




# Discourse prominence effects on interpretation of reflexive pronoun “ziji” in children with ASD

Gaowa Wuyun<sup>1</sup> · Long Zhang<sup>2,3</sup> · Kai Wang<sup>2,3</sup> · Yanhong Wu<sup>4,5</sup> 

Accepted: 20 November 2021 / Published online: 24 January 2022  
© The Author(s) 2021

## Abstract

The core of language disorders in children with autism spectrum disorder (ASD) is the loss of social function in language communication. Further, the correct use and processing of personal pronouns is the basis of language social function. Therefore, clarifying the mechanism of processing the pronoun reference in children with ASD is a major focus in autism research. Currently, the main contradictory focus of the anaphora processing ability in children with ASD is use of semantic pragmatic information in the process of pronoun processing. Therefore, this study will focus on the effect of semantic cues on pronoun processing in children with autism spectrum disorder. This study uses the Chinese reflexive pronoun “ziji” (eg., himself/herself) as the media, because the Chinese reflexive pronoun “ziji (oneself)” is relatively flexible, which is not only restricted by the rule of syntactic rules, but also influenced by the semantic information of the antecedent. This study investigated the processing mechanism of Chinese reflexive pronoun “ziji (oneself)” in children with autism spectrum disorder by manipulating the position of strong semantic cues. The results showed that participants from both the experimental group (children with ASD) and the two control groups (children with typical development and children with intellectual disabilities) were able to process strong semantic cues. When the second person pronoun “you” or the participant’s name appears in the remote subject position, children from both the experimental group and the two control groups could use semantic information to make long distance anaphora of the reflexive pronoun “ziji (oneself)”. Conversely, when the second person pronoun “you” appeared in the close subject position, the children with autism spectrum disorder and the two control groups would both make close anaphora with the reflexive pronoun “ziji (oneself)”. This study found that children with autism spectrum disorder can process semantic information normally during pronoun anaphora when the semantic cues are sufficiently prominence. The results of this study provide a more comprehensive understanding of the language processing mechanism of individuals with autism spectrum disorder.

**Keywords** ASD · Reflexive pronouns · Prominence · Long-distance anaphora · Eye movement

## Introduction

Language facilitates communication between individuals and the outside community. Children with typical developmental patterns gradually begin to communicate with the outside community through language to meet their own development needs between 9 and 20 months after birth. Children with autism spectrum disorder (ASD), however, are less likely to interact with others in the same manner as typically developing (TD) children (Cummings, 2014; Gernsbacher & Pripas-Kapit, 2012; Whyte, Nelson, & Khan, 2013). The core manifestation of their language barrier is the loss of social functions in language communication (Finnegan, Asaro-Saddler, & Zajic, 2020; Tager-Flusberg, 2004). In the process of using language, the first step in social interaction is to distinguish the relationship between the people in a discourse. The proper use and processing of pronoun reference is the basis for this social function of language (Zimmerman, Wolf, Bock, Peham, & Benecke 2013). Therefore, clarifying the mechanism by which children with ASD process pronoun reference, hence scientifically guiding them to improve their language communication skills and integrate into society, is a major focus in autism research.

Reference is a common language phenomenon in the process of daily language communication. It plays a very important role in simplifying expression, connecting context, and the coherence of meaning. In the process of daily communication, listeners must quickly and accurately identify the referent of the pronoun in the current context to ensure smooth communication (Zimmerman, Wolf, Bock, Peham, & Benecke 2013). In most cases, listeners use a variety of information (such as syntax restrictions and semantic information) to assign a unique referent to a pronoun, that is, to determine its antecedent. However, the pronoun reference can cause ambiguity in understanding when there are multiple possible referents in the context. At that time, the listener must use prominent clues to determine the relationship between pronouns and antecedents to determine the correct (or intended) referent (Swaab et al., 2004). In the processing of pronoun reference, the prominence of clue information is mainly affected by syntax and semantics. Of these, syntactic prominence can be reflected by the superficial syntactic structure in which the clue information is located. For example, an antecedent in the subject position or an antecedent mentioned for the first time has a higher syntactic prominence (Foraker & McElree, 2007; Gordon et al., 1993). However, semantic prominence must be reflected through the establishment of deep semantic associations, which refer to different individuals activating related antecedents in the cognitive process and establishing psychological connections with them (Speas, 1990). This kind of deep semantic association is particularly important for the resolution of reference ambiguity. If an antecedent can establish a close psychological connection with the listener, it can help the listener quickly activate the relevant concept, which can then be used to determine the reference object.

## The comprehension of pronouns and reflexives in children with autism

From a developmental perspective, children with typical developmental patterns can complete pronoun reference processing and use syntactic and semantic clues at approximately four years of age (Lukyanenko, Cynthia, Conroy, Anastasia, Lidz, & Jeffrey, 2014; Pyykkönen-Klauck, Matthews, & Järvikivi, 2010). Regarding language research on autism, existing studies have not yet reached a consensus on the ability of reference processing in children with autism spectrum disorders. Studies have found that children with autism spectrum disorders have obvious difficulties in reference processing, and they cannot correctly use semantic clues to determine the referent of pronouns (Edelson, 2011; Terzi, Marinis, & Francis, 2014, 2016). Nevertheless, some studies have pointed out that children with autism spectrum disorders have normal pronoun processing ability because they can correctly use syntactic clues to complete pronoun anaphora processing (Janke & Perovic, 2015; Perovic et al., 2013a, 2013b). This shows that children with autism spectrum disorders can correctly use syntactic information in the process of pronoun reference. The main challenge, then, is their grasp and use of semantic and pragmatic information in the process of pronoun reference. Analysis of the above research shows that researchers predominantly adjust the strength of syntactic prominence by changing the morphological syntactic information or the position of the antecedent in the sentence structure, whereas the strength of semantic prominence is adjusted more often by changing the semantic degree of verbs (such as transitive verbs or intransitive verbs) or prosodic information. As mentioned above, syntactic prominence can be embodied by changing the shallow syntactic structure, whereas semantic prominence requires the establishment of deep semantic associations of different strengths for adjustment. Therefore, previous studies have not fully reflected semantic prominence as these studies have merely changed the semantic degree of verbs or prosodic information. In this study, the second-person pronoun “you” and the subject’s name, which can establish a deep semantic relationship with subjects, are selected as semantic information with strong prominence so as to investigate the mechanism of pronoun reference processing by children with autism spectrum disorders.

## The processing of Chinese reflexive “ziji”

This study focuses on the reference processing of the most characteristic reflexive pronoun, “ziji” (oneself), in Chinese to fully investigate the processing of semantic prominence clues during reference processing in children with ASD. The Chinese reflexive pronoun “ziji (oneself)” has unique anaphora characteristics. Generally, the reference of the reflexive pronoun “ziji (oneself)” should comply with the Theory of Government and Binding proposed by Chomsky. The anaphor (i.e., ziji(oneself)) must be bound within the governing category (also called the “local constraint”) (Chomsky, 1981). However, the Chinese reflexive pronoun “ziji (oneself)” does not fully comply with the principle of constraint. It can be constrained within its governing category as well as outside the governing category (also known as “long-distance constraint”).

For instance, in example sentence (1), the antecedent of the English reflexive pronoun “himself” can only refer to Jack in the local governing category, but the Chinese reflexive pronoun “ziji(oneself)” can refer to both the near subject “Jack” in the local governing category and the distant subject “Ben” over a long distance.

(1)	本 <sub>i</sub>	知道	杰克 <sub>j</sub>	相信	自己 <sub>ij</sub>
	Ben	zhidao	Jieke	xiangxin	xiangxin
	Beni	knows	Jackj	believes	himselfj

Compared with the two antecedents, the antecedents in the local governing category have higher syntactic prominence because the antecedents are closer to the reflexive pronouns *ziji*. However, the long-distance constraint of “ziji (oneself)” cannot always be achieved. Researchers have found that when the near subject within the governing category of the reflexive pronoun “ziji (oneself)” has strong semantic prominence (the first/second personal pronouns), this near subject can block the long-distance constraint of “ziji(oneself).” As exemplified below where the near subject *ni* ‘you’ blocks the long-distance antecedent *Xiaohong* in the matrix clause from binding *ziji* self.

(2)	小虹 <sub>i</sub>	认为	你 <sub>j</sub>	恨	自己 <sub>*ij</sub>
	Xiaohong	renwei	ni	hen	ziji(oneself)
	Xiaohong	thinks	you	hate	himself

This phenomenon is called the blocking effect (Chien, Kenneth, & Hsing, 1993; Giorgi, 2006; Huang, & Liu, 2001; Pan, 1995). Pan (1995) employs self-ascription to account for the blocking effect. According to the interpretation of self-ascription theory, the first/second personal pronouns belong to obligatory self-ascribers. Once the first/second person pronoun appears in the antecedent, the experimenter will process information from the first-person perspective of “I”. Therefore, the first/second person pronouns have strong semantic prominence, while the third person pronouns or nouns are weak semantic salience information.

The above contents demonstrated that the anaphora of the Chinese reflexive pronoun “ziji(oneself)” not only relies on the restriction of syntactic rules but is also largely affected by the semantic information of the antecedent itself. Whether the specific reflexive pronoun “ziji(oneself)” follows local constraint or long-distance constraint depends on the location of strong semantic information (Li, & Zhou, 2010).

## Aims of the present work

Therefore, this study manipulates the position of strong semantic information to investigate the mechanism of semantic information processing during anaphora processing of the Chinese reflexive pronoun “ziji (oneself)” by children with autism spectrum disorders. If children with autism spectrum disorders can normally process strong semantic

information during the anaphoric processing of the Chinese reflexive pronoun “ziji (oneself),” they should give priority to the entity in which strong semantic information is located when determining the antecedent of the reflexive pronoun “ziji (oneself).” In other words, when strong semantic information clues appear in the long-distance subject position, they tend to yield long-distance anaphora processing of the reflexive pronoun “ziji (oneself)”; however, when strong semantic information clues appear in the near subject position, subjects tend to result in the near anaphora processing of the reflexive pronoun “ziji (oneself)” in accordance with the principle of local constraint.

In order to more accurately measure the reference processing of children with autism, this study employed a combination of visual-world paradigm and eye movement technology to conduct experiments. Tanenhaus et al. (1995) first used the visual world paradigm in sentence comprehension tasks. Thereafter, the paradigm was used in research on such issues as syntactic disambiguation, lexical semantic information extraction, and reference processing (Novick et al., 2008; Pyykkönen-Klauck, Matthews, & Järvikivi, 2010; Zhou, Ma, Zhan, & Ma, 2018). The visual world paradigm aids the observation of subjects’ real-time representations during the sentence comprehension process. In addition, this method can be applied to special groups of subjects who cannot perform language expression easily. Therefore, in this study, we presented both visual and auditory stimuli to the subjects, that is, when visually presenting pictures of scenes, sentence information was played over earphones, and in the process, we recorded the subjects’ eye movements while viewing the pictures.

## Experiment 1

In Experiment 1, “ni (you)” was used, with the semantically prominent function, to examine whether children with ASD are able to break through syntactic rules to use such prominent information and then determine who the referent of “ziji(oneself)” should be. According to Pan (2001) and Naigles & Chin (2017), both first/second person pronouns are obligatory self-ascribers which implies that they have they have strong semantic prominence. In this experiment, the experimental material is auditory presentation. The participant is the listener, so “ni (you)” is chosen as the strong semantic information with self-attribution. Therefore, being able to identify the distant “ni” as the antecedent of “ziji (oneself)” indicates that the participants are able to use prominent semantic information to determine the referent. The visual world paradigm and eye movement detection were used to explore participants’ anaphoric processing of “ziji (oneself).”

## Method

### Experimental design

This study adopted a two-factor mixed experimental design of 3 (antecedent word category: third-person noun + third-person noun / third-person noun + second-person noun/ second-person noun + third-person noun) × 3 (subject group:

ASD/TD/ID). The group is the inter-subject variable, and the antecedent category is the intra-subject design. The "Antecedent Category" variable contains three levels:

c1 (third-person noun + third-person noun): Both long-distance entities and short-distance entities are third-person nouns (e.g., "The little mouse lets the little piggy buy ice cream for himself.");

c2 (third-person noun + second-person noun): the long-distance entity is the third-person noun, and the short-distance entity is the second-person noun "you" (e.g., "The little mouse lets you buy ice cream for yourself.");

c3 (second-person noun + third-person noun): the long-distance entity is the second-person noun "you", and the short-distance entity is the third-person noun (e.g., "You let little mouse buy ice cream for himself.").

## Participants

The participants of the experiment consisted of three groups: 21 children with ASD, 20 TD children, and 23 children with intellectual disability (ID). Participants from TD group were from ordinary kindergartens in China, and participants from the ASD group and ID group were from special education schools. All ASD and ID participants were diagnosed by professional clinicians and met the required diagnostic criteria in the DSM-IV [APA, 1994]. The non-verbal and verbal IQs of the three groups were evaluated by the Combined Raven Test (CRT) and the Peabody Picture-Vocabulary Test (PPVT). As shown in Table 1, the verbal and non-verbal IQ of the ASD group was similar to that of the ID group, whereas both the ASD and ID groups' IQs were lower than the TD group's IQ. The ASD and ID groups were matched in terms of chronological ages, and both groups were older than TD children (see Table 1 for details). Since the current sample of ASD children were not high functioning enough to match the IQ of the typical children, we added a group of children with ID as a control group to examine the possible impact of IQ.

Our inclusion criteria were that all participants had to successfully establish a temporary connection between the self and the virtual subject. Initially, each group had 23 participants. However, two participants from the ASD group and three from TD group were unable to establish the temporary connection required between themselves and the virtual subject (Panda); hence, they were excluded from the experiment.

Two studies were approved by the Human Subjects Review Committee of Peking University. We obtained informed consent from participants' parents and oral assent from participants before the experiment.

## Materials

Thirteen images of animals and twelve photographic images depicting.

merchandise available for purchase in the supermarket (e.g., food and daily goods) were taken from the Internet. Twelve mini-stories were created in this experiment (see Table 2 for discourse structure). Each set of discourses consists of three

**Table 1** Characteristics of the participants in Experiments 1, & 2

	ASD	TD	ID	Group Differences		
				ASD vs. TD	ASD vs. ID	TD vs. ID
<i>Experiment 1</i>						
Age (years)	7.9 (0.99)	3.8 (0.70)	8.4 (2.02)	15.359***	-1.052	-9.767***
PPVT	67.71 (7.44)	80.15 (8.98)	68.91 (6.13)	-4.831***	-0.585	4.838***
CRT	15.71 (1.95)	19.05 (3.03)	15.13 (3.35)	-4.206**	0.698	3.998***
<i>Experiment 2</i>						
Age (years)	6.1 (2.06)	3.3 (0.9)	7.1 (1.99)	5.786***	-1.46	-7.878***
PPVT	69.57 (7.85)	79.61 (9.61)	70.88 (11.41)	-3.673**	-0.443	2.646*
CRT	17.91 (1.48)	19.46 (1.03)	17.19 (1.98)	-3.241**	1.353	3.946***

ASD, autism spectrum disorder; TD, typical development; ID, intellectual disabilities; CRT, combined raven test; PPVT, Peabody picture-vocabulary test

\* $P < .05$ . \*\* $P < .01$ . \*\*\* $P < .001$

single sentences. The first two sentences are content sentences, which involving two protagonists (e.g., a panda and a pig are neighbors) and provide the background of the story. The third sentence is the target sentence which contain two protagonists and corresponding object picture. In the target sentence, we use “let” as the verb of the main sentence and “buy, take, and give” as verbs of the subordinate clause (e.g., “The little mouse lets the little piggy buy ice cream for himself.”) (as shown in Fig. 1).

The experimental material was recorded by two people (one male and one female) who spoke standard Mandarin. The audio editing software Cool Edit Pro was used to Edit the recording. At the same time, the speech intensity of the stimulus was adjusted to achieve the same (Average RMS Power = -23 dB), to ensure that different stimuli were presented with a unified sound intensity in the experiment.

We adopt Tobii T120 eye tracker and its software package to record each subject’s gazing behavior in the experimental tasks. The eye tracker is connected to two computers, one of which is installed with Tobii Studio software package to record the subjects’ gazing behaviors, and the other is installed with Matlab software to complete the experimental procedure presentation. The computer is an entirely non-contact oculomotor system that can achieve real-time eye tracking. The system’s allowable head moving range is 44 cm × 22 cm × 33 cm, sampling precision is 0.5 degrees, and sampling frequency is 120 Hz. Five-point calibration is performed on each subject’s eyes. The point at which gazing lasts for at least 80 ms is the fixation point. The subject sits in front of the eye tracker in a natural posture, with the eyes and stimulants on the same level with 60 cm.

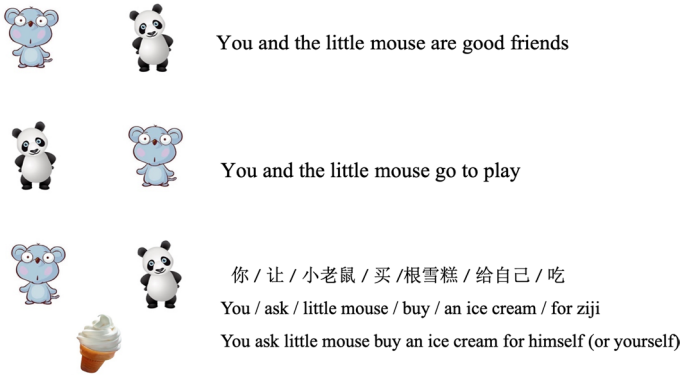
## Procedure

**Temporary self-connection phase** Before the formal experiment, each participant needs to establish a temporary self-connection with “panda”. In the mini-stories presented later, the panda represents the participant himself /herself. First, the experi-

**Table 2** The discourse structure in experiments 1

Antecedent category condition		
c1	c2	
Third-person noun + third-person noun	Third-person noun + second-person noun	
c3	Second-person noun/name + third-person noun	
Content sentence 小老鼠和小猪是好朋友 Little mouse and little pig are good friends	小老鼠和你是好朋友 Little mouse and you are good friends	你和小老鼠是好朋友 You and the little mouse are good friends
Content sentence 小老鼠和小猪一起玩 Little mouse and little pig play together	小老鼠和你一起玩 Little mouse and you play together	你和小老鼠一起玩 You and the Little mouse play together
Target sentence 小老鼠让小猪买雪糕给自己吃 The little mouse lets the little piggy buy ice cream for himself	小老鼠让你买雪糕给自己吃 The little mouse lets you buy ice cream for yourself/himself	你让小猪买雪糕给自己吃 You let little mouse buy ice cream for himself/yourself





**Fig. 1** The materials sample in Experiments 1. Each paragraph consists of three simple sentences, which the first two are content sentences that provide discourse context and the third is a target sentence. Content sentences are personification sentences, each of which has two coordinate subjects (e.g., “You and little mouse are neighbors”/ “You and little mouse go to play”). In the target sentence, we use “let” as the verb of the main sentence and “buy, take, and give” as verbs of clause (e.g., “You lets the little mouse buy ice cream for himself/yourself”). When the content sentence is present, the visual material serves as the long-distance entities and short-distance entities animal picture (e.g., lesser panda and mouse). When the target sentence appears, the visual material presents the long-distance entities and short-distance entities animal picture and corresponding object picture

menter needs to introduce the experimental steps and help participant complete the temporary self-connection of the panda and self. The instructions are given in the following manner. “Hello kids. Today we’re going to finish a game. First of all, let’s look. What is this animal in the middle of the screen? Do you like panda? In the following game, you need to play the role of a little panda and imagine yourself as the little panda in the game. From now on, you are this little panda, and this little panda is \*\*\* (name of participant). Now, would you please tell me who will play the panda now? The next phase can be conducted after the participant can smoothly answer “I am a panda” or “the panda is me”. If the participants can answer that “I am a panda”, it means that they have temporarily established a connection between themselves and the panda. Therefore, the little panda in the game represent themselves.

**Calibration** The subjects sat 60 cm from the eye tracker. Five-point calibration is performed on each subject’s eyes. The experimenter sits near the control computer to avoid interrupting the children during the experiment. Owing to the particularity of autistic children, teachers assist the experimenter to give commands and control the behavior of the autistic children.

**Test phase** Conducting the formal experiment on the subjects. As sentences are read to the subjects, the computer screen presents the corresponding discourse entities or scenes of discourse and records the gaze behaviors of subjects during the experiment. After each paragraph was presented, the participants rested for 10 s and did not need to complete any detection tasks.

## Data analysis and hypothesis

In order to investigate how children process prominent semantic information during the processing of reflexive pronoun reference, this study focused on two dependent variables (time to first fixation & fixation duration) of each group participants after the presence of the reflexive pronoun "ziji (oneself)" in the target sentence. Because in the first part of the experiment, the participants have established a temporary self-connection with the little panda, in the following data analysis, the target object representing the participants themselves is the little panda picture.

First, we analyzed the processing sequence of different groups of participants on three target images (long-distance object, short-distance object, and image of food/daily goods) under different experimental conditions. If the participants processed the reflexive pronoun "ziji" with long-distance anaphora, they would first look at the long-distance object when "ziji (oneself)" appeared; if the participants processed the reflexive pronoun "ziji" with the principle of local constraint, they would focus on the short-distance object first after the presence of "ziji (oneself)". The processing sequence was measured as the time to first fixation, the first observed target image is assigned value of 1, and so on. The processing sequence was analyzed using repeated-measures ANOVA and ordinal logistic regression model. The ordinal logistic regression is a more appropriate technique for the categorical data (Franklin et al., 2017). The robust variance estimator at the cluster level approximates a comparable Generalized Estimating Equations (GEE) ordinal model.

Additionally, we compared the fixation time of different groups of participants on three target images. If children can normally process strong semantic information during the anaphoric processing of the Chinese reflexive pronoun "ziji(oneself)", they would look more at the object of strong semantic information (panda) than other two objects. Linear regression with generalized estimating equations was performed to test the correlation between fixation time index and intergroup variables.

This study adopts Tobii interest elliptical tool and takes the area of interest (AOI) within 1° visual Angle (1.4 cm) at the edges of three target images as the area of interest (AOI).

## Results and discussion

Each child was presented with all 12 stories from one of three lists counterbalanced for the antecedent word category in the target sentence and order of presentation of stories.

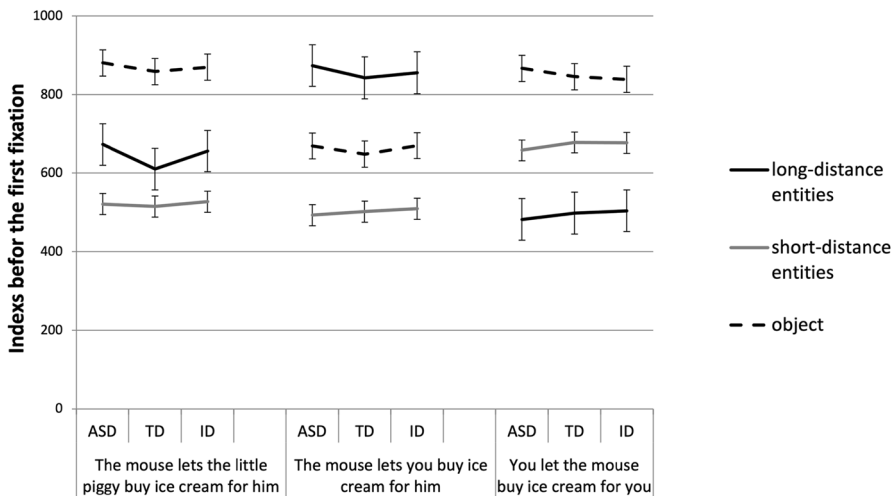
### Analysis of the processing sequence

The processing sequence is analyzed according to the eye movement index in the duration before first fixation. Results of analysis on variance of repeated measurements show that the main effect of the antecedent category is significant

( $F(2,122)=0.188, p=0.829, \eta_p^2=0.003$ ). The main effect of group is not significant ( $F(2,61)=0.933, p=0.399, \eta_p^2=0.30$ ), that is, no differences are observed among the target object fixation sequences of different groups. In addition, the main effect of different regions of interest is significant ( $F(2,122)=164.934, p<0.001, \eta_p^2=0.73$ ). The interaction between antecedent category and region of interest is significant ( $F(4,244)=112.353, p<0.001, \eta_p^2=0.648$ ) (see Fig. 2). Simple-effect analyses revealed that time to first fixation to each AOI was different under different antecedent categories. Specifically shown as when the long-distance entities are a third-person noun, the children spent less time before looking at the short-distance object ( $F(2,189)=147.074, p<0.001, \eta_p^2=0.609$ ). When the long-distance entities are a second-person noun, the children spent less time before looking at the long-distance object ( $F(2,189)=137.843, p<0.001, \eta_p^2=0.593$ ). To further investigate whether there was any difference in the processing sequence among each group, we used the ordered logistic regression model to fix the in-group effects and assess the relationship between the groups and the order of observation. In the ordinal logistic regression for long-distance object, there was no significant effect of Group (ASD vs ID:  $\beta=0.009, OR=1.009, 95\% CI: 0.785-1.296$ ; TD vs ID:  $\beta=0.086, OR=1.09, 95\% CI: 0.791-1.502$ ). Identically, the significant effect of Group was absent for short-distance object and image of food/daily goods. The results are summarized in Table 3.

**Analysis of the distribution pattern of gaze duration**

Analysis on the fixation duration of subjects on the target object can help determine the subjects' cognitive processing and interest level on the target object. A longer



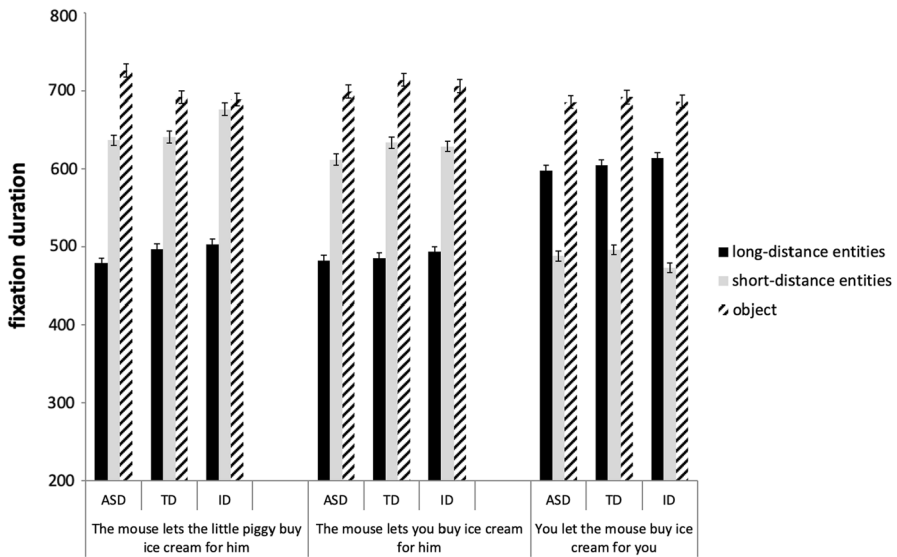
**Fig. 2** Indexes before the first fixation for the ASD, TD, and the ID groups in Experiment 1 (Error bars depicts standard errors)

**Table 3** Experiment 1: Results of ordinal logistic regression for processing sequence ( $df=1$ )

		$\beta$	SE	$\chi^2$	$p$	OR (95%CI)
Long-distance object	Intercept	-0.729	0.116	39.183	<0.001	
		0.729	0.113	41.586	<0.001	
	Group=ID	Ref.				
	Group=ASD	0.009	0.128	0.005	0.946	1.009(0.785,1.296)
	Group=TD	0.086	0.164	0.277	0.599	1.090(0.791,1.502)
Short-distance object	Intercept	-1.197	0.110	118.783	<0.001	
		0.340	0.103	10.887	0.001	
	Group=ID	Ref.				
	Group=ASD	0.186	0.145	1.641	0.200	1.204(0.906,1.599)
	Group=TD	0.156	0.140	1.245	0.264	1.169(0.889,1.537)
Image of food/daily goods	Intercept	-0.265	0.120	4.849	0.028	
		1.123	0.143	61.930	<0.001	
	Group=ID					
	Group=ASD	-0.176	0.156	1.268	0.260	0.839(0.618,1.139)
	Group=TD	-0.318	0.171	3.437	0.064	0.728(0.520,1.018)

ASD, autism spectrum disorder; TD, typical development; ID, intellectual disabilities

fixation duration corresponds to increased interest of the subject. Off-screen looks were treated as missing data. The percentage of loss trials was 14.68%, 16.38%, and 5.2% for ASD, TD and ID groups, respectively. Analysis of variance of repeated measurements is carried out on fixation duration on the target object. Results show that the main effect of the antecedent category is significant ( $F(2,122)=1.433$ ,  $p=0.242$ ,  $\eta_p^2=0.023$ ), whereas the main effect of the group is not significant ( $F(2,61)=0.095$ ,  $p=0.91$ ,  $\eta_p^2=0.003$ ). That is no difference was observed among the target object fixation sequences of the different subject groups. In addition, the main effect of the different regions of interest is significant ( $F(2,122)=43.022$ ,  $p<0.001$ ,  $\eta_p^2=0.414$ ). Moreover, the interaction between antecedent category and the region of interest is significant ( $F(4,244)=24.956$ ,  $p<0.001$ ,  $\eta_p^2=0.29$ ) (see Fig. 3). Simple-effect analyses revealed that when the long-distance entities are a third-person noun, the children spent the longest time at the image of food or daily goods, followed by the short-distance object, and the long-distance object was the shortest ( $F(2,189)=34.614$ ,  $p<0.001$ ,  $\eta_p^2=0.268$ ). When the long-distance entities are a second-person noun, children have the longest gaze time on the image of food or daily goods, followed by long-distance object, and the shortest gaze time on the short-distance object ( $F(2,189)=37.395$ ,  $p<0.001$ ,  $\eta_p^2=0.284$ ). Fixation time were also analyzed using Generalized Estimating Equations (GEE) to avoid type I errors that might be caused by ANOVAs. GEE was used to model fixation time towards the image of food/daily goods, the long-distance object, and short-distance object, as a function of participant within each condition. A separate cell means model was estimated for each outcome variable. Antecedent Category was included as a fixed effects term in the model and the within-subject correlation was modelled with a



**Fig. 3** Fixation duration for the ASD, TD, and the ID groups in Experiment 1 (Error bars depicts standard errors)

compound symmetry correlation matrix structure. See Appendix A for all model parameter estimates. Results of the GEE suggested that, in accordance with the processing sequence, fixation time on the three target objects were the same across groups.

The results showed that, when the proximate and distant entities of “*ziji (oneself)*” were both third-person nouns (such as a mouse and a calf), participants from both experimental and control groups were able to follow the principle of local binding and use syntactic strategy to determine that the proximate entity was the antecedent of “*ziji(oneself)*.”

## Experiment 2

In Experiment 1, “*ni*” was used with the prominent semantic function, as the second-person pronoun has a strong self-referencing property. However, in addition to the second-person pronoun, the listener’s name also has a self-referring function. Furthermore, many studies have shown that self-name processing is unique and easier to be identified among a range of varied information, and is thus unlikely to be inhibited by other information (Mack, Pappas, Silverman, & Gay, 2002). In fact, even in sleep or anesthesia, an individual is still able to react to their own name (Perrin et al., 1999; Shelley-Tremblay & Mack, 1999). The question, therefore, is whether children with ASD are able to use self-name as a semantic function with a prominent self-reference effect during anaphoric processing. In order to answer this question, Experiment 2 was designed, introducing the concept of self-name.

## Method

### Participants

The recruitment methods and criteria were the same as in Experiment 1. We initially recruited 23 children with ASD, 20 TD children, and 23 ID children with ID. However, 3 children with ID and 2 children with ASD dropped out due to their difficulties establishing the temporary connection required between themselves and the virtual subject. 20 TD children, 20 children with ID, and 21 children with ASD contributed to the final analysis. All the children with ASD and ID met the required diagnostic criteria of DSM-IV (American Psychiatric Association, 1994). The ASD and the TD groups were matched by their chronological age and IQ (measured by CRT and PPVT). The TD children were younger and had a higher IQ than the children in the other two groups (see Table 1 for more details). None of the participants in Experiment 2 participated in Experiment 1.

### Materials and procedure

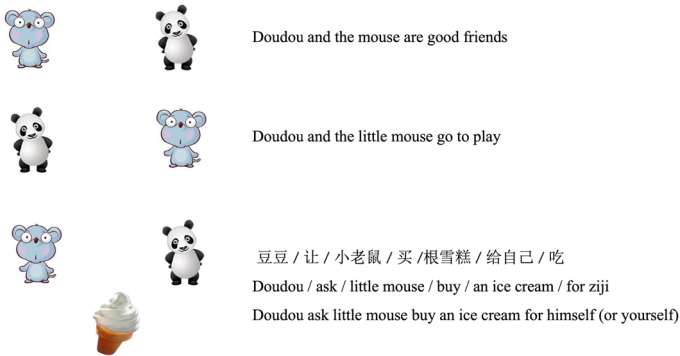
Thirteen images of animals and twelve photographic images depicting merchandise available for purchase in the supermarket (e.g., food and daily goods) were taken from the Internet. In addition to using third-person nouns and second-person pronouns as in Experiment 1, this experiment also uses the subject's name as the antecedent. Visual material is shown in Fig. 4 (see Table 4 for discourse structure).

All procedures and data analysis for this experiment were identical to those used in Experiment 1.

## Results and discussion

### Analysis of the processing sequence

The time until first fixation was analyzed. The results of repeated measures variance analysis (ANOVA) showed that the main effect of the antecedent was significant ( $F(2,466) = 6.38, p < 0.01, \eta_p^2 = 0.52$ ). The main effect of the participant type was not significant ( $F(2,466) = 0.65, p = 0.79, \eta_p^2 = 0.07$ ), indicating that there was no difference in the time until first fixation between participants from different groups. In addition, the main effect of different areas of interest was significant ( $F(2,466) = 18.72, p < 0.001, \eta_p^2 = 0.39$ ), and the interaction effect between the antecedent and the area of interest was also significant ( $F(4, 932) = 21.35, p < 0.001, \eta_p^2 = 0.55$ ). The simple effect analysis revealed that, when the long-distance object was a third-person noun, children first looked at the short-distance object picture, and the long-distance object picture at the latest ( $F(2, 195) = 90.807, p < 0.001, \eta_p^2 = 0.482$ ). However, when the long-distance object was either the participant's name or a second-person pronoun, children first looked at the long-distance object, while the short



**Fig. 4** The materials sample in Experiments 2. The design of experiment materials is the same as Experiment 1. Each paragraph consists of three simple sentences, which the first two are content sentences that provide discourse context and the third is a target sentence. The difference from Experiment 1 is that, in addition to the second-person pronoun and nouns, we choose the listener's name as the long-distance entity. Content sentences are personification sentences (e.g., "Doudou and little mouse are neighbors"/ "Doudou and little mouse go to play"). In the target sentence, we also use "let" as the verb of the main sentence and "buy, take, and give" as verbs of clause (e.g., "Doudou lets the little mouse buy ice cream for himself/yourself"). When the content sentence is present, the visual material serves as the long-distance entities and short-distance entities animal picture (e.g., lesser panda and mouse). When the target sentence appears, the visual material presents the long-distance entities and short-distance entities animal picture and corresponding object picture

distance object took the longest time before staring ( $F(2, 195) = 110.456$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.513$ ;  $F(2, 195) = 91.01$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.483$ ) (Fig. 5). The same as Experiment 1, to further investigate whether there was any difference in the processing sequence among each group, we used the ordered logistic regression model to fix the in-group effects and assess the relationship between the groups and the order of observation. In the ordinal logistic regression for long-distance object, there was no significant effect of Group (ASD vs ID:  $\beta = 0.064$ , OR = 1.066, 95% CI: 0.686–1.658; TD vs ID:  $\beta = 0.157$ , OR = 1.17, 95% CI: 0.759–1.802). Identically, the significant effect of Group was absent for short-distance object and image of food/daily goods. The results are summarized in Table 5.

### Analysis of the distribution pattern of gaze duration

Analyzing the gaze duration allows for better understanding of participants' cognitive processing and of the degree of interest in the target: a longer gaze duration indicates greater interest. Off-screen looks were treated as missing data. The percentage of loss trials was 7.6%, 7.5%, and 8.3% for ASD, TD and ID groups, respectively. The results of the repeated measures ANOVA showed that the main effect of the antecedent type was significant ( $F(2, 466) = 8.98$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.59$ ). Furthermore, the main effect of the participant type was not significant ( $F(2, 466) = 0.08$ ,  $p = 0.77$ ,  $\eta_p^2 = 0.08$ ), indicating that there was no difference in the gaze duration between participants from different groups. In addition, the main effect of different areas of interest was significant ( $F$

**Table 4** The discourse structure in experiments 2

Antecedent category condition			
	c1	c2	c3
	Third-person noun + third-person noun	Second-person noun + third-person noun	Child's name + Third-person noun
Content sentence	小老鼠和小猪是好朋友 Little mouse and little pig are good friends	你和小老鼠是好朋友 You and the little mouse are good friends	豆豆和小老鼠是好朋友 Doudou and the little mouse are good friends
Content sentence	小老鼠和小猪一起玩 Little mouse and little pig play together	你和小老鼠一起玩 You and the Little mouse play together	豆豆和小老鼠一起玩 Doudou and the Little mouse play together
Target sentence	小老鼠让小猪买雪糕给自己吃 The little mouse lets the little piggy buy ice cream for himself	你让小猪买雪糕给自己吃 You let little mouse buy ice cream for himself/ yourself	豆豆让小猪买雪糕给自己吃 Doudou let little mouse buy ice cream for himself/yourself



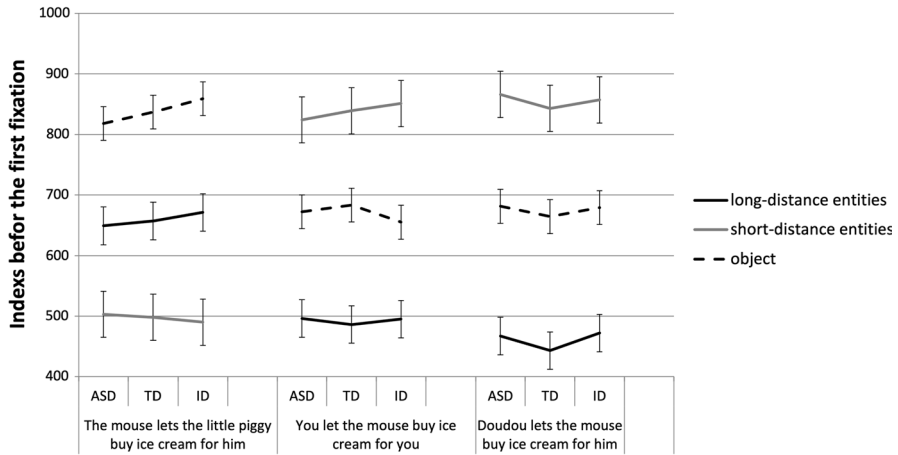


Fig. 5 Indexes before the first fixation for the ASD, TD, and the ID groups in Experiment 2 (Error bars depicts standard errors)

Table 5 Experiment 2: Results of ordinal logistic regression for processing sequence ( $df=1$ )

		$\beta$	SE	$\chi^2$	$p$	OR (95%CI)
Long-distance object	Intercept	-1.141	0.177	41.550	<0.001	
		0.257	0.176	2.126	0.145	
	Group = ID	Ref.				
	Group = ASD	0.064	0.225	0.081	0.776	1.066(0.686,1.658)
	Group = TD	0.157	0.221	0.505	0.477	1.17(0.759,1.802)
Short-distance object	Intercept	-0.037	0.186	0.039	0.844	
		1.033	0.205	25.308	<0.001	
	Group = ID	Ref.				
	Group = ASD	0.146	0.263	0.309	0.579	1.158(0.691,1.94)
	Group = TD	-0.021	0.258	0.007	0.934	0.979(0.59,1.623)
Image of food/daily goods	Intercept	-1.041	0.241	18.597	<0.001	
		0.880	0.230	14.666	<0.001	
	Group = ID					
	Group = ASD	-0.199	0.300	0.439	0.507	0.82(0.456,1.475)
	Group = TD	-0.028	0.306	0.008	0.928	0.973(0.534,1.772)

ASD, autism spectrum disorder; TD, typical development; ID, intellectual disabilities

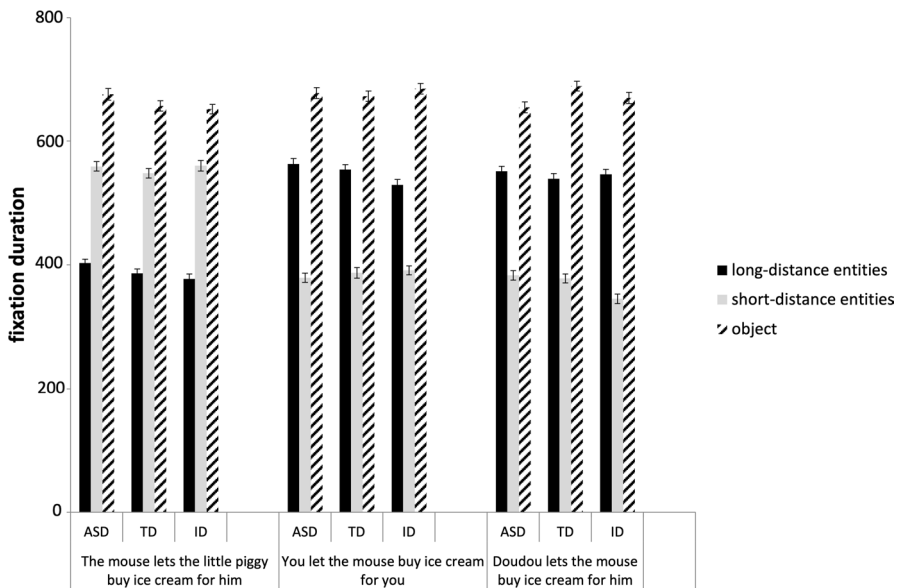
(2,466) = 11.54,  $p < 0.001, \eta_p^2 = 0.65$ ), and the interaction effect between the antecedent type and the area of interest was also significant ( $F(4, 932) = 17.39, p < 0.001, \eta_p^2 = 0.76$ ). The simple effect analysis showed that, when the long-distance object was a third-person noun, the gaze duration on the image of the food or daily goods was the longest, followed by the gaze duration on the image of the short-distance object; thus, the gaze duration on the image of the long-distance object was the shortest ( $F(2, 195) = 53.472, p < 0.001, \eta_p^2 = 0.354$ ). However, when the long-distance object was

either the participant's name or a second-person pronoun, the gaze duration on the image of the food or daily goods was the longest, followed by the gaze duration on the image of the long-distance object; thus, the gaze duration on the image of the short-distance object was the shortest ( $F(2, 195) = 58.522, p < 0.001, \eta_p^2 = 0.375$ ;  $F(2, 195) = 56.965, p < 0.001, \eta_p^2 = 0.369$ ) (Fig. 6). The same as Experiment 1, GEE was used to model fixation time towards the image of food/daily goods, the long-distance object, and short-distance object, as a function of participant within each condition. See Appendix B for all model parameter estimates. Results of the GEE also suggested that fixation time on the three target objects were the same across groups.

In Experiment 2, self-name was introduced as prominent semantic information to explore how children with ASD process the referent of “*ziji(oneself)*.” The results showed that, when self-name and second-person pronouns were used as the distant entity, participants from the experimental group were more inclined to perform long-distance anaphora and use semantic strategy, and identify the distant entity as the antecedent of the reflexive pronoun.

## General discussion

This study introduced the visual world paradigm and eye movement detection technique to explore participants' anaphoric processing of “*ziji(oneself)*.” In both experiments, participants with ASD exhibited a similar level of processing ability to that of children with typical development and those with intellectual disabilities.



**Fig. 6** Fixation duration for the ASD, TD, and the ID groups in Experiment 2 (Error bars depicts standard errors)

Specifically, they were found to prioritize prominent semantic information. In the absence of prominent semantic information, participants with ASD were able to perform anaphoric processing of the reflexive pronoun in the same way as did participants from the control groups. The results of this study indicate that Chinese children with ASD are not only able to use syntactic rules, but also prominent semantic information when reference-processing the reflexive pronoun.

Both experiments showed that, when the distant and proximate entities of “*ziji(oneself)*” were both third-person nouns, all participants were able to use the entity within the binding domain as the antecedent of the reflexive pronoun, which is in line with the Theory of Government and Binding. The findings of this study echoed the findings of previous studies on pronoun anaphoric processing among children with ASD. Those studies have also found that children with ASD are able to correctly use syntactic rules to determine the referents of the reflexive pronouns (Perovic et al., 2013a, 2013b; Janke & Perovic, 2015; Terzi, Marinis, and Francis 2014, 2016). Terzi et al., (2014, 2016) investigated pronoun anaphoric processing among children with ASD in Greece and found that their performance was similar to that of children with typical development in terms of using only syntactic rules to process reflexive pronouns. However, the children faced difficulties in understanding the attached pronouns that required the use of semantic information. The acquisition of syntactic rules for children with ASD is earlier than the acquisition of semantic and pragmatic information. This finding is also in line with the expected pathway of children’s language acquisition. Regardless of the target language, children tend to first master general grammatical rules, and then master the specific phonetic, semantic, and pragmatic information of the language (Chien., et al., 1993; Siguríósdóttir and Hyams 1992; Mckee, 1992; Jakubowicz, 1994; Ruigendijk et al., 2010; Lukyanenko et al., 2014; Tek, & Naigles, 2017).

More importantly, consistent with the research hypothesis, the results showed long-distance anaphora when processing the Chinese reflexive “*ziji(oneself)*.” Specifically, when the distant entity was “*ni*” (second-person pronoun) or a self-name, participants with ASD, like the participants from the control groups, were able to identify the distant entity as the antecedent of “*ziji(oneself)*” correctly. This finding suggests that Chinese children with ASD have the ability to use prominent semantic information in reference-processing, by breaking the syntactic rules and using semantic information. The results of this study are different from those of previous studies on children who speak Indo-European languages. According to those studies, children with ASD are unable to use semantic information accurately in anaphoric processing (Terzi, Marinis, and Francis ). Such differences can be caused by the following two reasons:

(1) The characteristics of processing Chinese language are different from those of processing Indo-European languages. The words of most languages in the Indo-European language family (such as English) have various morphological changes and strict syntactic rules. Individuals who speak these languages tend to adopt syntactic rules to understand a sentence. Conversely, researchers have found that non-syntactic cues, such as semantics and context are very important in the understanding of Chinese sentences (Chen, 1992; Zhang et al., 2010, 2013). Therefore, Chinese language is referred to as a context-dependent language. Particularly, due to the lack of explicit cues provided by morphological changes, determining the anaphora of

Chinese pronouns mainly relies on cues such as semantics and context owing to the lack of explicit cues provided by morphological changes (Xu et al., 2013). Consistently, this study found that participants of all three groups were able to use semantic information for long-distance anaphora identification.

(2) In addition, different from the comprehension/binding of clitics task used in previous studies, this study introduced “*ni*” and the participant’s name as prominent semantic information cues. Some researchers have pointed out that first and second-person pronouns and self-name have compulsory self-referring attributes. In other word, the semantic prominence becomes more pronounced when the component is more closely associated with the listener (closer to the self) (Pan, 1995). Similarly, Ariel (1990) also pointed out that based on the economic principle of language expression, when an entity has high prominence, the listener will automatically refer to the pronoun as the most prominent antecedent. Therefore, the prominence of the entity in the text has shifted to become the key information that affects the processing of pronouns. From the perspective of language acquisition, children with typical development begin to show sensitivity to text prominence and can use prominent cues to process pronouns from approximately three years of age (Song, 2007). By the age of four years, they are already able to comprehend pronouns like adults do and are more inclined to use semantically prominent and discourse-salient information rather than syntactic principles (Van Rij, Hollebrands, and Hendriks 2016). In this study, participants with ASD were able to use the prominent semantic information of the antecedent to process pronouns as well as do children with typical development or intellectual disabilities.

It is worth noting that, in this study, participants with ASD were able to perform dominant processing using their own name; however, past studies on the self-name of individuals with ASD found that they were not able to decipher the referent when their name was used during processing. Cygan et al. (2014) used electroencephalography (EEG) technology to investigate self-name recognition ability among individuals with ASD. The results showed that individuals from the typical development group tended to induce more P300 components when processing their own names, while individuals from the ASD group showed no difference in the P300 components between processing their own names, the names of individuals that they were familiar with, and faces. Therefore, the researchers concluded that individuals with ASD are not able to develop specific representation of self-names. The findings of this study, regarding the fact that participants with ASD were able to prioritize prominent semantic information, may be more closely associated to the speaker’s perspective (first-person perspective) and the concept of interpretation. At its semantic core, “*ziji(oneself)*” is reflexive; although the antecedent and the reflexive pronoun refer to the same entity, they serve different semantic roles (that of the performer and of the receiver of the action). Therefore, when the participants recognized their self-name as the subject of the action, they were able to process the self, prior to performing the action (Wuyun, Wang, Zhang, Wang, Yi, & Wu, 2020), thereby applying the prominent semantic information to identify the referent of the reflexive pronoun. This study found that, differently from people speaking languages of the Indo-European family, native Chinese-speaking individuals with ASD could prioritize processing of prominent semantic information. This finding thus serves as important guidance for language therapy interventions to improve the semantic and pragmatic information processing abilities of such children. In order to strengthen their

ability to process semantic and pragmatic information, interventions are recommended to help participants establish a first-person perspective. For example, we can allow children with autism to establish a temporary connection with the protagonist in the story, or perform the content of the story regarding themselves as the action agent in language processing.

Adding a group of children with ID in our study allowed us to examine the possible impact of IQ. Our finding of the similar pattern in the ID as the TD group implied that the priority processing about prominent semantic information among individuals with ASD could not be attributed to differences in IQ, but rather to autistic traits. However, since the current samples of children with ASD were not high functioning enough to match the IQ of typical children, further research on children with higher functions is needed when generalizing our findings.

## Limitations

In addition, this study has the following several limitations. First, we only used the PPVT for language testing. However, the PPVT focuses more on individuals' understanding of vocabulary, while the research focused mainly on language comprehension. Hence, future studies are suggested to adopt other language ability tests. Additionally, because ADOS-2 and CARS-2 have not been translated or normalized to be used in China when we did the study, other instrument for diagnosis were not used in this study. Future studies could consider using other scales to confirm the diagnosis of ASD. Another limitation is that no fillers were used in this study. Considering the attention limits of the children and the absence of reading comprehension tasks in this study, filler materials were not set in this study. However, because sufficient filler is important to the experiment, sufficient filler can improve the reliability of the measurement (Runner et al., 2006; Su, & Su, 2015). Therefore, future studies could consider using more fillers for language comprehension.

## Conclusions

In summary, this study used eye-tracking techniques and the visual world paradigm to investigate the reference-processing ability of Chinese children with ASD. The results showed that participants were able to prioritize prominent semantic information: in addition to respecting the syntactic rules, they were also able to use prominent semantic information to assist language understanding. The findings provide evidence for better understanding of the language processing mechanisms of individuals with ASD and provide important guidance for effective clinical speech therapy interventions in the future.

## Appendix

See Tables 6 and 7.

**Table 6** Parameter estimates for all GEE models in Experiment 1

	$\beta$	SE	Wald statistic	<i>p</i> -value
<i>Long-distance object fixation time</i>				
Intercept	0.537	0.018	914.820	< 0.0001
[ASD]	-0.017	0.025	0.457	0.499
[TD]	-0.008	0.024	0.101	0.751
[ID]	0 <sup>a</sup>			
<i>Short-distance object fixation time</i>				
Intercept	0.593	0.023	680.429	< 0.0001
[ASD]	-0.014	0.030	0.218	0.641
[TD]	-0.002	0.032	0.006	0.937
[ID]	0 <sup>a</sup>			
<i>Image of food/goods fixation time</i>				
Intercept	0.694	0.017	1643.801	< 0.0001
[ASD]	0.010	0.030	0.100	0.751
[TD]	0.005	0.038	0.018	0.892
[ID]	0 <sup>a</sup>			

<sup>a</sup>Set to 0, because this parameter is a nuisance parameter

**Table 7** Parameter estimates for all GEE models in Experiment 2

	$\beta$	SE	Wald statistic	<i>p</i> -value
<i>Long-distance object fixation time</i>				
Intercept	0.484	0.018	734.384	< 0.0001
[ASD]	0.022	0.027	0.644	0.422
[TD]	0.009	0.028	0.105	0.746
[ID]	0 <sup>a</sup>			
<i>Short-distance object fixation time</i>				
Intercept	0.432	0.022	402.690	< 0.0001
[ASD]	0.008	0.027	0.093	0.761
[TD]	0.000	0.027	0.000	0.999
[ID]	0 <sup>a</sup>			
<i>Image of food/goods fixation time</i>				
Intercept	0.669	0.020	1102.861	< 0.0001
[ASD]	0.000	0.027	0.000	0.987
[TD]	0.004	0.031	0.015	0.902
[ID]	0 <sup>a</sup>			

<sup>a</sup>Set to 0, because this parameter is a nuisance parameter

**Acknowledgements** This work was supported by the National Natural Science Foundation of China (61690205; 31771205), the National Key R&D Program of China (2017YFC0820200). The authors are thankful to the children, parents, and teachers who participated in this study.

## Declarations

**Conflict of interest** The authors declare no conflict of interest.

**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

## References

- American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders (4th ed., text revision)*. American Psychiatric Press.
- American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders*. American Psychiatric.
- Bavin, E. L., & Naigles, L. R. (2015). The Cambridge handbook of child language: language in children with autism spectrum. *Disorders*, 29(29), 637–658.
- Bergmann, C., Paulus, M., & Fikkert, P. (2011). Preschoolers' comprehension of pronouns and reflexives: The impact of the task. *Journal of Child Language*, 39, 777–803.
- Chen, P. (1992). The reflexive *ziji* in Chinese: Functional vs formalist approaches. In: Thomas Hun-Tak Lee (ed.), *Research on Chinese Linguistics in Hong Kong*: Linguistic society of Hong Kong. pp. 1–36
- Chien, Y. C., Wexler, K., & Chang, H. W. (1993). Children's development of long-distance binding in Chinese. *Journal of East Asian Linguistics*, 2(3), 229–259.
- Chomsky, N. (1981). *Lectures on Government and Binding*. Foris.
- Cummings, L. (2014). *Pragmatic Disorders and Social Communication*. Springer.
- Cygan, H. B., Tacikowski, P., Ostaszewski, P., Chojnicka, I., & Nowicka, A. (2014). Neural correlates of own name and own face detection in autism spectrum disorder. *PLoS ONE*, 9(1), 14.
- Edelson, L. R. (2011). Cues to pronominal reference resolution in children with and without autism spectrum disorders. p. 151
- Finnegan, E. G., Asaro-Saddler, K., & Zajic, M. C. (2020). Production and comprehension of pronouns in individuals with autism: A meta-analysis and systematic review. *Autism*, 25, 3–17.
- Foraker, S., & McElree, B. (2007). The role of prominence in pronoun resolution: Active versus passive representations. *Journal of Memory and Language*, 56, 357–383.
- Franklin, J. M., Eddings, W., Austin, P. C., Stuart, E. A., & Schneeweiss, S. (2017). Comparing the performance of propensity score methods in healthcare database studies with rare outcomes. *Statistics in Medicine*, 36(12), 1946–1963.
- Fromkin, V., Rodman, R., & Hyams, N. (2014). *An Introduction to Language* (10th ed.). Cengage Learning.
- Gernsbacher, M., & Pripas-Kapit, S. (2012). Who's missing the point? A commentary on claims that autistic persons have a specific deficit in figurative language comprehension. *Metaphor and Symbol*, 27(1), 93–105.
- Giorgi, A. (2006). From temporal anchoring to long distance anaphors. *Natural Language & Linguistic Theory*, 24(4), 1009–1047.
- Gordon, P. C., Grosz, B. J., & Gilliom, L. A. (1993). Pronouns, names and the centering of attention in discourse. *Cognitive Science*, 17, 311–347.


- Hu, J. H. (2002). *Prominence and Locality in Grammar: The Syntax and Semantics of Wh-questions and Reflexives*. Ph. D. Dissertation. City University of Hong Kong.
- Huang, C.-T. J., & Liu, C.-S. L. (2001). Logophoricity, attitudes, and ziji at the interface. In P. Cole, G. Hermon, & C.-T. J. Huang (Eds.), *Long-distance Reflexives, Vol. 33 of Syntax and Semantics* (pp. 141–195). Academic Press.
- Jakubowicz, C. (1994). Reflexives in french and danish: morphology, syntax and acquisition. In Barbara Lust, Gabriella Hermon, and Jaklin Kornfilt (eds.), *Syntactic Theory and First Language Acquisition: Cross-linguistic Perspectives. Binding Dependencies and Learnability*. Hillsdale, NJ: Lawrence Erlbaum.
- Janke, V., & Perovic, A. (2015). Intact grammar in HFA? *Evidence from Control and Binding. Lingua, 164*, 68–86.
- Li, X., & Zhou, X. (2010). Who is ziji? ERP responses to the Chinese reflexive pronoun during sentence comprehension. *Brain Research, 1331*(3), 96–104.
- Lukyanenko, C., Conroy, A., & Lidz, J. (2014). Is she patting katie? Constraints on pronominal reference in 30-Month-Olds. *Language Learning and Development, 10*(4), 328–344.
- Mack, A., Pappas, Z., Silverman, M., & Gay, R. (2002). What we see: The capture of attention by meaning. *Consciousness and Cognition, 11*(4), 488–506.
- McKee, C. (1992). A comparison of pronouns and anaphors in Italian and English acquisition. *Language Acquisition, 1*, 21–55.
- Novick, J. M., Thompson-Schill, S. L., & Trueswell, J. C. (2008). Putting lexical constraints in context into the visual-world paradigm. *Cognition, 107*(3), 850–903.
- Pan, H.H. (1995). *Locality, self-ascription, discourse prominence, and Mandarin reflexives*. Ph. D. Dissertation. The University of Texas at Austin.
- Perovic, A., Modyanova, N., & Wexler, K. (2013a). Comparison of grammar in neurodevelopmental disorders: The case of binding in williams syndrome and autism with and without language impairment. *Language Acquisition, 20*(2), 133–154.
- Perovic, A., Modyanova, N., & Wexler, K. (2013b). Comprehension of reflexive and personal pronouns in children with autism: A syntactic or pragmatic deficit? *Applied Psycholinguistics, 34*(4), 813–835.
- Perrin, F., García-Larrea, L., Mauguière, F., & Bastuji, H. (1999). A differential brain response to the subject's own name persists during sleep. *Clinical Neurophysiology, 12*, 2153–2164.
- Pyykkönen, P., Matthews, D., & Järvikivi, J. (2010). Three-year-olds are sensitive to semantic prominence during online language comprehension: A visual world study of pronoun resolution. *Language and Cognitive Processes, 25*(1), 115–129.
- Ruigendijk, E., Friedmann, N., Novogrodsky, R., & Balaban, N. (2010). Symmetry in comprehension and production of pronouns: A comparison of German and Hebrew. *Lingua, 120*, 1991–2005.
- Runner, J. T., Sussman, R. S., & Tanenhaus, M. K. (2006). Processing reflexives and pronouns in picture noun phrases. *Cognitive Science, 30*(2), 193–241.
- Shelley-Tremblay, J., & Mack, A. (1999). Metacontrast masking and attention. *Psychological Science, 10*(6), 508–515.
- Sigurjónsdóttir, S., & Nina, H. (1992). Reflexivization and logophoricity: Evidence from the acquisition of Icelandic. *Language Acquisition, 2*(4), 359–413.
- Song, H., & Fisher, C. (2007). Discourse prominence effects on 2. 5-year-old children's interpretation of pronouns. *Lingua, 117*(11), 1959–1987.
- Speas, M. (1990). *Phrase structure in natural language*. Kluwer Academic Publishers.
- Su, Y., & Su, L. Y. (2015). Interpretation of logical words in mandarin-speaking children with autism spectrum disorders: Uncovering knowledge of semantics and pragmatics. *Journal of Autism & Developmental Disorders, 45*(7), 1–13.
- Swaab, T. Y., Camblin, C. C., & Gordon, P. C. (2004). Electrophysiological evidence for reversed lexical repetition effects in language processing. *Journal of Cognitive Neuroscience, 16*(5), 715–726.
- Tager-Flusberg, H. (2004). Strategies for conducting research on language in autism. *Journal of Autism and Developmental Disorders, 34*, 75–80.
- Tanenhaus, M. K., Spivey-Knowlton, M. J., Eberhard, K. M., & Sedivy, J. C. (1995). Integration of visual and linguistic information in spoken language comprehension. *Science, 268*, 1632–1634.
- Tek, S., & Naigles, L. (2017). The shape bias as a word-learning principle: Lessons from and for autism spectrum disorder. *Translational Issues in Psychological Science, 3*(1), 94.
- Terzi, A., Marinis, T., & Francis, K. (2016). The Interface of syntax with pragmatics and prosody in children with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 46*(8), 2692–2706.



- Terzi, A., Marinis, T., Kotsopoulou, A., & Francis, K. (2014). Grammatical abilities of greek-speaking children with autism. *Language Acquisition*, 21(1), 4–44.
- van Rij, J., Hollebrandse, B., & Hendriks, P. (2016). Children’s eye gaze reveals their use of discourse context in object pronoun resolution. In A. Holler, & K. Suckow (Eds.), *Empirical perspectives on anaphora resolution* (pp. 267–293).
- Wexler, K. (1999). Maturation and growth of grammar. In C. R. William & K. B. Tej (Eds.), *Handbook of Child Language Acquisition* (pp. 55–109). Academic Press.
- Whyte, E., Nelson, K., & Khan, K. (2011). Learning of idiomatic language expressions in a group intervention for children with autism. *Autism*, 17(4), 449–464.
- Whyte, E., Nelson, M., Keith, E., et al. (2013). Learning of idiomatic language expressions in a group intervention for children with autism. *Autism the International Journal of Research & Practice*.
- Wyun, G., Wang, J., Zhang, L., Wang, K., Yi, L., & Wu, Y. (2020). Actions speak louder than words: the role of action in self-referential advantage in children with autism. *Autism research*, 13(5), 810–820.
- Xiao, H., & Elsi, K. (2016). Processing the Chinese reflexive “ziji”: effects of featural constraints on anaphor resolution. *Frontiers in Psychology*, 7, 284.
- Xu, L. (1994). The antecedent of ziji (oneself). *Journal of Chinese Linguistics*, 22, 115–137.
- Xu, X. D., Jiang, X. M., & Zhou, X. L. (2013). Processing biological gender and number information during Chinese pronoun resolution: ERP evidence for functional differentiation. *Brain and Cognition*, 81, 223–236.
- Zhang, Y. X., Li, P., Piao, Q. H., Liu, Y. Y., Huang, Y. J., & Shu, H. (2013). Syntax does not necessarily precede semantics in sentence processing: ERP evidence from Chinese. *Brain and Language*, 126, 8–19.
- Zhang, Y. X., Yu, J., & Boland, J. E. (2010). Semantics does not need a processing. License from syntax in reading Chinese. *Journal of Experimental Psychology Learning, Memory, and Cognition*, 36, 765–781.
- Zhou, P., Ma, W., Zhan, L., & Ma, H. (2018). Using the visual world paradigm to study sentence comprehension in mandarin-speaking children with autism. *Journal of Visualized Experiments* (140).
- Zimmermann, J., Wolf, M., Bock, A., Peham, D., & Benecke, C. (2013). The way we refer to ourselves reflects how we relate to others: Associations between first-person pronoun use and interpersonal problems. *Journal of Research in Personality*, 47, 218–225.

**Publisher’s Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

## Authors and Affiliations

Gaowa Wuyun<sup>1</sup> · Long Zhang<sup>2,3</sup> · Kai Wang<sup>2,3</sup> · Yanhong Wu<sup>4,5</sup> 

✉ Yanhong Wu  
wuyh@pku.edu.cn

<sup>1</sup> Teachers’ College, Beijing Union University, Beijing, China

<sup>2</sup> Laboratory of Cognitive Neuropsychology, Collaborative Innovation Centre of Neuropsychiatric Disorder and Mental Health, Hefei, China

<sup>3</sup> Anhui Province Key Laboratory of Cognition and Neuropsychiatric Disorders, Hefei, China

<sup>4</sup> School of Psychological and Cognitive Sciences, Beijing Key Laboratory of Behavior and Mental Health, Peking University, 5 Yiheyuan Road, Beijing 100871, China

<sup>5</sup> Beijing Key Laboratory of Behavior and Mental Health, Peking University, Beijing, China