foppolo et al. (2020) included Italian-speaking TD children (3;8-9;2, M = 6;2) and tested the relationship between scalar implicature derivation (measured using a picture selection task) and ToM abilities (measured using tasks adapted from Wellman & Liu (2004)), and found a positive relationship between them.

As for atypical populations, there have a series of studies over the last decade exploring scalar implicature derivation in populations that have been associated with impaired ToM abilities. The expectation was that, given these impairments, such populations would experience difficulties deriving scalar implicatures. As will become clear, the results of these studies have largely not been in line with this expectation. One exception is a study by Wampers et al. (2018), which included adult patients with psychosis (M = 23.4 years old) and found a positive relationship between ToM abilities and scalar implicature generation. In contrast, a series of studies including ASD participants have found that they derive scalar implicatures as readily as typical controls. Pijnacker et al. (2009) compared the rate at which adults with ASD (19-40 years of age, M = 26.8) derive scalar implicatures with their TD controls and found no difference. Similarly, Chevallier et al. (2010) investigated the rate at which adolescents with ASD (11;01-15;11, M = 13;04) derived scalar inferences and found no difference with TD controls. Moreover, Su & Su (2015) investigated two groups of children with ASD (11.7±1.8, 6.6±1.5) and found that they derived scalar implicatures at the same rate as their TD peers. In the same vein, Hochstein et al. (2018) examined scalar implicature derivation in adolescents with ASD (12-18, M = 14.9) and their TD peers, and again found no difference between them.

In fact, a study by Schaeken et al. (2018) reported that ten-year-old children with ASD (7-13, M = 10.18) derived more scalar implicatures than their control group. Finally, most recently, a study by Andrés-Roqueta & Katsos (2020) not only included a group of Spanish-speaking children (4-10) with ASD, but also directly measured ToM abilities to test for a relationship between them and scalar implicature derivation. The study found, not only, that their participants with ASD derived scalar implicatures as readily as controls, but also that there was no correlation between ToM abilities and scalar implicature derivation. In sum, these previous studies present somewhat of a mixed picture. On the one hand, there are a series of studies showing no difference in scalar implicature derivation between TD participants and ASD participants, a population with known ToM deficits (Andrés-Roqueta & Katsos 2020; Chevallier et al. 2010; Hochstein et al. 2018; Pijnacker et al. 2009; Schaeken et al. 2018; Su & Su 2015). On the other hand, when ToM abilities were directly measured, two out of three studies found a positive relationship between the two (Foppolo et al. 2020; Wampers et al. 2018).

Focusing on Andrés-Roqueta & Katsos (2020), which was the only of the atypical population studies just mentioned that directly measured ToM abilities, there are a few properties of this study which lead us to conclude that this area warrants further investigation. First, this study involved a relatively small sample size of children with ASD (N = 20) across a wide range of ages (4-10; M = 7). The study also only included measures of language ability and non-verbal reasoning ability, ToM skills, and pragmatic abilities. That is, it did not take any measurements of several other abilities that could also play an important role in scalar

implicature derivation and so should be controlled for. For example, obtaining some measure of executive function abilities is important because, such abilities have been found to have a positive relationship with both ToM abilities and understanding of pragmatic linguistic phenomena (Carlson et al. 2004; Cummings 2013b). Given these considerations, we believe it is worth conducting further investigations into this area, especially those that include measures of a wider range of relevant factors. Such work has the potential to shed further light on the abilities involved in scalar implicature derivation, as well as provide insights into the nature and unique difficulties faced by the ASD population in acquiring and using language (Su & Su 2015; Terzi et al. 2014).

To summarize, previous work has demonstrated inconsistent findings with respect to the role that ToM plays in the derivation of scalar implicatures. In this study, we aim to advance current understanding of the role of ToM skills in pragmatic knowledge by investigating Mandarin-speaking preschool children with ASD. Specifically, we seek to address the following question: are ToM skills associated with the ability to derive scalar implicatures? We propose to do this by examining whether, when other relevant factors are controlled for, there is a correlation between ToM skills and the derivation of scalar implicatures in children with ASD and their TD peers. In general, this study will add to the growing body of literature on the relationship between pragmatic skills and ToM abilities in both TD and ASD individuals.

3. Method and materials

3.1. Participants

Thirty-five Mandarin-speaking preschool children with ASD were recruited for the present study. All of the ASD participants have been diagnosed by experienced child psychiatrists or child neurologists as meeting the criteria of the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5; American Psychiatric Association 2013) and the Chinese version of the Autism Spectrum Quotient: Children's Version (AQ-Child; Auyeung et al. 2008) for ASD. They had been observed and recorded as demonstrating mild to moderate degrees of persistent deficits in social communication and social interaction as well as showing stereotyped, repetitive and restricted patterns of behavior and interests.

Thirty-three TD preschool children were recruited from a mainstream kindergarten. All of the TD participants had not been reported to have any developmental or psychiatric disorders, learning disabilities, or language impairments.

Both groups of participants were tested for receptive language ability, intelligence, and executive function in a random order. Two children with ASD did not complete the assessments, which left 33 participants with ASD. Table 1 presents descriptive characteristics for each group of participants.

Table 1. Descriptive statistics of participants.

	ASD	TD
Number of Participants	33	33
Age in years	6.01 (0.53)	5.39 (0.58)
Age range in years	4.26-6.66	4.71-6.99
C-PPVT-IQ	106.67 (20.25)	113.73 (11.47)
Verbal Intelligence (VIQ)	108.94 (12.68)	109.09 (7.90)
Non-verbal Intelligence (N-VIQ)	109.82 (14.72)	109.09 (9.47)
Full Intelligence (FIQ)	107.15 (12.26)	109.42 (7.94)
Executive Function	0.69 (0.34)	0.89 (0.28)

Note: Numbers presented are group means, with standard deviation shown in parentheses.

Participants' receptive language ability was assessed with the Chinese Peabody Picture Vocabulary Test (C-PPVT; Sung & Miao 1990).

Verbal Intelligence (VIQ), Non-Verbal Intelligence (N-VIQ) and Full Intelligence (FIQ) of each participant were evaluated using the Chinese version of the Wechsler Preschool and Primary Scale of Intelligence-Fourth Edition (C-WPPSI-IV; Li & Zhu 2014).

Executive Function (EF) was assessed with the Flexible Item Selection Task (FIST;

Jacques & Zelazo 2001).

3.2. Procedures

The assessments were conducted prior to experiments. Participants were tested individually in quiet rooms in the schools. Participants and their caregivers were informed of the contents and purposes of the study before they provided oral consent and written consent to participation, respectively. The procedures were in accordance with the ethical guidelines presented in the Declaration of Helsinki (World Medical Association General Assembly 1964) and its later amendments or comparable ethical standards.

3.3. Tasks

Both tasks were presented to participants via PowerPoint software on a laptop in a random order. In order to keep test trials consistent for all of the participants, utterances used in the tasks were pre-recorded by a female native Mandarin-speaker who had been trained in both linguistics and broadcasting and who produced the sentences at a moderate speed.

3.3.1. The ToM task

The ToM Task was designed to assess participants' ToM skills. For this we used the Sally-Ann task (Wimmer & Perner 1983). In this task, a participant and a toy puppet are presented with six stories. In the stories, objects are initially located in one place and later moved to a different location. The puppet is not watching while the object is being moved and so is not aware of its new location. After the object has been relocated, participants are asked to answer four

questions: (1) Belief question: where would the puppet look for the item? (2) Reality question: where is the item now? (3) Memory question: where was the item located? (4) Control question: what color is the item? Only those who answered more than half of the control questions correctly were included in the final dataset. All of the participants passed this benchmark.

3.3.2. The scalar implicature task

The scalar implicature task was designed to measure the rate at which participants derived scalar implicatures associated with the quantifier "some". We adopted a paradigm which was similar to the Quantifier task used in Katsos et al. (2011). In our task, participants were introduced to a cartoon Chinese girl "Xiaomei", who was learning Mandarin Chinese. Participants were instructed to help Xiaomei by listening to her descriptions of different contexts and when she said something wrong/silly to correct her and to explain why what she had said was wrong.

The test part consisted of one test condition (i.e., *some*-under informative) and four control conditions (i.e., *some*-true & *some*-false, *all*-true & *all*-false). The control condition was designed to test if participants understood the literal meaning of the quantifiers "some" and "all". In each condition, there was ten test/control trials as well as ten filler trials, interspersed with each other. Each trial was comprised of a picture and a sentence description. The filler trials were included to cover the purpose of the task, and to check that whether participants have problems with the experimental design and are paying attention during the experiment. The different conditions were presented in a pseudo-randomized order to avoid two items from the same condition being presented in immediate succession. The objects presented in the

pictures were all things that participants would be familiar with from daily life, for instance, socks, hats, fruits, toys and so forth. Six practice trials were presented prior to the commencement of the experiment in order to familiarize participants with the task. Three of them included sentences that were correct descriptions of the presented pictures and the other three included sentences that were incorrect descriptions of the presented pictures. When participants judged that a sentence was bad/silly, they were asked to provide a justification. Corrective feedback was provided to participants during these practice trials when their judgement was incorrect. In the following, we list an example sentence from each of the test conditions (i.e., (6)-(10)), the filler items (i.e., (11)), and the practice items (i.e., (12)).

(6) Yixie xingxing zai gezi li.
some stars be boxes inside
'Some stars are in the boxes.'

(7) Yixie caomei zai gezi li.
some strawberries be boxes inside
'Some strawberries are in the boxes.'

(8) Yixie xiaohua zai gezi li.
some flowers be boxes inside
'Some flowers are in the boxes.'

(9) suoyou qiqiu zai gezi li.
all balloons be boxes inside
'All balloons are in the boxes.'

(10) suoyou pingguo zai gezi li.
all apples be boxes inside
'All apples are in the boxes.'

(11) Xingxing shi hongse de.
stars are red DE
'The stars are red.'

(12) Gezi-li you putao.

Boxes-inside have grapes

‘There are grapes in the boxes.’

The *some*-true condition presented participants with sentences like that in (6) with the picture in Figure 1-1. The *some*-false condition presented sentences like (7) and the picture Figure 1-2. The *some*-under informative condition included sentences like (8) paired with pictures like Figure 1-3. Items in the *all*-true and *all*-false conditions paired sentences like those in (9) and (10) with the pictures in Figure 1-4 and 1-5, respectively. Our filler sentences like (11) were paired with pictures like Figure 1-1. Finally, in our practice items, we presented sentences like (12) with pictures like Figure 1-6.

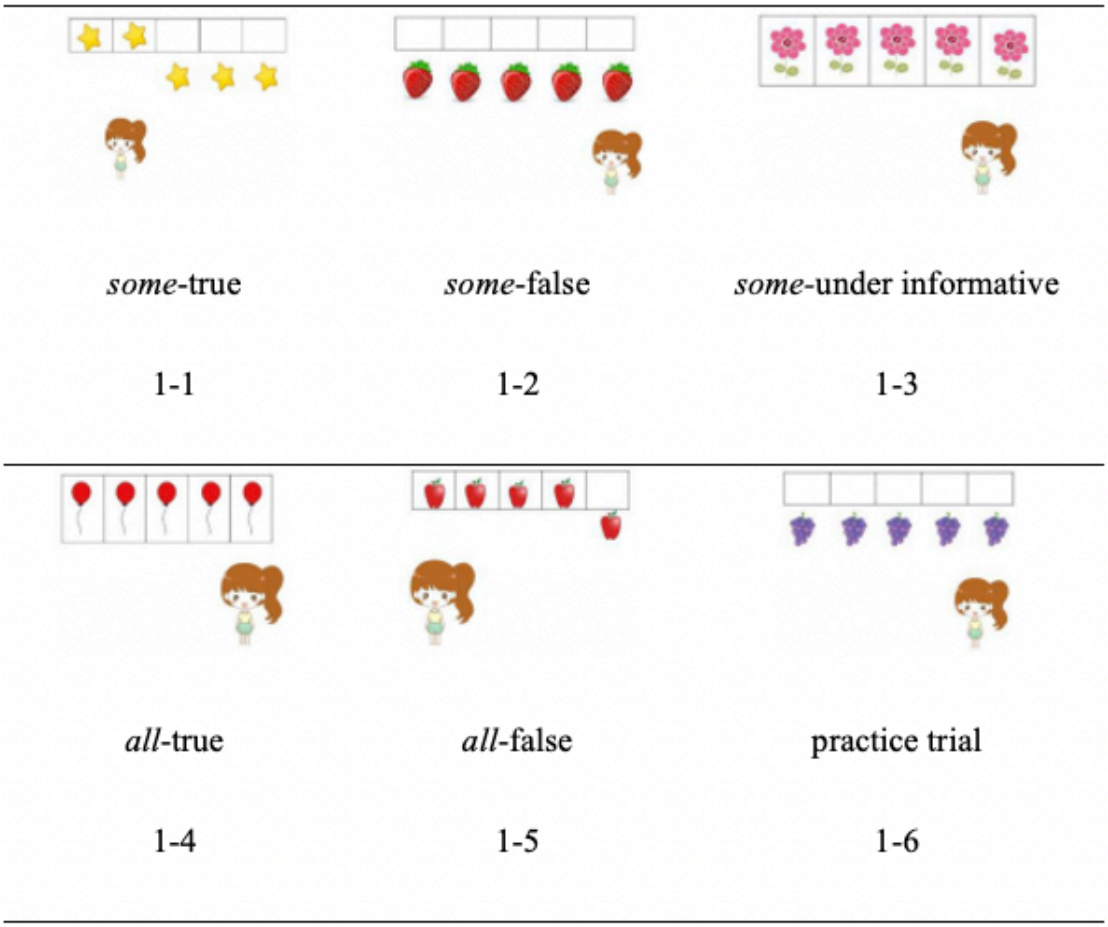

Figure 1. Examples of Scalar Implicatures Task conditions

If a participant had acquired an understanding of the basic meaning of "some" and "all", they were expected to judge the sentences presented in the *some*-true and *all*-true items as "good" and to judge the sentences in the *some*-false and *all*-false items as "bad". If a participant was deriving scalar implicatures, they were expected to judge sentences presented in the *some*-under informative items as "bad". In contrast, if they were not deriving scalar implicatures, they were expected to judge such sentences as "good".

4. Results

4.1. Overall performance

A series of independent sample *t* tests were used to identify any differences between the ASD and TD groups with regard to their performance on the ToM or the scalar implicature tasks. We did not conduct any statistical analyses on the results associated with the filler condition in the scalar implicature task as the participants in both groups provided correct responses at a rate of over 90%. We take this as indicating that participants understood and were not overly-challenged by the tasks. Table 2 presents proportions of different answers chosen by participants across the two tasks.

Table 2. Proportion of correct responses to answers in the tasks.

Tasks	Answer types	ASD (n=33)	TD (n=33)
ToM	ToM-Correct	0.41 (0.40)	0.90 (0.22)
Scalar Implicatures	*Some*-true	0.61 (0.45)	0.66 (0.42)
	Some-false	0.95 (0.18)	0.97 (0.17)
	Some-under informative	0.30 (0.35)	0.34 (0.31)
	All-true	1.00 (0.00)	1.00 (0.00)
	All-false	1.00 (0.00)	1.00 (0.00)

Note: Numbers presented in the table are means of each group, with standard deviation in parentheses.

With regard to the ToM task, an independent sample T test found a significant difference between the two groups (t(64) = -6.20, p<0.001, d = -1.52, 95% CI = -0.65, -0.33), with the TD group performing better than the ASD group. This result is consistent with previous studies which investigated ToM skills in ASD children (Baron-Cohen 2000; Baron-Cohen et al. 1985; Wellman et al. 2006).

As for the scalar implicature task, an independent sample *t* test found no difference between the ASD and TD groups with regard to their responses in the *some*-true condition (t(64) = -0.45, p = 0.65, d = -0.11, 95% CI = -0.26, 0.16), the *some*-false condition (t(64) = -0.55, p = 0.58, d = -0.11, 95% CI = -0.11, 0.06), or the *some*-under informative condition (t(64) = -0.48, p = 0.63, d = -0.12, 95% CI = -0.20, 0.13).

4.2. Correlational analyses

Further analysis was conducted to determine whether, in either participant group, there was a relationship between ToM abilities and scalar implicature derivation. We carried out Pearson bivariate correlational analyses, with variables, i.e., age, receptive language ability, VIQ, N-VIQ and EF, being controlled for. No correlation was found between performance on the ToM task and the scalar implicature task by either group of participants (ASD, r = - 0.261, p = 0.18; TD, r = - 0.006, p = 0.975).

5. Discussion

The present study investigated the relationship between ToM skills and scalar implicature

derivation. We did this by measuring and testing for a relationship between ToM skills and scalar implicature derivation in Mandarin-speaking preschool children with ASD and their TD peers. Additionally, we measured and controlled for the variables of age, receptive language ability, verbal intelligence, non-verbal intelligence, and executive function. We found no correlation between ToM skills and scalar implicature derivation in Mandarin-speaking preschoolers with ASD or their TD peers. Our finding is consistent with previous studies that also found no difference between the rates at which ASD and TD participants derived scalar implicatures (Chevallier et al. 2010; Hochstein et al. 2018; Pijnacker et al. 2009; Schaeken et al. 2018; Su & Su 2015). Moreover, the result is consistent with Andrés-Roqueta & Katsos (2020), which also found no relationship between ToM skills and scalar implicature derivation in children with ASD. Considering both the present results and those from previous studies, a clear pattern is emerging. That is, people with ASD, a disorder associated with ToM deficits, derive scalar implicatures as readily as their controls (Andrés-Roqueta & Katsos 2020; Chevallier et al. 2010; Hochstein et al. 2018; Pijnacker et al. 2009; Schaeken et al. 2018; Su & Su 2015). And moreover, when ToM abilities are measured more directly, they often do not correlate with scalar implicature derivation (Andrés-Roqueta & Katsos 2020). It is possible that the ToM measures employed in this and previous studies were not sensitive enough or were measuring the wrong aspect of ToM. However, if this pattern of results is taken at face value, it is difficult to account for on a traditional, Pragmatic account of scalar implicature derivation. That is, as we outlined in Section 2.2, according to the Pragmatic account (i.e., Grice 1975), scalar implicature derivation involves a hearer considering alternative utterances and drawing inferences about a speaker's attitude or mental state towards those utterances, a

process that clearly involves ToM abilities. Therefore, according to the Pragmatic account, a positive relationship between ToM abilities and scalar implicature derivation is clearly predicted. A prediction that, as just outlined, is not borne out in the noted experimental literature. We will explore two possible responses to this friction between the traditional account and empirical landscape. The first is to suggest that, rather than scalar implicature derivation, both our and many previous tasks have actually been measuring participants' "sensitivity to underinformativity". A second possible response is to abandon the traditional Pragmatic account to scalar implicature derivation in favor of an alternative analysis that posits less of a role for ToM abilities in scalar implicature derivation. We will consider each of these possibilities in turn.

5.1. Sensitivity to underinformativity vs. genuine scalar implicature derivation

As far as we know, Katsos & Bishop (2011) was the first to note that much and perhaps all of the previous experimental work investigating scalar implicature derivation had confounded competence with informativeness and genuine scalar implicature derivation. That is, according to the Pragmatic account, the derivation of a scalar implicature involves: 1) identifying that the speaker could have used a more informative sentence, and 2) concluding that the speaker must not have uttered this more informative sentence because she believes it to be false. However, as Katsos & Bishop (2011) pointed out, the tasks employed in the previous experimental literature are such that participants could provide the response associated with scalar implicature derivation while only having completed the first of these steps (i.e., only having identified the underinformativity of the target sentence). For example, a participant could reject

a sentence like (13) as a good description of a context where *all the stars are in boxes* because they noted that there was a better way to describe the context, namely (14), and not because they have interpreted (13) as actually conveying the scalar implicature in (15).

(13) Some stars are in boxes.

(14) All the stars are in boxes.

(15) Not all the stars are in boxes.

To put it another way, a rejection of (13) on the basis of underinformativity would be similar to rejecting a sentence because it refers to "a dog" as "an animal" or to "a chair" as "a piece of furniture".

After identifying this confound in the previous literature, Katsos & Bishop (2011) go on to present a series of experiments which they posit will shed light on this issue. However, despite producing some interesting findings, Katsos and Bishop (2011) conclude that even their experiments cannot tease apart responses based on sensitivity to underinformativity versus genuine scalar implicature derivation.[1] Due to the difficulties and perhaps impossibility of truly teasing apart responses based on these two motivations, the work following Katsos & Bisop (2011) (e.g., Chevallier et al. 2010; Hochstein et al. 2018; Katsos et al. 2011; Pijnacker et al. 2009; Wampers et al. 2018) has largely ignored this issue and has returned to the implicit

[1] The main finding produced by the series of experiments presented in Katsos & Bishop (2011) was that when participants judge sentences like (13) in scalar implicature violating contexts using a "ternary-judgment" measure (i.e., a measure that includes a "middle" response option between "good" and "bad") adults and children behave similarly.

assumption (at-least in data interpretation) that tasks including sentence judgment or picture selection measures are targeting scalar implicature derivation. However, the issue raised by Katsos & Bishop (2011) remains; namely, it is not clear whether these tasks are actually measuring scalar implicature derivation or "merely" sensitivity to informativeness.

Given these considerations, one way the Pragmatic account could respond to the challenge raised by our results and those of previous research is by pointing to to this confound. And in fact, a proposal somewhat along these lines seems to be explored in Andrés-Roqueta & Katsos (2017). Specifically, Andrés-Roqueta & Katsos (2017) attempt to account for the high rate of scalar implicature derivation by individuals with ASD by suggesting that the set of skills and processes traditionally associated with "pragmatics" should be re-categorized into two categories, called "linguistic-pragmatics" and "social-pragmatics". Linguistic-pragmatics, they propose, encompasses vocabulary knowledge, grammar, and knowledge of pragmatic norms (e.g., be informative). In contrast, social-pragmatics encompasses the ability to infer other people's mental states (i.e., ToM abilities). Andrés-Roqueta & Katsos (2017) claim that ASD individuals are impaired in social pragmatics but not in linguistic-pragmatics. Moreover, they claim that tasks which are designed to test a participant's understanding of pragmatic meaning often differ with regard to whether they actually require social-pragmatic abilities to achieve the "target" response. For example, they suggest that many tasks designed to test scalar implicature derivation only require linguistic-pragmatic abilities to achieve the response associated with scalar implicature derivation. Given that, according to a Pragmatic account, the derivation of genuiune scalar implicatures unavoidably requires "social-pragmatic" abilities,

Andrés-Roqueta & Katsos (2017) appear to be presenting a more refined version of the idea presented Katsos & Bishop (2011). That is, that tasks designed to measure a participant's ability to derive scalar implicatures might rather be measuring their sensitivity to a target utterance's informativity relative to alternative utterances (i.e., measuring their "linguistic-pragmatic" abilities rather than their "social-pragmatic" abilities).

The advantage of interpreting our results and the results of previous experiments along these lines is that it allows us to retain the traditional Pragmatic account of scalar implicature derivation. That is, the lack of a relationship between ToM abilities and scalar implicature derivation can be explained as being a result of the relevant tasks not actually providing an accurate measurement of scalar implicature derivation. As a result, the lack of a relationship between ToM and the rate of "scalar implicature" derivation found by these tasks no longer raises a challenge to this account.

This kind of explanation makes the prediction that, if a task could be identified or created that does accurately measure scalar implicature derivation, then the predicted positive relationship between ToM abilities and scalar implicature derivation will be discovered after all. However, as originally noted by Katsos & Bishop (2011), it is very difficult and perhaps even impossible to create a task that can cleanly tease apart responses based on sensitivity to informativeness versus those based on genuine scalar implicature derivations. Having said that, we would like to propose a few ideas for how some progress in this direction could be made. Firstly, it seems plausible that, while it might not be possible to create a task that only measures genuine scalar implicatures, it could be that tasks vary with regard to the ratio of these response

types that they elicit. That is, an underinformative sentence is still technically true, whereas, if a scalar implicature is included in the final interpretation of a sentence, it should genuinely affect the conditions under which that sentence is judged as "true" or "false". As a result, it seems possible that for tasks where participants need to judge the "truth-value" of an utterance, the "scalar implicature" type of response is more likely to be a result of a participant having derived a genuine scalar implicature, rather than from noting an utterance's underinformativity. Of course, it is always possible for a scalar implicature to be cancelled after it has been generated and so for the final sentence meaning to lack a scalar implicature after all. Therefore, such a task would only be predicted to be able to detect the cases where the scalar implicature is actually retained in the final meaning. That is, it could be thought of as a lower-bound of scalar implicature derivation for the targeted population. The flip side of this is that tasks where participants are asked to judge the "felicity" or "naturalness" of an utterance, as well as picture selection tasks, are likely to elicit "scalar implicature" responses that are motivated by a combination of genuine scalar implicature derivations and of objections to underinformativity. In other words, it seems plausible that tasks which focus on the truth-value of an utterance provide at least an accurate lower-bound estimate of scalar implicature derivation. In contrast, those that focus on the felicity of an utterance seem to inextricably combine responses based on scalar implicature derivation and objections to underinformativity. Notably, the current experiment as well as the previous work investigating the relationship between ToM abilities and scalar implicature derivation all included tasks of this latter type (i.e., judgments of sentence felicity/picture selection tasks). Therefore, one straightforward way to explore this possibility further would be to investigate the relationship between ToM abilities and scalar

implicature derivation using a task that focuses on the truth-value of the target utterances. The expectation would be that the expected but missing relationship between ToM abilities and scalar implicature would finally be found by such a task. We leave such an investigation to future research.

5.2. Alternative analysis of scalar implicature derivation

In addition to the Pragmatic account, according to which scalar implicature derivation clearly involves ToM abilities, several other accounts have been proposed, which importantly, derive scalar implicaturea through different processes. Two such accounts are the "Lexical" (Levinson 2000) and "Grammatical" (Chierchia 2004, 2006) accounts. These accounts both propose that scalar implicatures can be derived through processes that do not involve ToM abilities. Specifically, the Lexical account proposes that sentences which include quantifiers like some (e.g. (16)) include by default scalar implicatures like (17). In certain cases this implicature will then be canceled so that it is not included in the final meaning. However, importantly, the initial derivation of the implicature is automatic for such sentences and so no ToM abilities are involved. In fact, this account predicts that ToM abilities are more likely to be important in order to determine whether a given scalar implicature should be cancelled or not. That is, it could be taken to predict a negative relationship between ToM abilities and scalar implicature derivation.[2]

[2] Interestingly, the result found by Schaeken et al. (2018) could be interpreted as in line with this prediction. That is, they found that 10-year-old children with ASD derived significantly more scalar implicatures than their TD peers.

(16) Some stars are in boxes.

(17) Not all the stars are in boxes.

Another "non-pragmatic" analysis to scalar implicature derivation is proposed by the "Grammatical account". This account suggests that scalar implicatures are derived as a result of a silent grammatical operator. This operator has been described as a silent "only" and means that a sentence like (16) is often interpreted as though it was the sentence in (18). That is, its interpretation includes as part of its literal meaning the implicature in (17). According to this account the interpretation without an implicature can be accessed by through a sentence structure that does not include this operator.[3] That is, a sentence like (16) can be thought of as being ambiguous between a form that includes a silent only operator and one that does not. For a given utterance, determining whether the intended form is one that includes this operator or not is a process that does not necessarily require any or at-least not extensive ToM abilities.[4]

(18) Only some stars are in boxes.

In this way, according to the Grammatical account, scalar implicatures can be derived without the need for ToM abilities.

In sum, another way of accounting for the robust pattern of results showing no relationship between ToM abilities and scalar implicature derivation is to adopt an alternative analysis of

[3] The grammatical account also suggests that an interpretation without the relevant scalar implicature might be derived by "pruning" the associated alternatives based on contextual considerations.

[4] This is not to say that ToM abilities would never play a part in resolving this ambiguity. It is merely that, for a given instance, and crucially, for the instances that comprised our task and the tasks used by relevant previous studies, ToM abilities may not have been necessary to resolve this ambiguity.

how scalar implicatures are derived in the first place. Two such analyses are presented by the the Lexical (Levinson 2000) and Grammatical (Chierchia 2004, 2006) accounts.

5.3. Limitations

The current study provides important insights into both the nature of scalar implicatures, as well as the understanding that people with ASD have of them. However, there are a number of limitations which we should note and which should be considered when conducting any future investigations in this area. The first relates to the ToM tasks and executive function assessments we adopted. Specifically, our ToM task measured only a subset of ToM abilities, namely, so-called "cognitive ToM abilities", which relate to understanding other people's beliefs and intentions. That is, there are also "affective ToM abilities", which relate to understanding other people's emotions and feelings, and which we did not measure in this study. While the derivation of scalar implicatures would be predicted to rely more on cognitive than affective ToM abilities, it could be worth also measuring affective ToM abilities, especially given the lack of a correlation in our results between ToM abilities and scalar implicature derivation. Another limitation is with the choice of diagnostic standards. Due to limited medical resources, the present study did not adopt the gold standard, *Autism Diagnostic Interview-Revised* (ADI-R; Rutter et al. 2003) and *Autism Diagnostic Observation Schedule* (ADOS; Lord et al. 2012) for ASD symptomology diagnosis and confirmation. Those diagnosis tools are recommended for future research involving individuals with ASD, as this would provide more detailed and precise information regarding the ASD symptomology of participants.

6. Conclusion

The current study investigated the relationship between ToM skills and scalar implicature derivation in Mandarin-speaking preschoolers with ASD. Consistent with previous work (particularly Andrés-Roqueta & Katsos, 2020), ToM skills were found not to correlate with scalar implicature derivation in Mandarin-speaking preschool children with ASD. Given the clear role for ToM abilities in a traditional, Pragmatic analysis of scalar implicature derivation (Grice 1975), we propose two possible explanations for this (and similar results). One is that, as proposed by Katsos and Bishop (2011), the tasks used in our and much previous work (e.g., tasks focusing on sentence felicity) may not actually be measuring genuine scalar implicature derivation, but rather sensitivity to informativeness. The second is that the traditional Pragmatic account of scalar implicature derivation may be on the wrong track and an alternative account (e.g. We leave further investigation of these and any other possible explanations to future research.

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Declaration of interest

The authors declare no conflicts of interest.

Data Availability

Data can be accessed at:
https://osf.io/qea7n/?view_only=d94f5105ad4a46b4936747c19843332a

Compliance with ethical statements

This study has been reviewed and approved by Faculty of English Language and Culture, Guangdong University of Foreign Studies, China.

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Appendix: Experimental stimuli

The ToM task experimental stimuli (Six stories)

Story 1

1. 姐姐会去哪里找胡萝卜？	‘Where would the girl look for the carrots?’
2. 胡萝卜现在在哪里？	‘Where are the carrots now?’
3. 姐姐把胡萝卜放哪里了？	‘Where did the girl leave the carrots?’
4. 胡萝卜是什么颜色的？	‘What color is the carrots?’

Story 2

1. 哥哥会去哪里找小汽车？	‘Where would the boy look for the car?’
2. 小汽车现在在哪里？	‘Where is the car now?’
3. 哥哥把小汽车放哪里了？	‘Where did the boy leave the car?’
4. 小汽车是什么颜色的？	‘What color is the car?’

Story 3

1. 弟弟会到哪里找足球？	‘Where would the little brother look for the football?’
2. 足球现在在哪里？	‘Where is the football now?’
3. 弟弟把足球放哪里了？	‘Where did the little brother leave the football?’
4. 足球是什么颜色的？	‘What color is the football?’

Story 4

1. 小猪会去哪里找草莓？	‘Where would the piggy look for the strawberry?’
2. 草莓现在在哪里？	‘Where is the strawberry now?’
3. 小猪把草莓放哪里了？	‘Where did the piggy leave the strawberry?’
4. 草莓是什么颜色的？	‘What color is the strawberry?’

Story 5

1. 女孩会去哪里找布娃娃？	‘Where would the girl look for the doll?’
2. 布娃娃现在在哪里？	‘Where is the doll now?’
3. 女孩把布娃娃放哪里了？	‘Where did the girl leave the doll?’
4. 布娃娃是什么颜色的？	‘What color is the doll?’

Story 6

1. 小熊会去哪里找西瓜？	‘Where would the bear look for the watermelon?’
2. 西瓜现在在哪里？	‘Where is the watermelon now?’
3. 小熊把西瓜放哪里了？	‘Where did the bear leave the watermelon?’
4. 西瓜是什么颜色的？	‘What color is the watermelon?’

The scalar implicature task experimental stimuli

Practice trials (six items)

(1) liangge xingxing zai gezi li.	‘Two stars are in the boxes.’
(2) wuge caomei zai gezi li.	‘Five strawberries are in the boxes.’
(3) sanduo xiaohua zai gezi li.	‘Three flowers are in the boxes.’
(4) gezi-li you putao.	‘There are grapes in the boxes.’
(5) yige pingguo zai gezi li.	‘One apple is in the boxes.’
(6) qiqiu shi hongse de.	‘The balloons are red.’

Some-under informative test condition experimental stimuli

(1) Yixie caomei zai gezi li.	‘Some strawberries are in the boxes.’
(2) Wazi shi lanse de.	‘The socks are blue.’
(3) Yixie dangao zai gezi li.	‘Some cakes are in the boxes.’
(4) Tuzi baozhe xiangjiao.	‘The rabbit is holding a banana.’
(5) Yixie xingxing zai gezi li.	‘Some stars are in the boxes.’
(6) Nanhai zai shuijiao.	‘The boy is sleeping.’
(7) Yixie qiqiu zai gezi li.	‘Some balloons are in the boxes.’
(8) Maozi shi heise de.	‘The hat is black.’
(9) Yixie xiaoyu zai gezi li.	‘Some fish are in the boxes.’
(10) Nǚhai zai tiaowu.	‘The girl is dancing.’
(11) Yixie houzi zai gezi li.	‘Some monkeys are in the boxes.’
(12) Xiaoxiong zai zhaihua.	‘The bear is picking flowers.’

(13) Yixie boluo zai gezi li.	‘Some pineapples are in the boxes.’
(14) Yingtao shi lǜse de.	‘The cherries are green.’
(15) Yixie wawa zai gezi li.	‘Some dolls are in the boxes.’
(16) Milaoshu zai chifan.	‘Mickey Mouse is having meals.’
(17) Yixie xigua zai gezi li.	‘Some watermelons are in the boxes.’
(18) Zixingche shi hongse de.	‘The bicycle is red.’
(19) Yixie xiaohua zai gezi li.	‘Some flowers are in the boxes.’
(20) Qizi shi huangse de.	‘The flags are yellow.’

Some-true test condition experimental stimuli

(21) Yixie wazi zai gezi li.	‘Some socks are in the boxes.’
(22) Sange xiangjiao zai gezi li.	‘Three bananas are in the boxes.’
(23) Yixie xingxing zai gezi li.	‘Some stars are in the boxes.’
(24) Xingxing shi hongse de.	‘The stars are red.’
(25) Yixie qiqiu zai gezi li.	‘Some balloons are in the boxes.’
(26) Nanhai zai tiqiu.	‘The boy is playing football.’
(27) Yixie weijin zai gezi li.	‘Some scarves are in the boxes.’
(28) Nvhai zai dushu.	‘The girl is reading a book.’
(29) Yixie pingzi zai gezi li.	‘Some bottles are in the boxes.’
(30) Xiongmao zai tiaowu.	‘The panda is dancing.’
(31) Yixie laohu zai gezi li.	‘Some tigers are in the boxes.’
(32) Nǚhai zai huahua.	‘The girl is drawing pictures.”
(33) Yixie tuzi zai gezi li.	‘Some rabbits are in the boxes.’
(34) Pingguo shi lǜse de.	‘The apple is green.’
(35) Yixie xiezi zai gezi li.	‘Some shoes are in the boxes.’
(36) Tanglaoya zai qiche.	‘Donald Duck is riding a bicycle.’

(37) Yixie taozi zai gezi li. ‘Some peaches are in the boxes.’

(38) Beizi shi hongse de. ‘The cup is red.’

(39) Yixie dangao zai gezi li. ‘Some cakes are in the boxes.’

(40) Shubao shi huangse de. ‘The schoolbag is yellow.’

Some-false test condition experimental stimuli

(41) Yixie maozi zai gezi li. ‘Some hats are in the boxes.’

(42) Sange boluo zai gezi li. ‘Three pineapples are in the boxes.’

(43) Yixie xiaoyu zai gezi li. ‘Some fish are in the boxes.’

(44) Xingxing shi huangse de. ‘The stars are yellow.’

(45) Yixie caomei zai gezi li. ‘Some strawberries are in the boxes.’

(46) Nanhai zai chifan. ‘The boy is having meals.’

(47) Yixie kuzi zai gezi li. ‘Some trousers are in the boxes.’

(48) Nǚhai zai xiwan. ‘The girl is washing dishes.’

(49) Yixie jidan zai gezi li. ‘Some eggs are in the boxes.’

(50) Xiaozhu zai shuijiao. ‘The piggy is sleeping.’

(51) Yixie daxiang zai gezi li. ‘Some elephants are in the boxes.’

(52) Nǚhai zai qima. ‘The girl is riding a horse.’

(53) Yixie wawa zai gezi li. ‘Some dolls are in the boxes.’

(54) Daizi shi zise de. ‘The bag is purple.’

(55) Yixie xiaoshu zai gezi li. ‘Some trees are in the boxes.’

(56) Tanglaoya zai zuofan. ‘Donald Duck is cooking.’

(57) Yixie dianhua zai gezi li. ‘Some phones are in the boxes.’

(58) Zhuozi shi lǜse de. ‘The table is green.’

(59) Yixie shousi zai gezi li. ‘Some sushi is in the boxes.’

(60) Diannao shi heise de. ‘The computer is black.’

All-true test condition experimental stimuli

(61) Suoyou qiqiu zai gezi li.	‘All balloons are in the boxes.’
(62) Yizi shi fense de.	‘The chair is pink.’
(63) Suoyou maozi zai gezi li.	‘All hats are in the boxes.’
(64) Tuzi baozhe boluo.	‘The rabbit is holding a pineapple.’
(65) Suoyou xingxing zai gezi li.	‘All stars are in the boxes.’
(66) Nanhai zai xiyifu.	‘The boy is washing clothes.’
(67) Suoyou qingwa zai gezi li.	‘All frogs are in the boxes.’
(68) Weijin shi baise de.	‘The scarf is white.’
(69) Suoyou qianbi zai gezi li.	‘All pencils are in the boxes.’
(70) Nǚhai zai jiaohua.	‘The girl is watering flowers.’
(71) Suoyou xiaoniao zai gezi li.	‘All birds are in the boxes.’
(72) Xiaozhu zai qima.	‘The piggy is riding a horse.’
(73) Suoyou hudie zai gezi li.	‘All butterflies are in the boxes.’
(74) Yusan shi hongse de.	‘The umbrella is red.’
(75) Suoyou yingtao zai gezi li.	‘All cherries are in the boxes.’
(76) Xiaomao zai shuijiao.	‘The cat is sleeping.’
(77) Suoyou bingqiling zai gezi li.	‘All ice creams are in the boxes.’
(78) Xigua shi lanse de.	‘The watermelon is red.’
(79) Suoyou xiaomao zai gezi li.	‘All cats are in the boxes.’
(80) Gongzhu daizhe maozi.	‘The princess is wearing a hat.’

All-false test condition experimental stimuli

(81) Suoyou yanjing zai gezi li.	‘All glasses are in the boxes.’
(82) Nanhai zai dushu.	‘The boy is reading a book.’
(83) Suoyou daxiang zai gezi li.	‘All elephants are in the boxes.’
(84) Xiaogou baozhe gutou.	‘The dog is holdings a bone.’

(85) Suoyou xiaoji zai gezi li.	‘All chickens are in the boxes.’
(86) Nanhai zai qiche.	‘The boy is riding a bicycle.’
(87) Suoyou yazi zai gezi li.	‘All ducks are in the boxes.’
(88) Yifu shi lanse de.	‘The clothes are blue.’
(89) Suoyou xiangpi zai gezi li.	‘All erasers are in the boxes.’
(90) Nǚhai zai xiezi.	‘The girl is writing.’
(91) Suoyou shubao zai gezi li.	‘All schoolbags are in the boxes.’
(92) Xiaozhu zai youyong.	‘The piggy is swimming.’
(93) Suoyou shafa zai gezi li.	‘All sofas are in the boxes.’
(94) Damen shi heise de.	‘The door is black.’
(95) Suoyou xiaochuan zai gezi li.	‘All boats are in the boxes.’
(96) Xiaoma zai shuijiao.	‘The horse is sleeping.’
(97) Suoyou pingguo zai gezi li.	‘All apples are in the boxes.’
(98) Xuehua shi baise de.	‘The snowflake is white.’
(99) Suoyou zhaopian zai gezi li.	‘All photos are in the boxes.’
(100) Nǚhai nazhe qiqiu.	‘The girl is holding balloons.’