LINGUISTIC CODING OF SPACE IN MANDARIN-SPEAKING CHILDREN WITH AND WITHOUT AUTISM

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Linguistic Coding of Space in Mandarin-Speaking Children With and Without Autism

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CERTIFICATE OF ORIGINALITY

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Abstract

The present dissertation is concerned with the interpretation of spatial terms in Mandarin-speaking autistic children, compared to non-autistic children matched on receptive language ability. Spatial terms allow people to translate visuospatial perception into linguistic representations. Atypical visuospatial processing has been frequently reported in autistic people, which leads to certain predictions about their interpretation of spatial terms. Given that the interpretation of spatial terms is subjective to cross-cultural variations and that previous research mainly focused on individuals from western countries, the aim of this dissertation was to examine the interpretation of spatial terms in Mandarin-speaking autistic children. There are different types of spatial frames of reference (FoRs) underlying the interpretation of spatial terms. Three types — relative FoR, intrinsic FoR, and deictic FoR — were addressed in a collection of experimental studies.

The first study investigated Mandarin-speaking autistic and non-autistic children's interpretation of projective spatial terms ("front", "behind", "left", and "right") when locating an object in relation to an object without inherent orientation, where the underlying spatial FoR is the relative FoR. There are three variants of the relative FoR: translation, reflection, and rotation. Results showed that Mandarin-speaking non-autistic children, like Mandarin-speaking adults, accepted both translation and reflection variants of the relative FoR when evaluating the use of projective spatial terms in descriptions of a scene, while Mandarin-speaking autistic

children primarily relied on the translation variant. These findings suggest that Mandarin-speaking autistic children have difficulty in accepting multiple spatial FoRs, and the difficulty might be attributed to their theory of mind deficit.

The second study investigated the interpretation of projective spatial terms that were used to describe the position of an object in relation to an object with inherent orientation, to which both relative and intrinsic FoRs are applicable. Results showed that both autistic and non-autistic Mandarin-speaking children chiefly adopted the intrinsic FoR when the reference object had inherent front and back, as has been observed in Mandarin-speaking adults. There was no evidence for spontaneous activation of both intrinsic and relative FoRs in Mandarin speakers, which differs from the individuals in the West. The findings suggest that Mandarin-speaking autistic children, like their non-autistic peers, are more sensitive to the intrinsic FoR than to the relative FoR in the context where the reference object has inherent orientation. Additionally, the activation of the intrinsic FoR was found to be affected by the reference object's feature [± social] and associated with theory of mind understanding.

The third study examined Mandarin-speaking autistic and non-autistic children's knowledge of spatial demonstratives ("this", "that", "here", and "there") that encode spatial relationships depending upon the deictic FoR. Autistic children were found to perform worse than their non-autistic peers in comprehending the spatial demonstratives based on the deictic FoR in the condition where the children and the speaker (experimenter) had different perspectives, but not in the condition where they shared the same perspective. The findings suggest that autistic children have difficulties with spatial demonstratives in a certain situation. Furthermore, theory of mind understanding and executive function played a role in the interpretation of spatial demonstratives, suggesting impairment in the comprehension of spatial demonstratives might be linked to cognitive impairment.

The current dissertation offers evidence of selective atypical understanding of spatial terms previously overlooked in research on autism. The dissertation also highlights the effects of cognitive factors (theory of mind and/or executive function) on the interpretation of spatial terms. The dissertation's findings call for an increase in awareness among therapists and guardians of the profile of spatial language in autistic children. On a practical level, a spatial language-related training program could be included as part of speech intervention schemes. Additionally, intervention schemes targeting speech in autistic children could involve cognitive aspects such as theory of mind and executive function.

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List of Abbreviations

AIC: Akaike Information Criterion

ANOVA: Analysis of variance

AQ-C: Autism Spectrum Quotient-Chinese's Version

ASD: Autistic spectrum disorder

EF: executive function

FoR: frame of reference

ID: intellectual disability

IQ: intelligence quotient

MF-ER: mental flexibility measured by error rate switch cost

MF-RT: mental flexibility measured by reaction time switch cost

PPVT-R: the Peabody Picture Vocabulary Test-Revised (Chinese version)

SD: Standard deviation

ToM: theory of mind

VIF: variance inflation factor

WEIRD: Western, educated, industrialized, rich and democratic

WISC-IV (CN): the Wechsler Intelligence Scale for Children (Chinese version)

WM-B: working memory measured in the backward condition

WM-B: working memory measured in the forward condition

WPPSI-IV (CN): the Wechsler Preschool and Primary Scale of Intelligence (Chinese version)

Chapter 1. Introduction

1.1 Research Background

Autism spectrum disorder (ASD) is a neurodevelopmental disorder, characterized by a combination of early-onset deficits in social communication/interaction and highly restricted interests and unusually repetitive behaviors (American Psychiatric Association, 2013). Previous studies have reported an increased prevalence of the diagnosis of ASD in the West: from 1.57% among children in Cambridgeshire, England (age range: five to nine years; Baron-Cohen et al., 2009), to 1.69% among children living in the United States reported in 2014 (age: eight years; Baio et al., 2018) to 2.27% among children aged eight years in 2018 in the United States (Maenner et al., 2021). Lower prevalence has been reported in Asian countries such as 0.49% in China in a meta-analysis based on the published articles (Wang et al., 2018), which suggests the possibility of under-diagnosis in people who are not from Western, educated, industrialized, rich and democratic (WEIRD) societies (Henrich et al., 2010). A recent population-based epidemiological study by Zhou et al. (2020), using contemporary screening and diagnostic methods, reported a higher prevalence of ASD in China, that is, 0.70%. Given the high incidence of ASD, the need to improve our understanding of autistic people,[1] especially those who are not WEIRD, is urgent,

[1] The present dissertation considers the opinions of individuals who have been diagnosed as having ASD regarding the terms used to refer to them. Most autistic adults in Australia and the United Kingdom have a preference for identity-initial language (i.e., autistic person) over identity-final language (person with autism) (Bury et al., 2020; Kenny et al., 2016). Additionally, the use of identity-

since most people are not WEIRD but much research was conducted on WEIRD people (Henrich et al., 2010).

Spatial abilities are core components of cognitive development, which were found to positively correlate with scientific thought and mathematics achievement (Gardner, 2006, 2011; Rauscher & Shaw, 1998; Rauscher & Zupan, 2000). Thinking and talking about spatial relationships are omnipresent in everyday life, and are fundamental for understanding the world around us. Although autistic people are characterized by impairment in social communication/interaction (American Psychiatric Association, 2013), they seem to have overall enhancement in the visuospatial domain (Mitchell & Ropar, 2004; Stevenson & Gernsbacher, 2013). Notwithstanding the asymmetry between verbal and visuospatial abilities, it does not seem appropriate to treat the impairment and the strength in autistic people so categorically. This population's linguistic and cognitive profiles have been reported to be heterogeneous with a series of selective deficits. For example, while problems with pragmatic abilities have been consistently reported across the autistic spectrum such as the comprehension of figurative language and presupposition triggers found by our research team (Cheung, Rong, Chen, Chen, et al., 2020; Cheung, Rong, Chen, Leung, et al., 2020), autistic individuals' acquisition of grammatical aspects of language seems to follow the same developmental path as their non-autistic peers (Tager-

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final language presently prevalent in academia may aggravate the stigma connected with ASD (Gernsbacher, 2017). The present dissertation therefore applies identity-initial language.

Flusberg et al., 1990). Despite relatively intact grammar, specific difficulties have been observed in the area of morphosyntactic process, such as the use of perfective aspect marker (Zhou et al., 2015) and passive marker (Zhou et al., 2017), and the comprehension of double-complement subject control construction (Janke & Perovic, 2015). Regarding the visuospatial domain, autistic people are frequently reported to have superior performance in some tasks, such as the Embedded Figure task (Brosnan et al., 2012; de Jonge et al., 2006; Falter et al., 2008; Gregory & Plaisted-Grant, 2016; Hagmann et al., 2016; Jarrold et al., 2005; Jolliffe & Baron-Cohen, 1997; Kissine et al., 2012; Koh & Milne, 2012; Pellicano et al., 2006, 2005; Ropar & Mitchell, 2001) and the Block Design task (Caron et al., 2006; Ishida et al., 2009; Morgan et al., 2003; Pellicano et al., 2006; Pring et al., 2010; Shah & Frith, 1983, 1993; Soulières et al., 2011). However, a growing body of evidence points to autistic individuals' deficits in a range of spatial skills, including visual perspective-taking (Hamilton et al., 2009; Ni et al., 2021; Pearson et al., 2013; Yirmiya et al., 1994) and spatial working memory (see Lai et al., 2017 for a meta-analysis).

Visuospatial perception can be translated into linguistic representations using spatial terms, a domain of language that allows encoding the visuospatial relationships among objects (Laeng et al., 2003; Levinson & Wilkins, 2006; Talmy, 1983). Atypical visuospatial processing has been consistently reported in autistic individuals (overview in Mitchell & Ropar, 2004; Muth et al., 2014; Samson et al., 2012), which may impact their use of spatial terms. As the use of spatial terms, a key element of communicative interaction, allows communication of where someone or something is or which direction the person or the thing is moving, atypical use of these terms may have an influence on daily interaction. Nevertheless, the use of spatial terms in autistic individuals has been understudied.

1.2 Problems to Explore

The present dissertation is concerned with the interpretation of spatial terms in Mandarin-speaking autistic children without intellectual disability[2], compared to non-autistic children matched on receptive language ability. There are different types of spatial frames of reference (FoRs) underlying the use of spatial terms, including the relative FoR and the intrinsic FoR underlying the use of projective spatial terms, and the deictic FoR underlying the use of spatial demonstratives (Diessel, 2014; Levinson, 1996). The projective spatial terms (e.g., "front", "behind", "left", and "right") can provide directional information, while the spatial demonstratives (e.g., "this" and "that") can be used to indicate distance between the figure object (the object to be located) and the reference object (the object in reference to which the viewer represents spatial relationship) (Anderson & Keenan, 1985).

As for the use of projective spatial terms, when the reference object does not have inherent front and back (e.g., a ball), only the relative FoR is applicable. Three

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[2] The present dissertation focused on autistic children without intellectual disability because those with intellectual disability were found to be unable to complete the tasks designed for assessing the interpretation of spatial terms.

variants of the relative FoR have been proposed — reflection, translation, and rotation as shown in Figure 1.1 (Levinson, 2003). The reflection variant has been equated with the relative FoR in some standardized development tests and spatial language tests: that is, the reflection variant is assumed as the baseline for measuring spatial language, disregarding the other two variants (Bochyńska, Coventry, et al., 2020; Edwards et al., 2011; Surtees et al., 2012). A recent study revealed that, in the context where the reference object did not have inherent orientation, autistic individuals relied on a spatial FoR different from the one preferentially adopted by their non-autistic peers, resulting in an atypical use of projective spatial terms (Bochyńska, Coventry, et al., 2020). As only the reflection variant of the relative FoR was considered in Bochyńska, Coventry, et al. (2020), their autistic participants' sensitivity to other variants remains unknown. One aim of this dissertation was to identify the relative FoR underlying the interpretation of projective spatial terms in Mandarin-speaking autistic children in the context where the reference object did not have inherent front and back.

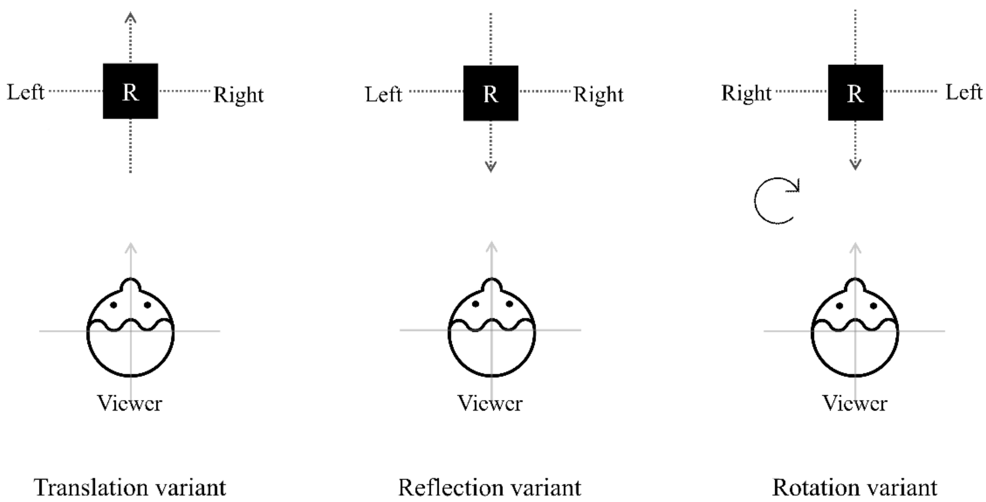

Figure 1.1. Three variants of the relative FoR.

Note: R = reference object. The front of a coordinate system is indicated by an arrow tip. Translation is to move the viewer's coordinate system to the reference object, without rotation or reflection; reflection is to move the viewer's coordinate system to the reference object by reversing the sagittal (antero-posterior) axis; rotation refers to a transformation of 180-degree rotation.

When the reference object has inherent front and back, both relative and intrinsic FoRs work, and the sensitivity to the latter will increase at the cost of the former (Beller et al., 2015). Figure 1.2 shows the illustration of the intrinsic FoR. There is evidence from non-autistic children and adults in Western countries showing that the use of projective spatial terms in the context of the reference object with inherent orientation frequently involves the activation of both relative and intrinsic FoRs (Carlson-Radvansky & Irwin, 1993; Carlson-Radvansky & Jiang, 1998; Surtees et al., 2012). However, whether the findings can be carried over to autistic and non-autistic children in mainland China remains unclear. In this dissertation, one aim was to examine whether the literature on the activation of multiple spatial FoRs can extend to the population with a different language background and a different neurodevelopmental condition.

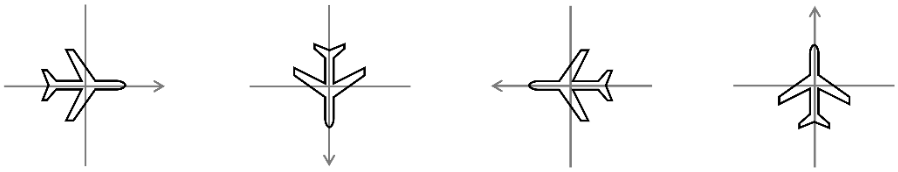

Figure 1.2. Illustration of the intrinsic FoR centered on a reference object with inherent orientation.

Note: The coordinate system is determined by the forward direction of the reference object (the airplane), independent of the viewer's coordinate system.

Regarding spatial demonstratives, one study suggests that autistic individuals have difficulties with the interpretation of these spatial terms based on the deictic FoR (Hobson, García-Pérez, et al., 2010). The deictic FoR is speaker-anchored: that is, the use of spatial demonstratives has reference to the location of the speaker who utters the words (Fillmore, 1975). Non-autistic children's comprehension of spatial demonstratives has been suggested to be associated with theory of mind (ToM) understanding (an ability to understand others' mental states; Baron-Cohen et al., 1985) and executive function (EF; a set of cognitive abilities that coordinate thoughts and actions for future goals; Miyake et al., 2000) (Chu & Minai, 2014, 2018). Hence, the two cognitive abilities were taken into account in the current dissertation to test whether ToM understanding and EF, which are more likely to be impaired in ASD (Baron-Cohen et al., 1985; Demetriou et al., 2018), also affected autistic children's comprehension of spatial demonstratives.

1.3 Structure of the Thesis

Before reporting experiments and results, Chapter 2 provides related literature including atypical perceptual processing and visuospatial processing in autistic individuals, and different types of spatial terms that can translate visuospatial perception into linguistic representations.

Chapter 3 presents the study that examined which variant of the relative FoR was preferentially adopted by Mandarin-speaking autistic and non-autistic children to interpret the projective spatial terms in the context of a featureless reference object. In addition, a post-test was conducted to explore whether the participants accepted other variants in addition to the one they preferentially adopted. The factors (autistic traits and ToM understanding) that had influence on the acceptance of more than one variant of the relative FoR were discussed.

Chapter 4 reports the experiment that tested whether Mandarin-speaking autistic and non-autistic children were able to spontaneously activate both intrinsic and relative FoRs in the context where the reference object had inherent orientation. Additionally, the influence of the reference object's feature [± social] on the sensitivity to the intrinsic FoR was investigated by involving the reference objects bearing the feature [+ social] (human) and those bearing the feature [- social] (furniture). Apart from the external factor (i.e., the feature of reference object), the influence of participants' ToM ability on the activation of the intrinsic FoR when interpreting the projective spatial terms was discussed.

Chapter 5 presents the experiment that was carried out to compare the comprehension of spatial demonstratives in autistic and non-autistic children speaking Mandarin. The children were asked to act out movements, according to the experimenter's instructions, containing spatial demonstratives in different conditions that varied as to whether or not the children and the experimenter shared the same perspective. Additionally, the factors (ToM understanding and EF) that had influence on spatial demonstrative interpretation in different conditions were discussed.

The results of different experimenters are discussed in Chapter 6. The last chapter summarizes the main findings and significance of the dissertation, and includes some considerations regarding the limitations and suggestions for future research.

Chapter 2. Literature Review

2.1 Atypical Perceptual Processing in Autistic Individuals

Atypical perceptual processing has been regarded as one of the associated characteristics of the autistic phenotype (American Psychiatric Association, 2013). The perceptual profile of autistic individuals shows a processing bias towards local details (Mottron et al., 2006; Mottron & Burack, 2001) accompanied by a weakness of synthesizing local elements into a coherent whole (Happé & Frith, 2006). Autism-related perceptual abnormalities can be generally grouped into hypersensitivity and hyposensitivity. As for the manifestation of hypersensitivity in the auditory modality, the superiority in sound identification and discrimination has been observed in autistic musical savants (Kanner, 1943; Miller, 2014; Mottron et al., 1999) and nonsavants (Bonnel et al., 2003; Heaton et al., 1998, 1999; O'Riordan & Passetti, 2006). Researchers have attributed autistic auditory strength to their hypersensitivity to isolated acoustic features (Haesen et al., 2011; O'Connor, 2012). When processing sounds where complex information (e.g., phonological information) needs to be considered and integrated, autistic individuals with reduced likelihood of integrating information often encounter difficulties (Chevallier et al., 2009; Diehl & Paul, 2013; Hesling et al., 2010; Paul et al., 2005; Wang et al., 2017; Yu et al., 2015). Regarding visuospatial processing, autistic individuals often demonstrate superiority in visual search and visual detection which are believed to require detail-focused processing (Baldassi et al., 2009; Gregory & Plaisted-Grant, 2016; Hagmann et al., 2016; Joseph et al., 2009; O'riordan, 2004; O'Riordan et al., 2001; Plaisted et al., 1998). As for visuospatial tasks that do not benefit from focusing on details, autistic individuals exhibit comparable or even worse performance than non-autistic controls (Beacher et al., 2012; Cardillo et al., 2020; Conson et al., 2013; Hamilton et al., 2009; Nejati et al., 2021). In short, relative to non-autistic individuals, the perceptual processing abilities in autistic individuals vary along a continuum from superiority to inferiority.

2.2 Visuospatial Processing in ASD

Visuospatial processing is crucial to normal cognitive and social development (O'riordan, 2004; O'Riordan et al., 2001). Autistic individuals who reportedly show atypical visuospatial processing patterns are characteristically impaired across these domains. Specifically, autistic visuospatial processing patterns alter the quality of the incoming information from the external world, which could compromise the product of the processing, thus affecting cognitive and social development. The visuospatial processing abnormalities of autistic individuals have been discussed in a number of systematic reviews (Mitchell & Ropar, 2004; Muth et al., 2014; Samson et al., 2012), which suggest that visuospatial processing performance in autistic individuals has been shown to be task-dependent.

2.2.1 Superior Visuospatial Abilities in ASD

Autistic visual strengths are frequently reported for visual search tasks (Baldassi et al., 2009; Gregory & Plaisted-Grant, 2016; Hagmann et al., 2016; Joseph et al., 2009;

O’riordan, 2004; O’Riordan et al., 2001; Plaisted et al., 1998), the Embedded Figure task (Brosnan et al., 2012; de Jonge et al., 2006; Falter et al., 2008; Gregory & Plaisted-Grant, 2016; Hagmann et al., 2016; Jarrold et al., 2005; Jolliffe & Baron-Cohen, 1997; Kissine et al., 2012; Koh & Milne, 2012; Pellicano et al., 2006, 2005; Ropar & Mitchell, 2001), and the Block Design task (Caron et al., 2006; Ishida et al., 2009; Morgan et al., 2003; Pellicano et al., 2006; Pring et al., 2010; Shah & Frith, 1983, 1993; Soulières et al., 2011). The visual search task consists of a set of pictures. The participant is required to judge whether a pre-specified target figure is present or absent in the pictures, with half of the pictures containing the target figure and distractors and the others only containing distractors. In the Embedded Figure task, after being presented with a target shape, the participant is required to locate the target shape in a picture depicting an image made up of geometrical shapes (e.g., circles, triangles, etc.). In the Block Design task, a set of cubes, with two faces painted red, two faces painted white, and two faces painted red and white are used to recreate a given pattern.

There are several explanations for autistic individuals’ superior performance on the tests of visual ability. Enhanced discrimination ability has been proposed to account for autistic superiority in visual research, which is corroborated by the studies of O’riordan (2004) and O’Riordan and Plaisted (2001). They found increases in target-distractor similarities had a significantly larger effect in non-autistic children and adults than in autistic children and adults respectively, which leads to the conclusion that autistic individuals have a superior visual discrimination ability. As the discriminability has been proven to be a factor determining search rate (Duncan & Humphreys, 1989; Treisman, 1988; Wolfe et al., 1989), autistic enhanced discrimination ability may account for their superior search performance (O'Riordan et al., 2001). Likewise, the discriminability, which underlies the ability to detect minor features or slight differences, could also explain the superior performance of autistic individuals on the Embedded Figure task, that is, to search for a shape embedded within a picture (O'riordan, 2004). With regard to the nature of enhanced discrimination ability in autistic individuals, it has been proposed that such enhancement may stem from their locally oriented perception (Happé & Frith, 2006; Mottron et al., 2006; Shah & Frith, 1983). While non-autistic individuals usually process incoming information as a whole, autistic individuals tend to focus attention on elemental parts. Local orientation allows autistic individuals to be detached from their prior knowledge when inspecting a visual display, which is beneficial to more objective and efficient processing (Brian & Bryson, 1996; Mitchell & Ropar, 2004). In other words, autistic individuals are less influenced by the meaning suggested by the whole picture. For example, when shown a picture depicting a pram-like shape made up of lines with embedded geometrical shapes, non-autistic individuals captivated by their prior knowledge regarding prams would be blind to the details, like a triangle — the embedded figure, whereas autistic individuals focusing attention on details would localize the embedded figure more effectively. Likewise, locally oriented perception could account for autistic strength in the Block Design task, that is, to use blocks (parts) to recreate a target pattern (whole) (Mottron et al., 2006; Muth et al., 2014). When the pattern was pre-segmented, non-autistic participants were found to perform better relative to their performance in the unsegmented condition. However autistic participants performed well whether the target pattern was pre-segmented or unsegmented, because they would analyze the elemental parts of the whole pattern separately even when presented unsegmented (Mitchell & Ropar, 2004; Shah & Frith, 1993). In a short, the findings of superior autistic performance in visuospatial tasks may be attributable to the possibility that autistic individuals have an aptitude for locally oriented perception.

2.2.2 Inferior Visuospatial Abilities in ASD

Autistic superiority is not observed in the visuospatial tasks that do not benefit from focusing attention on details, such as mental rotation (Beacher et al., 2012; Cardillo et al., 2020; Conson et al., 2013; Hamilton et al., 2009; Muth et al., 2014; Nejati et al., 2021) and level-1 visual perspective-taking (Baron-Cohen, 1989; Hobson, 1984; Tei et al., 2019; Warreyn et al., 2005). A level-1 visual perspective-taking task requires the participant to judge whether a person can see an object that may be occluded. In the task assessing mental rotation in autistic individuals (Hamilton et al., 2009), the participant is presented with an object placed on a turntable and four photographs of the object taken from four different angles. After covering the object and turning the turntable, the experimenter asks the participant to indicate which photograph matches the rotated object. Autistic superiority is absent in the mental rotation task and the level-1 visual perspective-taking task mainly because these tasks do not benefit from locally oriented perception, and thus there is no autistic advantage on such tasks.

Autistic individuals even show inferior performance on level-2 visual perspective-taking tasks relative to non-autistic controls (Hamilton et al., 2009; Ni et al., 2021; Pearson et al., 2013; Yirmiya et al., 1994). Several tasks were used in previous studies to assess level-2 visual perspective-taking, among which a review by Pearson et al. (2013) suggests the best is the one designed by Hamilton et al. (2009). The task is similar to the mental rotation task, but no turntable is involved. In addition, a boy/girl-like doll whose perspective differs from the participant's is introduced. After the object is covered, the participant is required to indicate which photograph matches what the doll sees. Autistic individuals are frequently reported to receive lower scores on the task assessing level-2 visual perspective than the comparison group. Their difficulty with visual perspective-taking is suggested to be associated with their impaired ToM, an ability to infer one's own and other people's mental states, such as beliefs, thoughts, etc. (Baron-Cohen et al., 1985; Hamilton et al., 2009; Premack & Woodruff, 1978). In order to imagine what the doll can see from a different perspective, it is necessary to decouple the representation in the doll's mind from that in one's own mind, for which ToM, the ability to infer one's own and other people's mental states, is required. Extensive studies examining autistic individuals over the previous three decades have consistently demonstrated the ToM deficit in this population (Andreou & Skrimpa, 2020; Baron-Cohen, 2001; Baron-Cohen et al., 1985; Frith, 2001). Thus, there is reason to hypothesize that autistic individuals may experience difficulties with visuospatial tasks that draw on the ability to take account of other people's minds.

2.3 Spatial Language

Visuospatial perception can be translated into linguistic representations using spatial language, a domain of language that allows encoding the visuospatial relationships among objects (Laeng et al., 2003; Levinson & Wilkins, 2006; Talmy, 1983). In Germanic languages, such as English, visuospatial relationships can be encoded using prepositions such as "on", "in", "behind", etc., while visuospatial relationships in Chinese languages cannot be expressed solely by prepositions (Li, 1988; Yip & Rimmington, 2006). Chinese languages usually employ a combination of prepositions and postpositions/localizers, e.g., 在…上(面) meaning "on…", where 在 is a preposition and 上(面) is a postposition/localizer. Other languages make use of different morphological or syntactic forms to express visuospatial relationships, such as prefix "do-" in Slavic languages and suffix "-da" in Turkish (Indefrey et al., 2017). The linguistic terms that describe static visuospatial relationships can be divided into two main categories: topological and projective spatial terms (Cuyckens, 1984; Frawley, 1992; Herskovits, 1981; Levinson, 2003; Talmy, 1983). The former denotes a visuospatial relationship in which the space occupied by one object coincides with the space occupied by another object (e.g., "in", "on"), whereas the latter denotes visuospatial relationships of objects separated in space (e.g., "front", "left"). There is evidence showing atypical use of these spatial terms in autistic individuals (Churchill, 1972; Ohta, 1987; Perkins et al., 2006; Ricks & Wing, 1975; Vulchanova, Talcott, Vulchanov, & Stankova, 2012; Vulchanova, Talcott, Vulchanov, Stankova, et al., 2012).

2.3.1 Topological Spatial Terms

Topological spatial terms refer to the terms that encode spatial contiguity such as support and containment (Frawley, 1992). One example of the topological spatial terms in English is “in” (a preposition), which can be used to describe the relation of containment, as in “a toy is in the box”. The corresponding topological spatial expression in Mandarin is 在…里(面), describing containment as in “玩具在盒子里(面)”. Regarding the spatial relation of support, the preposition “on” can be used to describe such relation in English, such as “a toy is on the table”. The counterpart in Mandarin is 在…上(面) in “玩具在桌子上(面)”.

A review of the literature suggests that spatial language acquisition builds on the development of space-related concepts (Choi & Bowerman, 1991; Johnston & Slobin, 1979; Wanska, 1984; Washington & Naremore, 1978). Infants of around six months of age can understand the concept of containment spatial relation (Casasola et al., 2003). After that, pre-verbal infants of around 10 months of age start forming the spatial concept of support (Papafragou et al., 2007). The linguistic terms encoding these spatial relations can be found in spontaneous productions of toddlers around two years old across languages (Gopnik, 1988; Jia, 2010; Johnston & Slobin, 1979; Kong & Wang, 2002; Slobin, 1982).

In a recent study by Bochyńska, Coventry, et al. (2020), one of the tasks tapped into the production of topological spatial terms. Autistic and non-autistic participants aged between nine and 27 years were required to name one object's position in relation to another object using topological spatial terms. Autistic participants exhibited comparable performance to non-autistic participants when describing the spatial relations denoted by topological spatial terms, suggesting that autistic children and adults did not encounter difficulties in using this type of spatial terms. Nevertheless, autistic individuals were found to perform significantly worse in the peripheral uses of topological spatial terms (e.g., "a bird in the tree") than their non-autistic peers (Bochyńska, 2018). As the two groups of individuals exhibited differences on the verbal comprehension index while they were matched on chronological age, the author posited that the successful mastery of the peripheral uses of these terms relied on the overall level of language ability (Bochyńska, 2018).

2.3.2 Projective Spatial Terms

Projective spatial terms, which encode spatial relationships of objects separated in space, can be used to describe the location of one object with respect to another object (Coventry & Garrod, 2004; Frawley, 1992). The former object is referred to as the figure object, while the latter is referred to as the reference object. A figure object can be located in different directions with respect to a reference object, which can be denoted by the corresponding projective spatial terms (e.g., “left”, “front”, “below”). Likewise, Mandarin conveys the direction to a reference object by using projective spatial terms, including 上(面) “above”, 下(面) “below”, 前(面) “front”, 后(面) “behind”, 左(边) “left”, and 右(边) “right”(Chao, 1968; Zhu, 1982).

Projective spatial terms tend to emerge slightly later than topological spatial terms (Johnston, 1984). The latter can be observed in two-year-old neurotypical children’s spontaneous production, while the former is usually reported in their speech by the age of three years (Ames & Learned, 1948; Boyd, 1914; Durkin, 1980; Jia, 2010; Kong & Wang, 2002; Nice, 1915). However, neurotypical children aged above three years still experience difficulties with projective spatial terms, especially those related to the horizontal plane (“front”, “behind”, “left”, and “right”). For example, when asked to place an object in front of another one, three- and four-year-old children would place the first object **on** the second one. Additionally, the children would incorrectly use “in” to describe “behind” configuration (Clark & Clark, 1977; Johnston, 1984). Some scholars have commented that the projective spatial terms are difficult to acquire because the use of this type of spatial terms depends upon spatial frame of reference (FoR), which changes in different contexts (Piaget & Inhelder, 1956). Spatial FoR usually refers to a spatial coordinate system, with a set of orthogonal axes centered on an origin (Levinson, 1996). In the context where the reference object has inherent front and back, the reference object can serve as the origin with the sagittal (antero-posterior) axis pointing in the direction the front of the reference object is facing. In such a case, describing the position of a figure object placed along the sagittal axis is independent of the viewer's position. For example, when the reference object is facing the viewer, the viewer can describe the position of an object between the reference object and the viewer as in front. The description will not be influenced by the change of viewer's position. However, in the context of the featureless reference object without identifiable front and back, the spatial FoR depends on the viewer's position. For example, when a figure object, a featureless reference object, and a viewer align, forming an invisible straight line, the viewer will describe the position of the figure object as in front or behind. Then, the viewer moves to a new position where the viewer and the reference object can form an invisible line orthogonal to the one formed by the figure and reference objects. This change of viewer's position will result in using different spatial terms for the same spatial location of the figure object. In contrast with the cases in the horizontal plane, the description of spatial relationships in the vertical plane, determined by gravity, is independent of spatial FoR and viewer's position.

Previous studies across languages have revealed that projective spatial terms related to the vertical plane (e.g., "below" and "above") are acquired before those related to the horizontal plane (Ames & Learned, 1948; Jia, 2010; Johnston & Slobin, 1979). Two- to three-year-old neurotypical children could appropriately use projective spatial terms to describe spatial relationships in the vertical plane (Kong & Wang, 2002; Nice, 1915). After the age of four, they could successfully interpret "front" and "behind" in the context where the reference object has inherent front and back, whereas in the context of a featureless reference object, around 35% of them had difficulties with these spatial terms (Cox, 1981; Kuczaj & Maratsos, 1975). With advancing age, more neurotypical children would consider the viewer's position and perspective, like adults, when locating the position of a figure object described by "front" or "behind" with respect to a featureless reference object (Cox, 1979, 1981; Kuczaj & Maratsos, 1975). With regard to the use of projective spatial terms in autistic individuals, a study examining spatial language of Dutch-speaking autistic children and adults (age range: nine to 27 years) observed that some autistic participants used "front" and "behind" inappropriately for locations along the vertical axis that should have been described using "above" and "below" (Bochyńska, Vulchanova, et al., 2020). In another study, Bochyńska and colleagues examined the comprehension of "front" and "behind" by the same group of participants (Bochyńska, Coventry, et al., 2020). The results showed that non-autistic children consistently encoded the position of the figure object in the space between the viewer and the featureless reference object as in front, whereas some autistic participants encoded the space as behind the reference object, resulting in front-behind inversion.

Regarding the acquisition of "left" and "right", four-year-old neurotypical children were found to map these words to their own body parts correctly, that is, they could understand "the left/right side" (Shusterman & Spelke, 2005). One thing to note is that the use of "left" and "right" in that case does not involve projective space.

After the age of five, neurotypical children obtain partial knowledge about “left” and “right” as projective spatial terms, as reflected by the fact that they could locate the object “to the left/right of” another object as well as their own bodies (Shusterman & Li, 2016). Zhang et al. (1987) carried out an experiment to investigate the comprehension of “left” and “right” used as projective spatial terms in Mandarin-speaking neurotypical children aged from two to six years. The results showed that 100% of Mandarin-speaking neurotypical five-year-olds could correctly comprehend “right”, while the percentage of children in this age group who could successfully interpret “left” was 67%, which increased to 75% when they were six years old (Zhang et al., 1987). The studies investigating the use of “left” and “right” by autistic individuals did not report difficulty in the production or comprehension of these projective spatial terms (Bochyńska, Coventry, et al., 2020; Bochyńska, Vulchanova, et al., 2020). More specifically, autistic and non-autistic participants showed comparable performance in using “left” and “right” to specify the figure object’s direction in relation to the reference object (Bochyńska, Coventry, et al., 2020). In addition, the two groups of participants did not differ in locating a figure object after hearing a sentence describing its direction in relation to a reference object (e.g., object A is to the left/right of object B, Bochyńska, Vulchanova, et al., 2020).

As mentioned, the use of projective spatial terms depends upon spatial FoRs. There are two primary types of spatial FoRs underlying this class of spatial terms, namely relative and intrinsic FoRs (Carlson-Radvansky & Logan, 1997; Garnham, 1989; Levelt, 1984; Levinson, 1996). Relative FoR is a kind of viewer-centered frame, where the coordinate system of reference object is determined by the viewer's coordinate system, while intrinsic FoR belongs to an object-centered frame, where the coordinate system of reference object is determined by the reference object's forward direction. Therefore, intrinsic FoR is not applicable to reference objects that do have identifiable front and back. For example, when a cube without pattern serves as the reference object, the front or the back of the reference object, which is necessary for determining the sagittal and the transverse axes, cannot be identified. Thus, there is no coordinate system centered on the reference object that can serve as a reference system. To locate in relation to a featureless reference object, one can adopt the relative FoR, as this viewer-centered frame presupposes a viewer, and the viewer's coordinate system can derive a set of coordinates on the reference object (i.e., a secondary coordinate system). That is, for the relative FoR, there are two related coordinate systems: primary and secondary, with the latter derived from the former.

Levinson (2003) proposed three ways to derive the secondary coordinate system: translation, reflection, and rotation, as shown in Figure 2.1. As secondary coordinates derived from different sources do not differ in terms of their vertical axis, which is determined by gravity and is fixed, this dissertation focus on the horizontal planes (i.e., sagittal and transverse axes), thus using top view for illustration. As shown in Figure 2.1, translation is to move the viewer's coordinate system to the reference object, forming a secondary coordinate system, without rotation or reflection. Specifically, the front of the secondary coordinate system is assigned to the space beyond the reference object; the back is the space between the viewer and the reference object. The left is assigned to the side that is the same as that of the viewer, and so is the right. The secondary coordinate system derived through this process is shown in the left panel of Figure 2.1. A secondary coordinate system can also be derived by reflection (see the middle panel of Figure 2.1). In this way, the sagittal axis is reversed: the tip of the arrow of the derived coordinate system, which indicates the front, points in the opposite direction relative to the viewer's coordinate system. As for the transverse axis of the derived coordinate system, no reversal is involved: that is, the left of the secondary coordinate system is assigned to the side that is the same as that of the viewer, and so is the right. The last way to derive a secondary coordinate system is a transformation of 180-degree rotation, resulting in reversed sagittal and transverse axes. As shown in the right panel of Figure 2.1, the front of the secondary coordinate system is assigned to the space between the viewer and the reference object; the back is the space beyond the reference object. Meanwhile, the left is assigned to the side falling into the right region of the viewer, while the right side falls into the left region of the viewer.

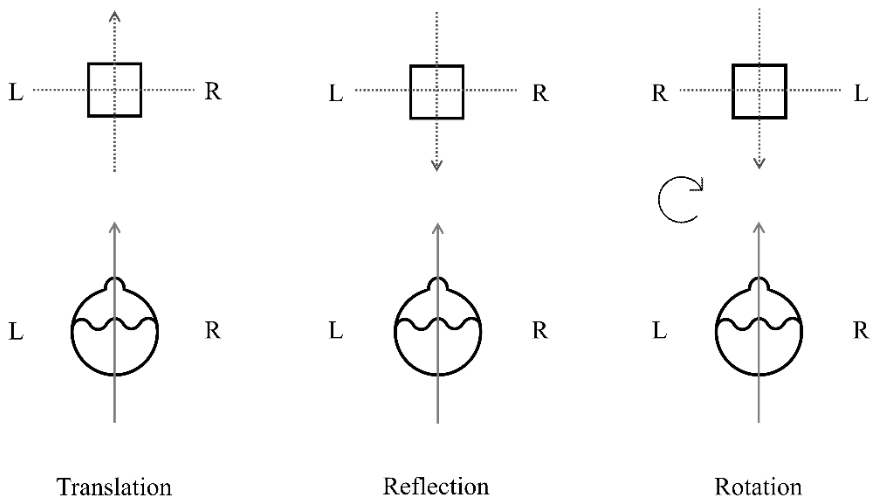

Figure 2.1. Three ways to derive a secondary coordinate system based on the coordinate system anchored in the viewer.

Note: A secondary coordinate system is indicated by dashed lines. The front of a coordinate system is indicated by the tip of an arrow. L = left; R = right.

Both relative and intrinsic FoRs can be adopted when the reference objects have inherent fronts and backs. Take a toy airplane. The front of the toy airplane is the facet that lies in the direction of motion, which provides the basis for a coordinate system. After designating the front, 90-degree rotations will yield side, back, and side, forming a coordinate system centered on the reference object (see the left panel of Figure 2.2). This coordinate system is determined by the intrinsic features of the reference object, which is independent of the viewer's coordinate system. Although there is an intrinsic FoR centered on the toy airplane, the viewer can still adopt a relative FoR to describe the spatial relations when the toy airplane serves as the reference object. The viewer can map his/her own coordinate system onto the reference object, deriving a secondary coordinate system. As introduced above, the mapping involves translation, reflection, or rotation, which is also illustrated in Figure 2.2 for comparison between intrinsic and relative FoRs.

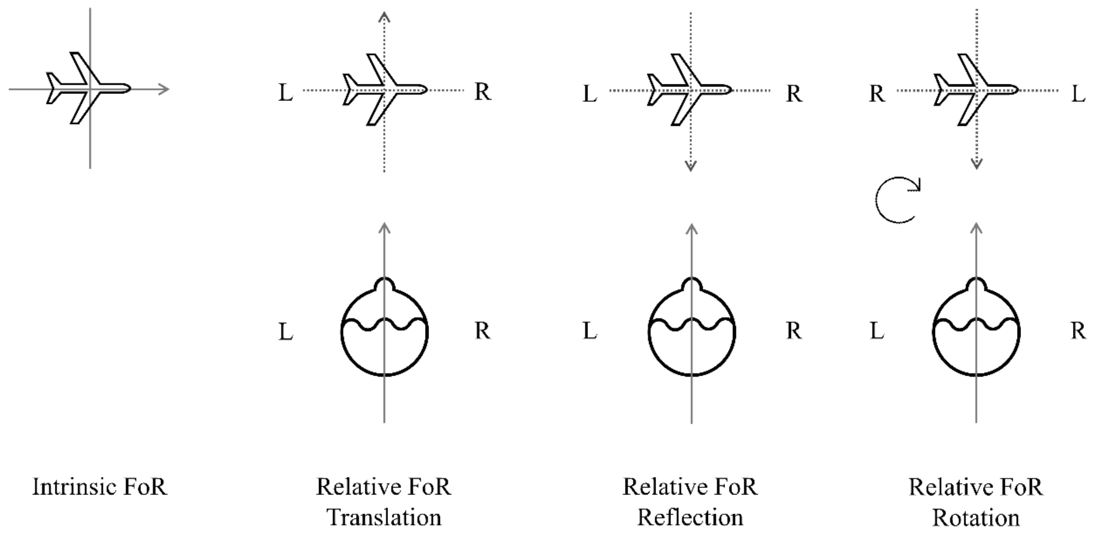

Figure 2.2. The intrinsic FoR and the relative FoR.

Note: The front of a coordinate system is indicated by the tip of an arrow. A secondary coordinate system is indicated by dashed lines. L = left; R = right.

Neurotypical people with different language backgrounds differ in the preference for the ways to derive secondary coordinate systems (Levinson, 2003). A preference for using the reflection strategy to map the secondary coordinate system has been found in English, German, and Norwegian neurotypical speakers, whereas for Mandarin and Tongan neurotypical speakers the preference is for using the translation strategy (Beller et al., 2016; Bennardo, 2000; Bochyńska, Coventry, et al., 2020). A recent study whose participants were from Norway found that autistic individuals used the translation strategy differently from their non-autistic peers who consistently used the reflection strategy (Bochyńska, Coventry, et al., 2020). Given the difference between Norwegian and Mandarin speakers in the preference for mapping strategies (reflection vs. translation), the findings based on Norwegian autistic individuals may not be carried over to autistic individuals speaking Mandarin. Therefore, one aim of the current study is to identify Mandarin-speaking autistic children's preference for the way to form a relative FoR when interpreting projective spatial terms (see Chapter 3 for more details). As mentioned above, six-year-old non-autistic children still experience difficulty with projective spatial terms, especially left (Shusterman & Spelke, 2005; Zhang et al., 1987). To avoid the possibility that prior knowledge of these terms affects the performance on the task designed for identifying the relative FoR preference, the current study focused on children aged around seven years old.

In addition, there is evidence from neurotypical individuals that more than one spatial FoR is activated spontaneously when evaluating the use of projective spatial terms in the spatial description of a scene (Carlson-Radvansky & Irwin, 1993; Carlson-Radvansky & Jiang, 1998; Deng & Yip, 2016; Guo, 2004; Surtees et al., 2012). For instance, in Surtees et al. (2012), English-speaking neurotypical children aged between six and 11 years were required to judge whether a viewer used appropriate projective spatial terms to describe the spatial relationship between two objects (see Figure 2.3 for examples). The left panel of Figure 2.3 shows the viewer who adopted the intrinsic FoR describing the position of the ball in this way: the ball is behind the airplane,[3] while the right panel shows the viewer utters “the ball is in front of the airplane”, which shows that the viewer adopts the relative FoR and uses the reflection strategy to map the secondary coordinate system. The authors found that the participants accepted both descriptions, suggesting that more than one type of spatial FoR can be activated in neurotypical children’s brains when they evaluate spatial descriptions (Surtees et al., 2012). However, little is known about autistic children’s sensitivity to more than one type of spatial FoR. Therefore, one aim of the current study was to examine whether autistic children were able to activate both intrinsic and relative FoRs when making judgments about the use of projective spatial terms in spatial descriptions (see Chapter 4 for more details).

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[3] The viewer who adopts relative FoR and uses the translation strategy will also think “the ball is behind the airplane”. Given the participants were English speakers, Surtees et al. (2012) only considered one way of deriving a secondary coordinate system, the reflection strategy, ignoring translation and rotation. Therefore, in Surtees et al. (2012), the description “the ball is behind the airplane” reflects the adoption of intrinsic FoR.

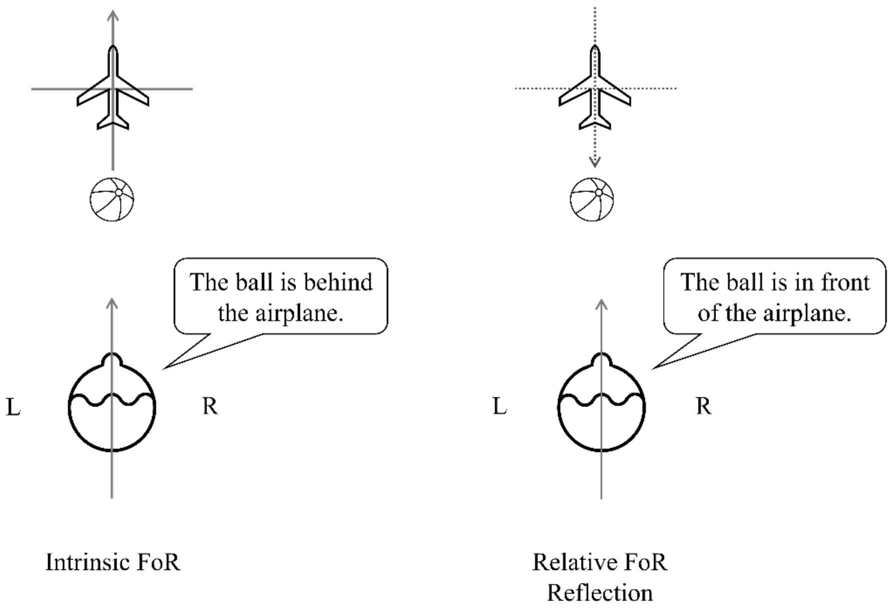

Figure 2.3. Examples of descriptions of spatial relationships between two objects when adopting intrinsic or relative FoR.

2.3.3 Spatial Deictic Terms

There is a class of spatial terms that encodes spatial relationships depending upon a spatial FoR distinct from the intrinsic and relative FoRs: spatial deictic terms (alternative terminology: spatial demonstratives; Diessel, 2014). Spatial demonstratives invoke a deictic FoR that is speaker-anchored: that is, the use of spatial demonstratives, such as “this” and “that”, and “here” and “there”, has reference to the location of the speaker who utters the words (Fillmore, 1975). For example, “this” is used to encode a place that is near the speaker, whereas “that” is used to encode a more distant place (Clark & Sengul, 1978; Levinson, 1983; Tfouni &

Klatzky, 1983). According to Diessel (1999), almost all languages have at least a pair of spatial demonstratives that can differentiate between places at different distances to the origin, which is usually centered on the speaker. In Mandarin, there are corresponding spatial demonstratives for “this” and “that”, and “here” and “there”, as summarized in Table 2.1 below.

Table 2.1. English and Mandarin spatial demonstratives.

Target in space	Proximity		Non-proximity	
	English	Mandarin	English	Mandarin
Entity-referring	This	这	That	那
Place-referring	Here	这里/这儿	There	那里/那儿

Please note that the difference between the entity- and place-referring demonstratives (in Table 2.1) should not be considered as absolute. The entity-referring demonstratives encode relation to both entity and position/place in a broad sense. For example, the phrase 这个/那个苹果 “this/that apple” can be paraphrased as “the apple near/distal to the speaker” or “the apple here/there”. In the phrase, the noun 苹果 “apple” identifies an entity, while the demonstrative 这/那 “this/that” signals the noun’s position in terms of proximity or non-proximity in relation to the speaker’s location.

According to three case studies published in The Pedagogical Seminary, Western neurotypical children’s spatial demonstratives usually appear by the age of two and a half years (Boyd, 1914; Grant, 1915; Nice, 1915). The production of spatial demonstratives in toddlers' one- and two-word utterances has been agreed to be early and frequent in many studies in various languages, including English, German, Japanese, Korean, Italian, etc. (Clark & Sengul, 1978, p. 459). However, some studies revealed that toddlers who could spontaneously produce spatial demonstratives did not fully master these terms (Huxley, 1970; Snyder, 1914). In order for a hearer to correctly interpret spatial demonstratives, he/she needs to consider the speaker's position and perspective (de Villiers & de Villiers, 1974). Otherwise, the hearer may show spatial demonstrative reversals, that is, interpreting "this" as referring to the place distal to the speaker and interpreting "that" as referring to the place near the speaker. Piaget (1959) argued that neurotypical children below seven years of age were not able to take into account other persons' perspectives. This argument suggests that neurotypical children even up to seven years old do not seem immune from making mistakes when interpreting spatial demonstratives. However, contrary to Piaget's hypothesis, de Villiers and de Villiers (1974) found that English-speaking neurotypical four-year-old children were capable of shifting to the speaker's perspective when comprehending spatial demonstratives in a situation where the shift was needed. This finding indicates that it is incorrect to propose that neurotypical children below seven years of age are unable to consider other people's points of view or take/switch perspective.

Additionally, there is some disagreement on which member of a spatial demonstrative pair is acquired earlier, the one that denotes the proximal place that is relatively near ("here" and "this") or the one that denotes the more distant place ("there" and "that"). Some studies found that "here" and "this" were developed earlier than "there" and "that", whereas some showed that "there" and "that" were the simpler terms (Tfouni & Klatzky, 1983; Zhao, 2007). Among these spatial demonstratives, Tfouni and Klatzky (1983) found it was more difficult to comprehend "this" and "here" than "that" and "there" for English-speaking neurotypical children. Their explanation for this finding is that the former is marked, whereas the latter is unmarked. In general, the marked member of a pair will be mastered later than the unmarked one (Clark, 1971; Donaldson & Balfour, 1968; Klatzky et al., 1973). However, Zhao (2007) found that Mandarin-speaking neurotypical children performed better in the comprehension of 这 "this" and 这里 "here" than 那 "that" and 那里 "there".

Regarding the spatial demonstratives in autistic individuals, it has been reported that this population have difficulty in the production and comprehension of this type of spatial terms (Hobson, García-Pérez, et al., 2010; Landry & Loveland, 1988, 1989; Loveland & Landry, 1986). Loveland and Landry conducted a series of studies to examine the production of spatial demonstratives in English-speaking autistic children and adolescents (age range: five to 13 years; Landry & Loveland, 1988, 1989; Loveland & Landry, 1986). They found autistic participants produced less spatial demonstratives than the language-delayed controls matched on chronological age. Hobson et al. (2010) examined the comprehension of spatial demonstratives in English-speaking autistic children and adolescents aged between five to 14 years as well as their production of spatial demonstratives. Their performance was compared to that of a group of children and adolescents without a diagnosis of ASD but with intellectual disability, with two groups of participants matched on language ability and chronological age. Results showed that the autistic group was less accurate in comprehending spatial demonstratives, and the participants in the autistic group used “this” or “here” to refer to a place that was distal to themselves. However, Hobson et al. (2010) did not compare participants’ use of “that” and “there” with that of “this” and “here”, leaving it unsettled as to which member of a spatial demonstrative pair is mastered better by autistic individuals. Therefore, the gap will be addressed by examining the comprehension of two pairs of spatial demonstratives in autistic children (see Chapter 5 for more details). As described above, some four-year-old non-autistic children were able to take speaker’s perspective to interpret spatial demonstratives, and autistic children have demonstrated a delay in spatial demonstrative interpretation (de Villiers & de Villiers, 1974; Hobson et al., 2010). Thus, the youngest children to be recruited for this research was four years old.

Chapter 3. Relative Frame of Reference Underlying the Interpretation of Projective Spatial Terms in Mandarin-Speaking Autistic and Non-Autistic Children

3.1 Introduction

Relative FoR is a viewer-centered FoR, based on which, using the projective spatial terms to locate an object depends upon the viewer's perspective. This is because the process of locating relies upon the coordinate system of the reference object, which is projected from the body of the viewer (i.e., the viewer's front and back, and left and right). Levinson (2003) proposed three ways of projection: translation, reflection, and rotation, as shown in Figure 2.1, giving rise to three variants of relative FoR.

Of the three variants of the relative FoR, the reflection variant has been considered as the canonical one (Clark, 1971). The reflection variant is even presupposed as the prototype of the relative FoR in some development tests, e.g., the New Reynell Developmental Language Scales (Edwards et al., 2011), and the spatial language tests (Markostamou & Coventry, 2022). Beller et al. (2015) pointed out the necessity to acknowledge different variants of the relative FoR when examining the use of projective spatial terms. With all three variants of relative FoR taken into consideration, some recent studies examined the variation in relative FoR preference (Beller et al., 2016; Hüther et al., 2016). A preference for the reflection variant of the relative FoR has been found in German and English neurotypical speakers, whereas

Mandarin and Tongan neurotypical speakers were found to have a preference for the translation variant (Beller et al., 2015, 2016; Bennardo, 2000).

Although Mandarin speakers show a *preference* for the translation variant, they seem to *accept* the use of projective spatial terms based on both translation and reflection variants (Deng & Yip, 2016; Guo, 2004, 2008). For instance, in Deng and Yip (2016), Mandarin-speaking children (age range: three to six years) and adults were required to select out of a pair of sentences the one that described pictures correctly. For each pair of sentences containing “left” and “right”, there was a picture depicting a figure object at the side of a featureless reference object (e.g., a ball). When seeing pictures with the figure object on its right panel and the reference object on its left panel, the participants consistently selected the sentence containing “right”. This reflects that Mandarin speakers reject the rotation variant. For each pair of sentences containing “front” and “behind”, there was a picture depicting two objects aligning along the sagittal axis. When seeing a picture with the figure object on the far side beyond the reference object, some participants judged both sentences as correct descriptions of the picture. The findings suggest that both translation and reflection variants can serve as the underlying spatial FoRs for the use of projective spatial terms in Mandarin speakers.

To the best of my knowledge, there is only one study addressing the relative FoR in autistic individuals: Bochyńska and colleagues (2020) investigated the interpretation of projective spatial terms, including “front” and “behind”, and “left” and “right”, in autistic individuals from Norway. The task was to judge the statements about the positions of figure objects in relation to reference objects as true or false. The scoring method was based on the reflection variant, which was presupposed as the prototype by the authors. In other words, the participants who made judgments depending on the reflection variant would obtain points. The autistic group’s points were significantly lower relative to the non-autistic group. The finding indicates that there is divergence between autistic and non-autistic Norwegians in the preference for the reflection variant when using projective spatial terms to describe spatial relationships. However, the study did not reveal autistic individuals’ relative FoR preference, neither did the study uncover whether there is more than one variant of relative FoR underlying autistic individuals’ interpretation of projective spatial terms, since other variants of relative FoR were not taken into account.

An aim of the present study was to investigate the relative FoR underlying Mandarin-speaking autistic children’s interpretation of projective spatial terms, compared to Mandarin-speaking non-autistic children. Previous studies suggest that six-year-old non-autistic children still have difficulty in interpreting projective spatial terms (Shusterman & Spelke, 2005; Zhang et al., 1987). To avoid the possibility that prior knowledge of these terms affects the performance on the task designed for identifying the relative FoR preference, the current study focused on children around seven years old. Considering autistic individuals are characterized by restricted or repetitive linguistic representations (American Psychiatric Association, 2013), this population may be obsessive about one variant when using spatial terms to encode space, and reject other variants. Based on the characteristic of autistic individuals — "egocentric in the extreme" (Frith & de Vignemont, 2005; Kanner, 1943), it is hypothesized that this population may tend to rely upon the translation variant of the relative FoR, as relying upon this variant has been regarded as an indication of egocentrism (Deng & Yip, 2016; Li, 1988). Depending on the translation variant, people view the reference object as aligned in the same direction as themselves. The reflection and rotation variants, on the other hand, require the viewers to imagine that the forward direction of the reference object is counter to their own forward direction. The shift from the translation variant to the reflection or the rotation variant reflects a process of decentering, which seems to be difficult for autistic individuals, who are characterized by an extreme orientation toward the self[4] and mind blindness. Lacking the capacity to read mind, which is referred to as ToM, autistic individuals have a problem with the shift to others' mental states (Begeer et al., 2012; Moses & Flavell, 1990; Zhou et al., 2019). Thus, this population may rely solely upon the translation variant to encode space. As for non-autistic children, according to the canonical encounter account, their choice of relative FoR is expected to be different from autistic children's. One characteristic of most daily interactions between two persons is that they will face each other (see the left panel of Figure 3.1), labeled as the canonical encounter (Clark, 1973). The canonical encounter will influence the

[4] In "autism spectrum disorder", the term "autism" from Greek means "self".

projection of the sagittal axis (i.e., the assignment of front and back) in the way shown in the right panel of Figure 3.1. More specifically, the early front-back concept rests on the physical and functional differences of human bodies, and “front” will be interpreted to mean near the face while “behind” will be interpreted to mean near the back (Harris & Strommen, 1972). Therefore, during the normal interactions that are usually carried out face-to-face, “front” will be interpreted to mean the space between the two persons, that is, near their faces, and “behind” will be interpreted to mean the far side for each person, that is, near their backs. Thus, non-autistic children, who are more likely to be affected by the canonical encounter, may rely on the reflection variant to interpret the projective spatial terms.

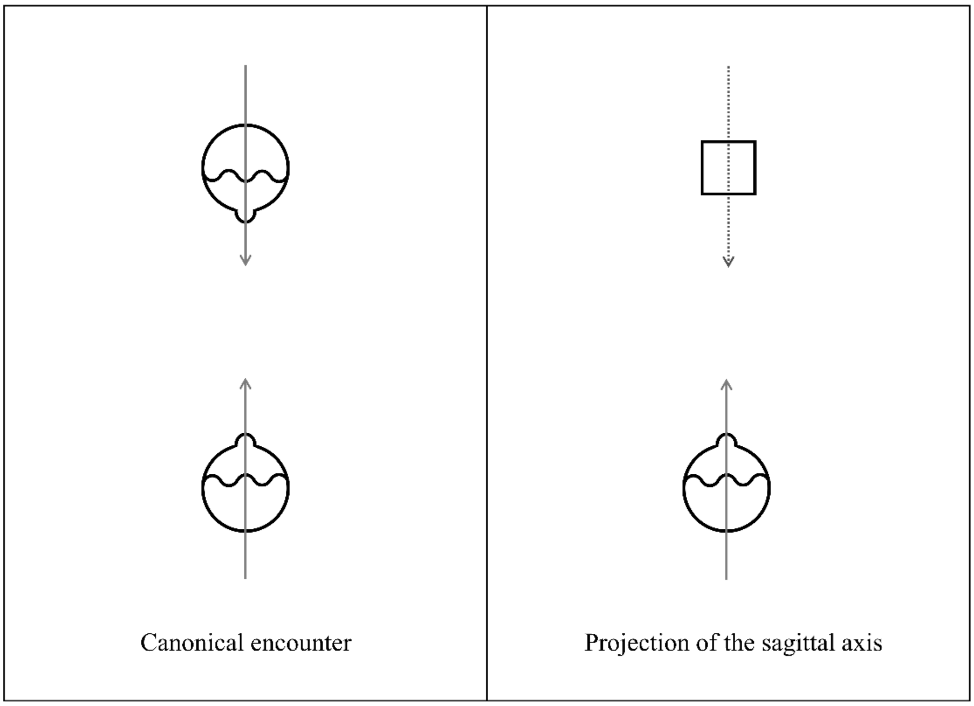

Figure 3.1. The illustration of the canonical encounter and the projection of the sagittal axis.

To conclude, this study aimed to address three main questions: (1) whether Mandarin-speaking non-autistic children and autistic children without intellectual disability (ID) differ in relying on relative FoR when interpreting the projective spatial terms (“front”, “behind”, “left”, and “right”), (2) whether the two groups of children accept multiple variants of relative FoR when interpreting the projective spatial terms, and (3) whether the acceptance of multiple variants of relative FoR is associated with the capacity to read mind (assessed using the ToM test) or autistic traits (assessed using the Autism Spectrum Quotient).

3.2 Method

3.2.1 Participants

Autistic group. Twenty-five Mandarin-speaking autistic children without ID were recruited through the Xiaohaixing Service Center for Special Children and the Yuxing Training School for Autistic Children, Xiamen, China. To participate in this study, all children in the autistic group had to have received an official clinical diagnosis of ASD by a pediatrician or a clinical psycholinguist, either in public hospitals or in child assessment centers using the criteria in the fourth (American Psychiatric Association, 2000) or fifth (American Psychiatric Association, 2013) edition of the Diagnostic and Statistical Manual of Mental Disorders. All clinical records of applicants who attempted to sign up for the autistic group were inspected and those that lacked detailed information about the official source of diagnosis were not included in either autistic or non-autistic group. To further confirm the autistic participants' diagnoses, each of them was evaluated using the Autism Spectrum Quotient-Chinese Version (AQ-C; Sun et al., 2019). One child did not meet the autism cut-off on the AQ-C and her data were not included in the final analyses. Autistic individuals without ID are those with an intelligence quotient (IQ) score not lower than two standard deviations below the population mean (American Psychiatric Association, 2013). IQ scores of autistic participants were measured using the Wechsler Intelligence Scale for Children (Chinese version) (4th ed.; WISC-IV (CN); Zhang, 2008)[5]. The standard deviation and mean of the intelligence test are 15 and 100, respectively, so the cut-off point for ID is 70 (100 – 15 × 2). The autistic participants with IQ ⩾ 70 were allowed to proceed to the actual test. To ensure the children could fully understand the instructions of the tasks, only those who scored above cut-off levels on a standardized language test, the Peabody Picture Vocabulary Test-Revised (Sang & Miao, 1990), were included. In addition, to avoid the inclusion of children who did not understand the concepts of front and back, and left and right, a pretest assessing the knowledge of "front" and "behind", and "left" and "right" was administered. A minimum accuracy score of 80% in the pretest was required to proceed. All autistic participants met the accuracy criterion.

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[5] WISC-IV (CN) was not administered in non-autistic children for two reasons. First, IQ score only served as an inclusion criterion for autistic group. Second, no previous study seems to suggest IQ score is a predictor of interpretation of spatial terms. WISC-IV (CN) measures verbal and non-verbal abilities (e.g., working memory, processing speed, etc.). The abilities of interest would be assessed using separate tests.

Non-autistic group. Twenty-eight Mandarin-speaking non-autistic children were recruited via advertisements posted on the WeChat a social media platform or flyers sent to the Xiamen Foreign Language School Affiliated School and the Xiamen Haicang School Affiliated to Beijing Normal University. Exclusion criteria for the non-autistic participants were diagnosis or suspicion of a language or mental health disorder or a learning disability. They were also screened using the AQ-C, and none of them met the autism cut-off level (Sun et al., 2019). Three of the 28 non-autistic participants were not included in the final analyses, because they failed to meet the accuracy criterion (80%) on the pretest assessing the knowledge of "front" and "behind", and "left" and "right". The other 25 non-autistic participants all scored above cut-off levels on the Peabody Picture Vocabulary Test-Revised (Sang & Miao, 1990).

The overview of autistic and non-autistic participant characteristics is presented in Table 3.1. Mann-Whitney *U*-tests were performed to compare the two groups of participants' chronological age and AQ-C scores, since their chronological age and AQ-C scores were not normally distributed according to the results of the Shapiro-Wilk tests (p-values $< .05$). The results showed the autistic group was significantly older than the non-autistic group ($U = 735.50$, $p = .001$), and scored significantly higher on the AQ-C than the non-autistic group ($U = 899.00$, $p < .001$). The groups of participants were sampled from normal distributions with equal variances in terms of receptive language ability, so a two-sample t-test was conducted to compare the two groups in receptive language ability. No significant difference was detected between the two groups in terms of receptive language ability (t = 1.01, p = .317).

Table 3.1. Description of the autistic and non-autistic participants.

	Autistic (n = 24)	Non-autistic (n = 25)
Sex (boys : girls)	19：5	13：12
Chronological age (SD)	7.82 (1.02)	7.25 (.83)
Receptive language ability (SD)	117.29 (16.88)	121.74 (13.65)
Autism-spectrum quotient (SD)	59.63 (7.13)	29.04 (7.95)
IQ (SD)	94.25 (11.29)	N.A.

In addition, 23 Mandarin-speaking adults were recruited (age range: 22 to 33 years, mean age = 27.96 years). They only participated in the task regarding the spatial terms.

Ethical approval for the study was obtained from the Human Subjects Ethics Subcommittee at the Hong Kong Polytechnic University. All child participants' legal guardians and adult participants provided written informed consent in compliance with the Human Subjects Ethics Subcommittee guidelines prior to the start of the tests.

3.2.2 Tasks

The present study consisted of five tests: the relative FoR test, the ToM test, the receptive language ability test, intelligence quotient test, and the Autism Spectrum

Quotient. Autistic participants were tested individually in a quiet room at the Xiaohaixing Service Center for Special Children or the Yuxing Training School for Autistic Children, while non-autistic participants were tested in the resource rooms of primary schools. The tests were administered in a fixed order: first, the intelligence quotient test (for autistic participants only); second, the receptive language ability test; third, the relative FoR test; and fourth, the ToM test. The Autism Spectrum Quotient was completed by the participants' teachers or guardians.

3.2.2.1 The Intelligence Quotient Test

The Wechsler Intelligence Scale for Children (Chinese version) (fourth ed.; WISC-IV (CN); Zhang, 2008) was administered to measure autistic participants' IQ. Autistic participants were required to have full-scale IQ scores equal to or higher than 70 (American Psychiatric Association, 2013). WISC-IV (CN) is a norm-referenced standardized intelligence test for children aged six years to 18 years 11 months in mainland China. It consists of 14 subtests, and the full-scale IQ is based on 10 of the 14 subtests measuring abilities from four aspects: verbal comprehension (three subtests: Similarities, Vocabulary, and Comprehension), perceptual reasoning (three subtests: Block Design, Matrix Reasoning, and Picture Concept), working memory (two subtests: Digit Span and Letter-Number Sequencing), and processing speed (two subtests: Coding and Symbol Search). Among the three subtests of verbal comprehension, Similarities was used to assess children's ability to identify similarities between two objects, Vocabulary required children to provide definitions for nouns, verbs, and adjectives, and Comprehension measured children's ability to explain actions, activities, and situations. To measure working memory, in the Digit Span subtest, children were required to recite numbers accurately by recalling them in the same and reverse order, while in the Letter-Number Sequencing subtest, children were required to arrange letters and numbers that they heard before. For perceptual reasoning, the Block Design subtest asked children to put blocks together according to an intact pattern, the Matrix Reasoning subtest asked children to complete 2 × 2 or 3 × 3 picture matrices with every picture matrix missing a picture, and the Picture Concept subtest assessed children's categorical ability by asking them to select two(three) pictures that share common characteristics from two(three) rows of pictures. The subtests of processing speed were administered to measure children's speed in processing simple visual information. Specifically, in the Coding subtest, children were shown a key, comprised of boxes, with each box containing a numeral in its upper part and a symbol in its lower part, and they were then required to write down the symbols corresponding to the provided numerals as soon as possible. In the Symbol Search subtest, children were asked to determine whether a target symbol appeared among a group of symbols.

3.2.2.2 The Receptive Language Ability Test

Participants' receptive language ability was measured by the Peabody Picture Vocabulary Test-Revised (Chinese version) (PPVT-R; Sang & Miao, 1990). It is a norm-referenced standardized language test for children in mainland China. The normative sample of the Chinese version is based on 600 children between the age of three years six months and nine years 11 months in mainland China. The test is individually administered to measure receptive vocabulary and to estimate receptive language ability. It includes 175 items of rising complexity. The starting item varies for different age groups (e.g., Item 30 for children aged between three years six months and three years 11 months, Item 42 for children aged between four years and four years five months, etc.). In the test, participants were required to select out of four pictures the one that depicted the word uttered by the experimenter. The test ended once the participant missed six out of eight consecutive items. The standardized receptive language test yielded verbal ability for every participant based on the raw score of the test and chronological age.

3.2.2.3 The Relative Frame of Reference Test

The relative FoR test was used to examine the participants' preferentially adopted relative FoR variant when interpreting projective spatial terms in the context where the reference objects did not have inherent fronts and backs. In each trial, participants saw a photograph displaying two objects on a computer screen[6]. Simultaneously, they heard a pre-recorded sentence describing the spatial relationship between the two

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[6] Pictures were widely used in previous studies examining spatial FoRs (Beller et al., 2016; Hüther et al., 2016; Surtees et al., 2012). Participants could tell whether a vertical perspective was involved in the relations between objects in pictures.

objects in the photograph using the projective spatial terms (“front”, “behind”, “left”, and “right”). Participants were required to rate the acceptability of the sentence.

The test made use of two sets of photographs taken by a camera, with one set consisting of four photographs depicting a small basket and a ball, and one set consisting of four photographs depicting a small box and a ball. The small basket and the small box, which did not have inherent fronts and backs, served as the reference objects for the two sets of photographs, respectively. In each set of photographs, the figure object (i.e., the ball) had four positions in relation to the reference object, as shown in Figure 3.2. Every photograph appeared three times accompanied by three different sentences, generating three picture-sentence pairs. The sentences described the spatial relationships between two objects based on the three variants of the relative FoR, that is, translation, reflection, and rotation, respectively. Table 3.2 shows the picture-sentence pairs for one set of photographs, that is, 12 pairs (four photographs × three paired sentences). As there were two sets of photographs, in total, the participants needed to rate 24 picture-sentence pairs.

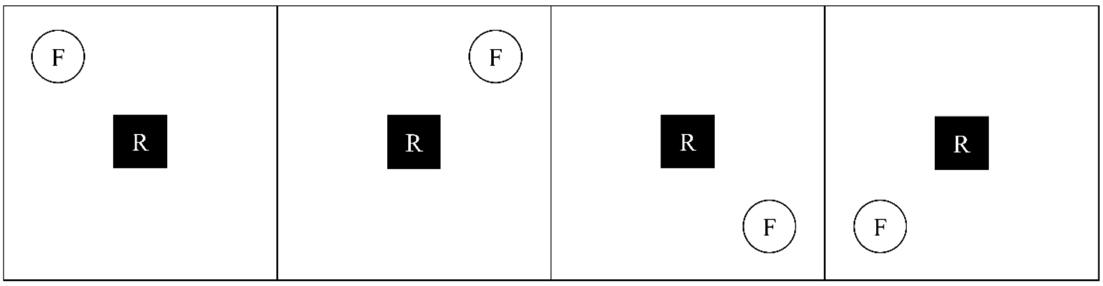
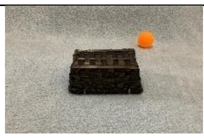
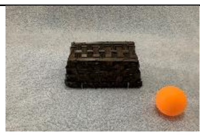
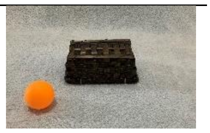


Figure 3.2. Four positions for the figure object in relation to the reference object.

Note: R = reference object; F = figure object.

Table 3.2. The picture-sentence pairs for one set of photographs used in the relative FoR test.

P					
S	Translation	小球在篮子的左前方。 The ball is located in front and to the left of the basket.	小球在篮子的右前方。 The ball is located in front and to the right of the basket.	小球在篮子的右后方。 The ball is located behind and to the right of the basket.	小球在篮子的左后方。 The ball is located behind and to the left of the basket.
	Reflection	小球在篮子的左后方。 The ball is located behind and to the left of the basket.	小球在篮子的右后方。 The ball is located behind and to the right of the basket.	小球在篮子的右前方。 The ball is located in front and to the right of the basket.	小球在篮子的左前方。 The ball is located in front and to the left of the basket.
	Rotation	小球在篮子的右后方。 The ball is located behind and to the right of the basket.	小球在篮子的左后方。 The ball is located behind and to the left of the basket.	小球在篮子的左前方。 The ball is located in front and to the left of the basket.	小球在篮子的右前方。 The ball is located in front and to the right of the basket.

Note: P = picture; S = sentence.

At the beginning of the test, participants were introduced to a cartoon character that was learning Mandarin. The cartoon character was observing the picture and trying to describe it. Participants were required to rate how well the cartoon character had done using a five-point scale, which was made up of five cartoon faces (see the bottom of Figure 3.3). The best description was to be given a score of five and the worst one assigned a score of one. The picture-sentence pairs were presented in random order using the computer software E-Prime 2.0. Participants gave responses by pressing numeric keys on a keyboard, while under no time pressure.

Figure 3.3. An example trial in the warm-up phase of the relative FoR test.

Before the start of the actual test, there was a warm-up phase to familiarize participants with the task. In the warm-up phase, the pictures depicted spatial relationships irrelevant to the projective spatial terms, “front”, “behind”, “left”, and “right”. Simpler spatial concepts without variants were adopted in this phase, such as the spatial relationship of support as shown in Figure 3.3. All participants selected the target rating scores (e.g., five for the warm-up trial shown in Figure 3.3), which indicated that they understood the task.

Before the relative FoR test, a screening test was used to assess participants' knowledge of "front" and "behind", and "left" and "right". In each trial, four identical containers with covers were placed on the four sides of participants (see Figure 3.4). Participants were given instructions containing "front", "behind", "left", or "right" (e.g., "贴纸在你左边的盒子" "the sticker is in the box on your left side"), and they were asked to indicate the box with the sticker. The experimenter would stand to the right or left side of the participant, but slightly behind, and they would face the same direction. There were two blocks for this test, with eight trials per block. If participants gave correct responses for all the trials of a block, they would skip another one.

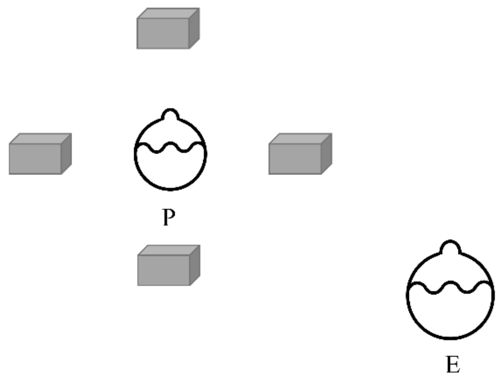


Figure 3.4. Set-up of the screening test for the relative FoR test.

Note: P = participant; E = experimenter.

After the relative FoR test, a post-test was used to assess whether the participants who showed acceptance of one variant of the relative FoR in the test accepted other variants. For instance, if the participants showed acceptance of the translation variant (i.e., accepted at least six out of eight sentences describing spatial relationships based on the translation variant by giving a score of four or five), the post-test would assess whether they accepted the spatial descriptions relying on the reflection or rotation variants.[7] Thus, there were three versions of the post-test designed for the participants relying upon the three different variants, respectively. For each trial of the post-test, two objects that were used in the relative FoR test were placed on a table in front of the participants[8]. At the same time, they were asked whether they accepted a statement as the description of the spatial relationship between the two objects. There were four different configurations for one set of objects, as shown in Figure 3.5. As

[7] The current study adopted the criterion, six out of eight, following Li (1988) and Deng and Yip (2016). If the participants showed a preference for more than one variant in the relative FoR test, they would be marked and skip the post-test. Two non-autistic child participants and four adult participants showed acceptance to both translation and reflection variants by giving scores of four/five to all the sentences based on the translation or reflection variant. In addition, one adult participant gave score of three to all the sentences based on the translation or reflection variant and gave score of one to the sentences based on the rotation variant. After finishing the relative FoR test, the adult participant provided feedback spontaneously that the spatial descriptions relying on the translation or reflection variant were all acceptable. Therefore, this participant was labeled as accepting the two variants. The data of two autistic participants did not show evidence of accepting any variant. They were labelled as unknown and did not proceed to the post-test.

[8] The relative FoR test was used to examine the relative FoR *preference*, while the post-test was designed to examine the *acceptance*. In the relative FoR test, the two objects were shown in pictures, whereas in the post-test, the objects were presented on a table in front of the participants. The change of experimental setting would help to mitigate the effect of *preference* on *acceptance*.

there were two sets of objects, the participants received eight configurations in total, with each accompanied by a statement of spatial description.

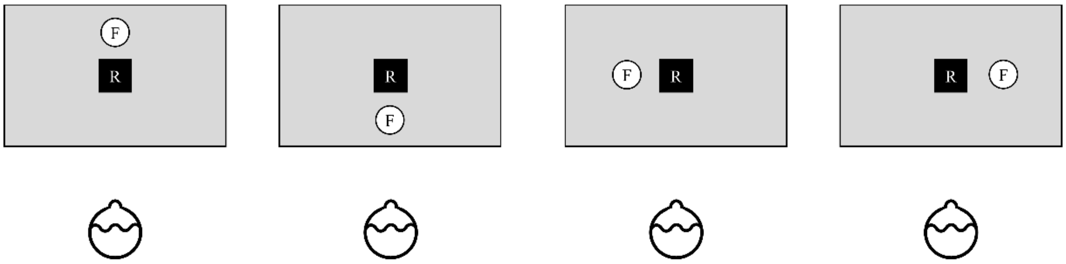
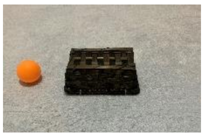
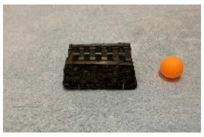


Figure 3.5. Set-up of the post-test of the relative FoR test.

Note: R = reference object; F = figure object.

The statement for each configuration varies in the three versions. Table 3.3 shows the statements for one set of objects in the three versions. Version I would be used if a participant showed a preference for the translation variant. Participants who relied upon the translation variant would assign the front to the space beyond the reference object, the back to the space between the reference object and themselves, and the left/right to the side that is the same as theirs. In order to examine whether these participants accepted the reflection variant, they were required to judge the acceptability of the assignment of “front” and “behind” in reverse. More specifically, the participants were asked whether they accepted the statement “the ball is located behind the basket” for configuration A, and “the ball is located in front of the basket” for configuration B. In order to examine whether these participants accepted the rotation variant, they were asked to judge the assignment of “left” and “right” in reverse (i.e., the statements for configuration C and D in version I), in addition to the reversed assignment of “front” and “back”. For each set of objects, there were two trials for the reflection variant, and four for the rotation variant. As there were two sets of objects, participants would receive four trials for the reflection variant, and eight for the rotation variant. A participant who accepted three out of four statements appropriate for a variant was considered to accept the variant, in accordance with the criteria used in previous studies (Deng & Yip, 2016; Li, 1988).

Table 3.3. Statements in the three versions of post-test of the relative FoR test.

	Configuration A	Configuration B	Configuration C	Configuration D
				
Version I	小球在篮子的后面。 The ball is located behind the basket.	小球在篮子的前面。 The ball is located in front of the basket.	小球在篮子的右边。 The ball is located to the right of the basket.	小球在篮子的左边。 The ball is located to the left of the basket.
Version II	小球在篮子的前面。 The ball is located in front of the basket.	小球在篮子的后面。 The ball is located behind the basket.	小球在篮子的右边。 The ball is located to the right of the basket.	小球在篮子的左边。 The ball is located to the left of the basket.

Version III	小球在篮子的前面。 The ball is located in front of the basket.	小球在篮子的后面。 The ball is located behind the basket.	小球在篮子的左边。 The ball is located to the left of the basket.	小球在篮子的右边。 The ball is located to the right of the basket.

Version II was designed for participants who showed evidence of accepting the reflection variant in the relative FoR test. Participants who relied upon the reflection variant would assign the front to the space between the reference object and themselves, the back to the space beyond the reference object, and the left/right to the side that is the same as their own. To examine whether these participants accepted the translation variant, they were asked to judge the acceptability of the assignment of “front” and “back” in reverse: that is, to judge the statements for configuration A and B in version II. For the acceptance of the rotation variant, they were asked to judge the assignment of “left” and “right” in reverse, that is, the statements for configuration C and D in version II. If the participants showed acceptance towards the rotation variant, they would be required to judge the acceptability of statements in version III so as to examine whether they accepted the translation variant. For the acceptance of the reflection variant, these participants would be asked whether they accept the statements for configuration C and D in version III. Likewise, a participant who accepted three out of four statements appropriate for a variant was considered to accept the variant.

3.2.2.4 The ToM Test

Participants' ability to read mind was assessed using two second-order ToM tasks: the look-predication task (Perner & Wimmer, 1985) and the say-prediction task (Sullivan et al., 1994). Second-order ToM tasks were adopted for the following reasons. Previous research suggested that the ability to pass first-order ToM tasks developed around the age of four (Wellman et al., 2001), while success in second-order ToM tasks was found to emerge at around age six (Miller, 2009). Given participants were about seven years, second-order ToM tasks were considered suitable for this age group. In the say-prediction task, participants heard a story about a birthday gift, accompanied by full-color pictures that were presented one by one. In the story, Mom had got a birthday gift (a game console) for her son, called Xiaoming, but she had hidden the gift in the basement. Xiaoming hoped Mom would get him a game console for his birthday. Mom, who wanted to surprise Xiaoming with the game console, told Xiaoming she had not got a game console, but got a puppy instead. However, Xiaoming accidentally saw the hidden game console when Mom was out. At the end of the story, Xiaoming went out to play with his friends. After the story, the participants received two control questions to check their attention and memory (control question 1: "Did Xiaoming see the game console?"; control question 2: "What does Xiaoming think he will get for his birthday?") and one first-order ToM question about the false belief of Mom ("Does Mom think Xiaoming saw the game console?") In addition, the participants received two second-order ToM questions about Mom's false belief about Xiaoming's thoughts: "What does Mom think

Xiaoming will tell his friends he is getting for his birthday?” and “Why does Mom think this?” The control questions needed to be answered correctly before proceeding to the test questions. If the participants failed to provide a correct answer for any control question, the story would be repeated, but no more than twice. For the first-order ToM question and two second-order ToM questions, the participants were credited with one score if they gave the correct answer to one question.

In the look-predication task, the participants were introduced to two characters, Xiaomei and Xiaofei, who were in a room. Xiaofei put a bar of chocolate into a chest of drawers and then left the room. When Xiaomei saw Xiaofei had left, she moved the chocolate from the chest of drawers to a box. Xiaofei saw Xiaomei do this from a window, but Xiaomei did not notice Xiaofei. After the story, the participants received two control questions first (control question 1: “Can Xiaofei see Xiaomei?”; control question 2: “Where does Xiaofei think the chocolate is?”) If the participants failed to correctly answer any control questions, the story would be repeated. If the participants gave the wrong responses or did not answer for twice, they were credited with the score of zero for the task. If the participants correctly answered the control question, they received one first-order ToM question about the false belief of Xiaomei (“Does Xiaomei think Xiaofei can see her?”) and two second-order ToM questions: “Where does Xiaomei think Xiaofei will look for the chocolate?” and “Why does Xiaomei think this?” For each ToM question, the participants were credited with one point if they gave the correct answer.

3.2.2.5 The Autism Spectrum Quotient

Participants' autistic traits were assessed using the Autism Spectrum Quotient-Chinese Version (AQ-C) (Sun et al., 2019). The Autism Spectrum Quotient was first developed to quantitatively measure English-speaking children's traits associated with the autistic spectrum (Auyeung et al., 2008) and was later adapted for Mandarin-speaking children. Test norms were based on results from 1,020 non-autistic and 134 autistic children between the ages of four years and 10 years 11 months living in mainland China. The test is a guardian-report questionnaire with 30 items assessing five domains of autistic traits: socialness, social communicative competence, imagination, patterns, and attention switching.

3.2.3 Data Analyses

Regarding the first aim of comparing the relative FoR preference in autistic and non-autistic children, a mixed-effects ordinal regression model was fit, by using the CLMM function from the ordinal package, to accommodate the ordinal outcome variable, acceptability rating (Christensen, 2019). Specifically, the regression model was built with Group (autistic child, non-autistic child, and adult), Variant (translation, reflection, and rotation), and their interaction acting as fixed factors to analyze the acceptability rating. Subject and Item were included as random factors, which was justified, as the Akaike Information Criterion (AIC) of the model with the random intercepts was substantially lower than the AIC of the model without the random intercepts (3836.98 vs. 4547.15; d.f. = 2, $p < .001$). Post hoc pairwise comparisons were performed with Bonferroni adjustment using the lsmeans package (Lenth, 2016). There was no significant effect of Sex (z = -.10, p = .935), and since there was no hypothesis related to Sex, data were collapsed across sex. For completeness, in addition to the comparison among groups, Kruskal-Wallis tests were run for each participant to compare the acceptability ratings of the three variants, deriving individual relative FoR preference. Post hoc pairwise comparisons were performed using the dunnTest function in the FSA package with Bonferroni adjustment (Dunn, 1964). If a participant’s acceptability ratings for spatial descriptions that rely on the translation/reflection/rotation variant were significantly higher than those relying on the other two variants, the participant would be labeled as showing a preference for the translation/reflection/rotation variant. If there was no significant difference between a participant’s acceptability ratings of spatial descriptions that rely on two variants, which meanwhile were significantly higher than acceptability ratings of spatial descriptions that rely on the other variant, the participants would be labeled as showing preference for the former two variants. The participants whose performance showed other patterns were labeled as having no preference.

With respect to the acceptance of more than one variant of the relative FoR, two sets of analyses were performed. First, the data of the post-test were analyzed using a generalized linear mixed model to accommodate the repeatedly measured binary outcome variable (1 for accepting, 0 for not accepting). Specifically, the generalized linear mixed model was built with Group (autistic child, non-autistic child, and adult) acting as fixed factor, and Subject and Item acting as random factors. The inclusion of random intercepts was permitted as the AIC of the model with the random intercepts was significantly smaller than the AIC of the model without the random intercepts (324.33 vs. 589.77; d.f. = 2, $p < .001$). Post hoc pairwise comparisons were performed with Bonferroni adjustment using the lsmeans package (Lenth, 2016). Second, comparisons were performed with regard to the proportion of accepting more than one variant of the relative FoR in the three groups. The participants who accepted at least one variant in the post-test were labeled as 1, indicating the participants accepted one more variant in addition to the one they preferentially adopted in the relative FoR test. Those who did not show acceptance towards any variant in the post-test were labeled as 0. To accommodate the binary outcome variable, a generalized linear model was built to compare the acceptance of more than one of the variants in autistic and non-autistic groups. Before fitting the generalized linear model, it was checked whether including a random effect, Subject, was justified by comparing the AIC of the baseline model without random effect to the AIC of the model with random effect. The results showed that the AIC of the model with random effect was larger, suggesting the inclusion of the random effect was not justified (100.98 vs. 98.98). Thus, a generalized liner model rather than a generalized linear mixed model was used. The model was built with Group (autistic child, non-autistic child, and adult) as fixed factor. Post hoc pairwise comparisons were performed with Bonferroni adjustment using the lsmeans package (Lenth, 2016).

Aiming at examining the role of ToM and autistic traits in the acceptance of multiple variants of the relative FoR, another set of analyses was run. First, the cognitive profile of the autistic participants was sketched by comparing their performance with that of non-autistic participants in the ToM test. Next, generalized linear models were constructed to examine the potential variables contributing to the acceptance of multiple variants of the relative FoR when interpreting projective spatial terms (1 for accepting multiple variants; 0 for not accepting). Generalized linear mixed models were not used because the inclusion of the random effect Subject was not justified by a lower AIC value (62.87 > 60.87). It began with a generalized linear model with chronological age and receptive language ability as control factors. If receptive language ability or chronological age did not have an effect on the acceptance of multiple variants of relative FoR, the factor(s) would be removed from the model one by one, starting with the effect with the larger *p*-value. The two parameters derived from the ToM test (ToM) and the AQ-C (Autistic traits) were examined, one by one, in separate analyses to decide which parameters were to be retained. The parameters that led to a significant improvement over the model without the parameter in question were combined along with receptive language ability and/or chronological age to evaluate effects of parameters adjusted for one another, while those with no effect were removed (i.e., $p \geqslant .05$).

3.3 Results

3.3.1 Relative FoR Preference

The study investigated the preferentially adopted variant of the relative FoR by autistic and non-autistic participants when interpreting projective spatial terms in the context of featureless reference objects. Table 3.4 shows the acceptability ratings of autistic and non-autistic participants for each variant of the relative FoR.

Table 3.4. Average acceptability ratings for the three variants of the relative FoR in the autistic child, non-autistic child, and adult groups.

Group	Translation	Reflection	Rotation
Autistic child	4.17 (1.35)	2.28 (1.52)	1.23 (.59)
Non-autistic child	2.99 (1.83)	3.57 (1.79)	1.25 (.67)
Adult	4.22 (1.21)	2.89 (1.41)	1.03 (.22)

The mixed-effects ordinal regression model on acceptability ratings yields a significant two-way interaction of Group × Variant, confirmed by a likelihood ratio test obtained with the ANOVA method ($p < .001$). The interaction effect was further analyzed under different groups using post-hoc pairwise comparisons with Bonferroni adjustment. In the adult group, acceptability ratings of spatial descriptions that relied upon the translation variant were significantly higher than those relying upon the reflection variant ($\beta = 1.56$, $SE = .19$, $z = 8.01$, $p < .001$), whose acceptability ratings were significantly higher than those relying upon the rotation variant ($\beta = 4.82$, SE

= .60, z = 8.07, p < .001). The pattern was also observed in the autistic group (translation > reflection: β = 2.35, SE = .21, z = 11.31, p < .001; reflection > rotation: β = 1.74, SE = .24, z = 7.29, p < .001). In the non-autistic child group, acceptability ratings were highest when spatial descriptions were based on the reflection variant, while the acceptance of the spatial descriptions relying on the translation variant ranked second (reflection vs. translation: β = .75, SE = .20, z = 3.73, p = .001; translation vs. rotation: β = 2.64, SE = .24, z = 10.86, p < .001).

Next, Kruskal-Wallis tests were run to examine individual relative FoR preference when interpreting projective spatial terms. Table 3.5 reports the proportions of showing preference for different variants in the three groups. In the adult group, 69.57% of participants showed a preference for the translation variant when interpreting projective spatial terms, and 13.04% of participants showed a preference for the reflection variant. In addition, 17.39% of participants preferred both translation and reflection variants, while no adult participant showed a preference for the rotation variant. Turning to the non-autistic child group, it can be seen that the participants in this group were more likely to adopt the reflection variant to interpret the projective spatial terms (56.00%), whereas fewer participants exhibited a preference for the translation variant (36.00%). One non-autistic child exhibited a preference for both reflection and translation variants, while one did not show a clear preference. For autistic participants, the highest proportion was seen in the translation variant preference (70.83%), and a few participants exhibited a preference for the reflection variant (12.5%). Additionally, one autistic participant showed a preference for both reflection and translation variants, whereas the data from three autistic participants showed no reliable evidence of their preference for any variant. The results, together with the results of the mixed-effects ordinal regression model, suggest that Mandarin-speaking autistic and non-autistic children differ in the choice of relative FoR variant in interpreting projective spatial terms. One interesting finding is that autistic rather than non-autistic children exhibited adult-like performance.

Table 3.5. Individual relative FoR preference in each group.

Group	Translation	Reflection	Translation + reflection	No preference
Adult	69.57%	13.04%	17.39%	/
Non-autistic child	36.00%	56.00%	4.00%	4.00%
Autistic child	70.83%	12.5%	4.17%	12.5%

3.3.2 Acceptance of Multiple Variants of Relative FoR

The study examined whether autistic and non-autistic participants accepted one more variant of the relative FoR when interpreting projective spatial terms in the post-test. The participants who showed acceptance toward one variant were asked whether they accepted the statements that rely on the variants that were different from the confirmed one. Table 3.6 reports the average acceptance rates of the statements in the post-test in the autistic child, non-autistic child, and adult groups.

Table 3.6. The average acceptance rates of statements in the post-test of the relative FoR test in each group.

Group	Acceptance rates
Adult	45.14%
Autistic child	18.75%
Non-autistic child	36.96%

The generalized linear mixed model showed a significant main effect of Group (χ^2 = 27.71, d.f. = 2, *p* = .001).[9] The post hoc test revealed that the acceptance rate of statements that relied on different variants was significantly lower in the autistic child group than in the non-autistic child group (*β* = -2.06, *SE* = .57, *z* = -3.61, *p* = .001) and the adult group (*β* = -1.55, *SE* = .54, *z* = -2.90, *p* = .011). The acceptance rates did not significantly differ in the non-autistic child and adult groups (*β* = -.51, *SE* = .52, *z* = -1.00, *p* = .959).

Next, this study examined the participants' acceptance of more than one variant of relative FoR individually. Table 3.7 reports the proportions of participants who accepted more than one variant when interpreting the projective spatial terms in each

[9] Freedom degree is 2 because Group is a categorical variable with three levels, which is dummy coded with a default baseline in R. For example, if the autistic group serves as the baseline, the two dummy coded variables will be (1) non-autistic vs. autistic and (2) adult vs. autistic.

group. Most Mandarin-speaking adults accepted more than one variant of the relative FoR (82.61%), and the acceptance of multiple variants was observed in more than half of the non-autistic children (52.00%), whereas most autistic children mainly relied on one variant of the relative FoR when interpreting projective spatial terms (90.91%). In addition, there was little evidence of accepting the rotation variant in any group: that is, the accepted variants were translation and rotation in the adult and non-autistic child groups.[10]

Table 3.7. The proportion of accepting more than one variant of relative FoR in each group.

Group	Multiple variant	Single variants
Adult	82.61%	17.39%
Autistic	9.09%	90.91%
Non-autistic	52.00%	48.00%

The generalized linear model on the acceptance of multiple variants showed a significant main effect of Group (d.f. = 2, $p < .001$). The post hoc test revealed that the participants in the autistic child group were significantly less likely to accept more than one variant of the relative FoR when interpreting projective spatial terms, compared to the participants in the non-autistic child group ($\beta = -2.38$, $SE = .84$, $z = -2.83$, $p = .014$) and adult participants ($\beta = -3.86$, $SE = .92$, $z = -4.18$, $p < .001$). There

[10] Two adult participants exhibited knowledge that all three variants of relative FoR could be used in a single situation.

was a marginally significant difference between the latter two groups in the proportion of acceptance of more than one of the variants (non-autistic child vs. adult: β = -1.48, *SE* = .68, *z* = -2.17, *p* = .089). The results, together with the results of the generalized linear mixed model, suggest that Mandarin-speaking adults accept multiple variants of the relative FoR (usually translation and reflection) underlying the use of projective spatial terms, and non-autistic children, like adults, are more likely to accept multiple variants of the relative FoR than their autistic peers, who mainly rely on the translation variant to interpret the projective spatial terms.

3.3.3 Role of ToM and Autistic Traits in the Acceptance of Multiple Variants of Relative FoR

Table 3.8 reports the performance of autistic and non-autistic children in the ToM test (maximum = six). Shapiro-Wilk normality tests were performed to check the distribution of ToM data. The results showed that the data regarding ToM were not normally distributed (*p*s < .05), so the table presents the median, which is believed to be representative when data is not normally distributed, as well as the mean. Next, a Mann-Whitney *U*-test was conducted to compare the two groups of children in ToM. The results showed that autistic children performed significantly worse than non-autistic children in the ToM test (*U* = 369.50, *p* < .001). With regard to participants' autistic traits, the AQ-C scores of the two groups of children are reported in Table 3.1. The autistic group was found to score significantly higher on the AQ-C than the non-autistic group (*U* = 899.00, *p* < .001).

Table 3.8. Performance of autistic and non-autistic children.

Group	ToM test
Autistic (n = 24)	1.42 (SD = 1.04; median = 1)
Non-autistic (n = 25)	4.04 (SD = 1.77; median = 4)

Generalized linear models were used to examine whether the participants' acceptance of multiple variants of relative FoR was associated with their ToM or autistic traits (measured by AQ-C). The inclusion of control factors was checked first. The generalized linear model showed a significant effect of receptive language ability (β = .10, *SE* = .03, *z* = 2.73, *p* = .006), while no effect of chronological age was found (β < .01, *SE* = .03, *z* = -.003, *p* = .998). Thus, it started from a model with receptive language ability. After adding ToM, the result showed there was a significantly improved fit over the model with receptive language ability only (d.f. = 1, *p* = .001); the addition of AQ-C had the same effect (d.f. = 1, *p* = .006). Therefore, ToM and AQ-C were combined along with receptive language ability to evaluate effects of predictors adjusted for one another on the acceptance of multiple variants of the relative FoR. Variance inflation factor (VIF) was used to check for the presence of collinearity across the factors retained in the final model. The VIFs with a maximum value of 1.92 < 3 suggest there was no sign of harmful collinearity (Hair et al., 2011). The final model showed a significant main effect of ToM (β = .81, *SE* = .36, *z* = 2.25, *p* = .024). With the inclusion of ToM, the main effect of AQ-C disappeared (β = -.003, *SE* = .04, *z* = -.10, *p* = .920). Together, the results suggest that ToM plays a role in the acceptance of multiple variants of the relative FoR. More specifically, children with a low ToM ability do not take kindly to the acceptance of multiple variants, relative to those with a high ToM ability. The difference between autistic and non-autistic groups in terms of the ability to read mind might explain why autistic participants were less likely to accept multiple variants of the relative FoR than non-autistic participants.

3.4 Discussion

This study examined the relative FoR underlying the use of projective spatial terms (“front” and “behind”, and “left” and “right”) when locating an object in relation to another object without inherent front and back in Mandarin-speaking autistic children, compared to Mandarin-speaking non-autistic children matched on receptive language ability.

3.4.1 Comparison of Relative FoR Preference in Autistic and Non-Autistic Children

Regarding the aim of comparing relative FoR preference when decoding the projective spatial terms in Mandarin-speaking non-autistic children and autistic children without ID, the results showed that the two groups differed in the choice of relative FoR’s variant in interpreting the projective spatial terms. Specifically, non-autistic children gave significantly higher scores to the spatial descriptions that relied on the reflection variant of the relative FoR than to the spatial descriptions that relied on the translation or rotation variant. For autistic children, the acceptability ratings of spatial descriptions that relied on the translation variant were significantly higher than of those that relied on the reflection or rotation variant. The findings suggest that Mandarin-speaking non-autistic children aged around seven years exhibited a preference for the reflection variant of the relative FoR, while the receptive-language-ability-matched Mandarin-speaking autistic children without ID preferred to rely on the translation variant when interpreting the projective spatial terms that encoded an object's position in relation to another object without inherent front and back. This fits with previous findings by Bochyńska, Coventry, et al. (2020) that Norwegian-speaking autistic individuals "interpreted the direction within front/back axis differently" when compared with Norwegian-speaking non-autistic individuals. To be more specific, their non-autistic participants used the reflection of the front/back axis (sagittal axis) where "front" was assigned to the space between the reference object and themselves. Their autistic participants, by contrast, used a translation projection strategy where "front" was placed on the side beyond the reference object, which was regarded as an error in Bochyńska, Coventry, et al. (2020). The authors proposed that the error observed in the autistic group stemmed from their delay in the mastery of projective spatial terms "front" and "behind". However, it has been argued that the translation projection strategy, utilized in certain languages such as Hausa as well as Mandarin (Beller et al., 2015; Hill, 1982, 1975), should not be considered as an error (Beller et al., 2016; Levinson, 2003; Tanz, 1980).

One possible explanation for autistic individuals' preference for the translation variant of the relative FoR is that their egocentrism contributes to the use of the translation projection strategy. According to the concept of egocentrism (Piaget, 1959), autistic individuals look at the external world differently compared with non-autistic individuals. More specifically, autistic individuals would see things from their own point of view and lack the ability to take other perspectives in their environment (Begeer et al., 2012; Hamilton et al., 2009; Moses & Flavell, 1990; Pearson et al., 2013). The translation projection strategy underlying the use of the projective spatial terms "front" and "behind" is in accordance with one's own perspective. Using the translation variant of the relative FoR, autistic individuals will view the reference object as aligned in the same direction as themselves. Along the axis of this direction, the figure object that is on the far side of the reference object is further forward than the reference object. In contrast, when the figure object is in the space between the reference object and the viewer, the reference object becomes further forward, giving rise to the spatial relationship: the figure object is behind the reference object. Therefore, it is not surprising to find that Mandarin-speaking autistic children exhibited a preference for the translation variant of the relative FoR in decoding space.

By contrast, Mandarin-speaking non-autistic children tended to rely upon the reflection variant to interpret projective spatial terms. This finding fits with previous evidence that Mandarin-speaking non-autistic children older than four years frequently adopted the reflection projection strategy to interpret "front" and "behind"

(Deng & Yip, 2016; Li, 1988). For instance, in Deng and Yip (2016), the participants were required to judge whether a sentence correctly described the position of an object in relation to a featureless object (e.g., a ball). When the figure object was between the reference object and the participants, most participants accepted the sentence involving “front” and rejected the sentence involving “behind”, suggesting they adopted the reflection projection strategy. This finding could be explained by the canonical encounter proposed by Clark (1973). According to the concept of canonical encounter, two persons will face each other during most daily interactions, which may have an influence on the projection of front/back axis. To be more specific, during normal interactions that are usually carried out face-to-face, “front”, which is interpreted to mean near the face, will be assigned to the space between the two interlocutors that is near their faces, and “behind”, which is interpreted to mean near the back, will be assigned to the far side for each interlocutor that is near their backs. Thus, non-autistic children, affected by the canonical encounter, tend to adopt the reflection projection strategy to interpret the projective spatial terms. One thing to note: Mandarin-speaking adults showed a preference for the translation variant. The relative FoR preference is influenced by multiple factors (Hüther et al., 2016). In addition to canonical encounter, other factors may contribute to Mandarin-speaking adults’ preference for the translation variant. The weights of these factors may vary by age. The change from reflection to translation variant might be attributed to the principle of least effort. Specifically, translation projection produces less cognitive cost as it does not involve an inversion on the sagittal or transverse axis (Beller et al., 2015; Grabowski, 1999).

In addition, neither autistic nor non-autistic participants exhibited a preference for the rotation variant of the relative FoR. One explanation for this finding is that the rotation projection produces arguably more cognitive cost than the translation projection and the reflection projection (Beller et al., 2015). Forming a coordinate system centered on the reference object by way of rotation involves not only an inversion on the sagittal axis (front-back), but also on the transverse axis (left-right) (Grabowski, 1999), which seems challenging for young children. Given the cognitive complexity of the rotation variant, it is not surprising to find that neither group of children preferentially adopted this variant. Another explanation is that very few Mandarin-speaking adults accepted the inversion of left and right terms when the reference objects do not have inherent orientation (Deng & Yip, 2016; Guo, 2004, 2008). Mandarin-speaking adults who reject the inversion on the left-right axis may correct children who reverse “left” and “right”, resulting in the low preference for the rotation variant in Mandarin-speaking children.

Notably, the relative FoR preference of Mandarin-speaking non-autistic children differed from that of Mandarin-speaking adults, who preferentially adopted the translation projection strategy in encoding the location of an object in relation to a featureless object. According to Deng and Yip (2016), adult input could not fully account for child acquisition of spatial terms, which may help to explain the divergence between Mandarin-speaking non-autistic children and adults. In addition, although the translation variant preference was observed in Mandarin-speaking adults, they also showed acceptance towards the reflection variant underlying the use of projective spatial terms. Therefore, Mandarin-speaking adults might not correct spatial descriptions made by children relying on the reflection variant.

3.4.2 Comparison of Accepting Multiple Variants of the Relative FoR in Autistic and Non-Autistic Children

Turning to the research aim regarding the comparison between Mandarin-speaking non-autistic children and autistic children without ID in accepting more than one variant of the relative FoR, the results showed that the two groups of children differed in the acceptance of multiple variants. Specifically, autistic children were less likely to accept the spatial descriptions that did not rely on the variant they preferentially adopted, compared with non-autistic children. The non-autistic child participants, like the adults, exhibited an inclination to accept the spatial descriptions that relied upon different variants of relative FoR. This fits with previous evidence that Mandarin-speaking adults possess knowledge that different projection strategies could be used in a single situation (Deng & Yip, 2016; Guo, 2004). For instance, in Guo (2004), Mandarin-speaking adults were required to describe the spatial relationships between two objects shown in pictures. They needed to describe the position of an object in relation to the other object that did not have inherent front and back using the projective spatial terms “front” and “behind”, and “left” and “right”. The participants adopted one strategy to encode the direction within the transverse axis: they consistently used “right” when seeing the pictures with the figure object on its right panel and the reference object on its left panel, while they always used “left” when the figure object swapped places with the reference object. By contrast, when the figure object was between the reference object and the participants, some participants provided two responses: one involving “front”, and the other involving “behind”. Likewise, someone provided two responses to describe the location of the figure object on the far side of the reference object. This reflects the acceptance of more than one projection strategy, that is, translation and reflection, in Mandarin-speaking adults. The results, converging with the findings in Mandarin-speaking adults, extended this literature by finding the acceptance of multiple variants of the relative FoR (usually translation and reflection) in Mandarin-speaking non-autistic children aged around seven years.

Interestingly, even the rotation variant was found to be accepted in Mandarin-speaking adults to a small extent, confirming the finding by Beller et al. (2015). The authors attributed the substantial flexibility in adopting different variants of the relative FoR to cultural influence (Beller et al., 2015). The speakers of Mandarin living in collectivistic cultures (Chiu & Kosinski, 1995; Greenfield et al., 2003) are reported to have interdependent selves (Shweder & Bourne, 1982). It has been found that the cultural patterns of interdependence, which focus attention on other persons, enable Mandarin speakers to flexibly switch between their own perspective and that of others (Wu & Keysar, 2007). Therefore, even though Mandarin-speaking individuals have a preferentially adopted variant of the relative FoR when encoding space, they are capable of switching to other variants if needed, so as to facilitate communication.

3.4.3 Role of ToM and Autistic Traits in Accepting Multiple Variants of the Relative FoR

To understand the difference between autistic and non-autistic children in accepting more than one variant of the relative FoR, this study examined whether ToM and autistic traits were associated with the acceptance of multiple variants. Specifically, autistic children were found to exhibit a preference for the translation variant in interpreting projective spatial terms, and they did not take kindly to accepting the other two. Compared with autistic children, non-autistic children were more likely to accept different variants in addition to the preferentially adopted one. The results of generalized linear models revealed that ToM and autistic traits were predictors of the acceptance rate of variants that were not preferentially adopted.

With regard to the role of ToM, participants with poor performance in the ToM test had a tendency to rely upon one variant of the relative FoR and reject other variants. How can the role of ToM in the acceptance of multiple variants be explained? In order for a hearer to accept a spatial description made by someone relying on a different variant, he/she needs to switch from his/her own perspective to the speaker's to understand why the speaker encodes space in that way. The ToM test assessed the capacity of predicting other people's behaviors based on their mental states, which differed from one's own (Baron-Cohen et al., 1985; Perner & Wimmer, 1985). The participants with a low ToM ability might encounter difficulties when inhibiting their own perspective and switching to a different perspective, and thus only accept the spatial descriptions relying on the variant preferred by themselves and reject the spatial descriptions relying on a different variant. There is an alternative way to explain the role of ToM in autistic participants' acceptance of multiple variants of the relative FoR. Autistic participants were found to exhibit a preference for the translation variant. Accepting more than one variant for this group of participants means accepting the reflection or the rotation variant in addition to the translation variant. Depending on the translation variant, children would view the reference object as aligned in the same direction as themselves, while the reflection variant and the rotation variant at least require the children to imagine that the forward direction of the reference object is counter to their own forward direction. ToM ability might help children to disengage from their own default perspective, and to accept that the reference object's forward direction differs from their own. Therefore, if autistic participants had a low ToM ability, they would have problems with a shift to the reflection or rotation variant. In addition, autistic participants were found to perform significantly worse in the ToM test than non-autistic participants, which might be the reason for the finding of a lower acceptance of multiple variants in the autistic group than in the non-autistic group.

In addition to ToM ability, autistic traits also played a role in the acceptance of multiple variants of the relative FoR. Specifically, participants with low AQ-C scores exhibited an inclination to accept a variant of the relative FoR that was different from the one they preferentially adopted. AQ-C, with lower scores indicating less autistic-like behavior, assesses autistic-related domains such as attention switching and imagination. Autistic participants with significantly higher AQ-C scores were reported to have stereotyped and repetitive patterns of behavior, like “prefers to do things the same way”, “gets strongly absorbed in one thing”, etc. With these autistic traits, it became difficult to divert attention from one variant to other variants, which could help to explain why autistic participants solely relied on one variant of the relative FoR and did not take kindly to others. One thing to note: the effect of autistic traits disappeared when taking into account the participants’ ToM ability. This is not surprising, given the strong relation between ToM and AQ-C according to the result of a Spearman correlation test ($r = -.70$, $p < .001$). Also, AQ-C is a more broadly defined variable than ToM. In addition to measuring the ability to understand other people’s mental state (Kung, 2020), AQ-C also assesses other abilities, like making new friends and keeping up a conversation, which do not seem to have direct influence on the use of spatial FoRs.

Moreover, autistic participants’ low acceptance of other variants might be attributed to their deficits in inhibitory control. It has been well established that autistic children exhibit deficits in inhibitory control, and therefore often fail to revise/inhibit their initial commitment when encountering new information. Once autistic participants accepted a certain variant of relative FoR (i.e., the translation variant) in the relative FoR test, they were less capable of switching to another in the post test as compared with non-autistic children. Future studies with precise measure of inhibitory control would allow to uncover the influence of this cognitive ability on the acceptance of multiple variants.

3.5 Conclusion

The present study investigated the relative FoR underlying the interpretation of projective spatial terms when the reference objects did not have inherent orientation in Mandarin-speaking non-autistic children and autistic children without ID matched on receptive language ability. Autistic and non-autistic children differed with respect to their relative FoR preference. Specifically, autistic children were found to preferentially adopt the translation variant of the relative FoR when interpreting projective spatial terms, while non-autistic children exhibited a preference for the reflection variant. In addition, compared with autistic children, non-autistic children showed a higher acceptance rate for multiple variants (usually the reflection variant and the translation variant). The divergence between autistic and non-autistic children could be explained by their difference in ToM and autistic traits, which were found to be significant predictors of the acceptance rate of multiple variants. Furthermore, the acceptance of both reflection and translation variants and even the rotation variant was observed in Mandarin-speaking adults, which suggests that the reflection variant should not be assumed as the baseline for assessing the acquisition of spatial terms in child development or in autistic individuals, let alone for research focusing on the spatial FoRs underlying the use of spatial terms.

Chapter 4. Intrinsic Frame of Reference Underlying the Interpretation of Projective Spatial Terms in Mandarin-Speaking Autistic and Non-Autistic Children

4.1 Introduction

When using projective spatial terms to encode an object's position in relation to another object that has inherent front and back, intrinsic as well as relative FoRs are applicable. Intrinsic FoR is an object-centered FoR. The use of projective spatial terms based on this object-centered FoR depends upon the orientation of the reference object. Previous research revealed that sensitivity to the intrinsic FoR would increase at the cost of the relative FoR in neurotypical speakers of some languages (e.g., Chinese, English, etc.; Beller et al., 2015; Surtees et al., 2012).

Notwithstanding the findings that neurotypical speakers usually have a preference for one particular type of spatial FoR in a given situation, there is evidence from English-speaking neurotypical adults that more than one type of spatial FoR is activated *spontaneously* when judging spatial descriptions of a scene (Carlson-Radvansky & Irwin, 1993; Carlson-Radvansky & Jiang, 1998). Previous studies have observed both relative and intrinsic FoR underlying the use of projective spatial terms in neurotypical children from Western countries (Bialystok & Codd, 1987; Cox, 1981; Harris & Strommen, 1972), but their findings are not sufficient to support the activation of dual types of spatial FoRs in young neurotypical brains. These studies examined the interpretation of projective spatial terms in neurotypical children by asking them to place an object in relation to another object using instructions containing projective spatial terms. When the reference object did not have inherent orientation (e.g., a ball), young participants would put the figure object between the reference object and themselves after hearing the instructions containing “front” (e.g., “put a cube in front of the ball”), while putting the figure object on the far side beyond the reference object after hearing the instructions containing “behind”, such as “put a cube behind the ball”, as has been observed in adult controls. This finding indicates the activation of relative FoR (more precisely, the reflection variant) underlying the interpretation of spatial projective terms.[11] For reference objects with inherent fronts and backs (e.g., a doll), when the reference object faced away, both children and adults would put the figure objects between the reference object and themselves for instructions with “behind” and on the far side for instructions with “front”. This is evidence of the activation of intrinsic FoR (Cox, 1981; Harris & Strommen, 1972). However, it is too early to arrive at a conclusion that neurotypical children are capable of activating more than one type of spatial FoR instinctively when they make judgments about spatial descriptions of a single scene. An alternative possibility is that only one FoR is activated in children’s brains for a given situation. In other words, the intrinsic FoR is activated when the reference object has inherent front and back, while the relative FoR is activated for reference objects without inherent orientation.

[11] In the literature on English-speaking children’s spatial FoR, the relative FoR was equated with the reflection variant, and using other variants was considered as errors (Cox, 1981; Harris & Strommen, 1972).

To distinguish between the two alternatives, Surtees et al. (2012) investigated the activation of spatial FoRs in English-speaking children aged six to 11 years by asking them to rate the acceptability of descriptions of spatial relationships between two objects using a five-point scale rather than a true-value judgment task that only requires a bipolar judgment. The participants were divided into three age groups: six- to seven-year-olds, eight- to nine-year-olds, and 10- to 11-year-olds. Of the two objects, one that had inherent orientation served as the reference object. They found that children of all age groups rated both sentences, "the figure object is behind the reference object" and "the figure object is in front of the reference object", to be good descriptions of the spatial relationship of the two objects in Figure 4.1.

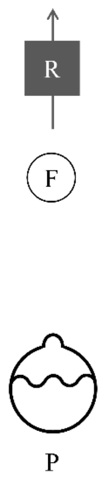


Figure 4.1. An illustration of one trial in Surtees et al. (2012).

Note: P = participant; F = figure object; R refers to the reference object with inherent front and back with the front indicated by an arrow tip.

High rating scores of the former description, "the figure object is behind the reference object", suggest the activation of intrinsic FoR, as the figure object is near the reference object's back, while the high acceptability of the latter, "the figure object is in front of the reference object", suggests the activation of relative FoR, more specifically the reflection variant. As mentioned, when the reflection variant of relative FoR is activated, the front will be assigned to the space between the observer and the reference object by English speakers, and the description "the figure object is in front of the reference object" for the position of the figure object in Figure 4.1 reflects the activation of the reflection variant. The data from the study by Surtees et al. (2012) suggest that English-speaking neurotypical children as young as six years old can activate more than one type of spatial FoR underlying the use of projective spatial terms. However, these findings are based on neurotypical children from Western countries; whether they can be carried over to Mandarin-speaking neurotypical and autistic children remains uncertain. The difference between English and Mandarin speakers in the preference for spatial FoRs provides motivation to investigate Mandarin-speaking children's activation of intrinsic and relative FoRs underlying the use of projective spatial terms in the context where the reference object has inherent orientation.

In addition, the activation of intrinsic FoR has been found to be influenced by the feature of reference object: [+ social] vs. [- social] (Surtees et al., 2012). Humans are a typical example of reference object bearing the feature [+ social]. When a person serves as the reference object, the spatial FoR involves socially relevant information. Some scholars claimed that judging what other persons see was a demanding task

(Michelon & Zacks, 2006), and ignoring one's own perception comes at a cost (Nickerson, 1999), which seem to suggest that the intrinsic FoR is less likely to be activated when the reference object is a person, especially when the observer's perspective differs from the person's. On the other hand, some research suggests that simple visual perspective-taking, instead of being an effortful task, may be automatic in children as well as adults (Samson et al., 2010; Surtees & Apperly, 2012), and observers may spontaneously take others' perspective when making spatial descriptions (Tversky & Hard, 2009). The latter evidence indicates that when describing an object in relation to the position of a person (reference object), observers will consider the reference object's perspective, which is consistent with the person's inherent front and back, giving rise to the activation of an intrinsic FoR. To examine the influence of the reference object's feature [± social] on the activation of intrinsic FoR, Surtees et al. (2012) compared the acceptability ratings of spatial description in two types of scenes: in one type of scene, the reference object was a boy-like doll that bore the feature [+ social]; in the other, the reference object was a chair that was nonsocial but had identifiable orientation. The authors found that the English-speaking neurotypical children and adults showed a higher acceptability of the descriptions based on the intrinsic FoR when the reference object was social (the boy) than when the reference object was nonsocial (the chair). This finding suggests that the feature [+ social] of the reference object may facilitate the activation of intrinsic FoR in neurotypical speakers of English, fitting with the latter evidence that taking another person's perspective may be spontaneous or even automatic when making spatial descriptions (Samson et al., 2010; Tversky & Hard, 2009).

Regarding the spatial FoRs underlying the use of projective spatial terms in autistic individuals, while previous research has suggested that autistic individuals' use of projective spatial terms deviated from the typical pattern (Bochyńska, Coventry, et al., 2020; Bochyńska, Vulchanova, et al., 2020), it remains unclear whether autistic children are capable of activating both intrinsic and relative FoRs for spatial judgements as has been observed in English-speaking neurotypical children (Surtees & Apperly, 2012). In addition, as autistic individuals often have difficulties in the realm of social communication (American Psychiatric Association, 2013), the influence of a social reference object observed in non-autistic individuals' activation of intrinsic FoR may be altered in this clinical population.

There are two cognitive theories widely used to explain autistic individuals' atypical visuospatial processing: the weak central coherence hypothesis and the theory-of-mind deficit, which may also play a role in their activation of spatial FoRs. Some scholars proposed that autistic individuals' weak central coherence contributed to their superior performance in some visuospatial perception tasks such as the Embedded Figures Test (Jolliffe & Baron-Cohen, 1997) and the Block Design Test (Happé, 1994; Shah & Frith, 1993). According to the weak central coherence hypothesis (Frith, 1989; Frith & Happé, 1994; Happé, 1994), autistic individuals suffer from a reduced ability to process global information accompanied by an abnormal focus on fine details, so they excel at identifying target figures in the Embedded Figures Test by ignoring gist and focusing on parts of objects, and they specialize in decomposing the target patterns in the Block Design Test. Some scholars believed that theory-of-mind deficit could account for autistic individuals' impairment at visual perspective-taking (Aichhorn et al., 2006; Hamilton et al., 2009). Theory of mind (ToM), a somewhat misleading term presented by Premack and Woodruff (1978) in chimpanzees and further developed by Baron-Cohen, Leslie, and Frith (1985) in ASD, refers to cognitive ability to infer one's own and other people's mental states, such as desires, beliefs, thoughts, and intentions in order to predict and explain actions. Autistic individuals lacking ToM cannot simultaneously represent two different points of view or consider what other people see, so it becomes difficult for them to see the world from other people's perspectives (Pearson et al., 2013). The role of ToM in visual perspective taking has been supported by some evidence from imaging studies. Aichhorn et al. (2006) found activation in the temporo-parietal junction when judging other people's visual perspectives, and this brain area had been proved to be involved in reasoning about other people's mental states (Saxe & Kanwisher, 2003). Considering the roles of central coherence and ToM in visuospatial processing, autistic individuals' weak central coherence and ToM deficit may impact the activation of spatial FoRs and give rise to atypical use of projective spatial terms.

As mentioned, the weak central coherence hypothesis indicates that autistic individuals, focusing on fine details, have difficulty in diverting attention from local areas to the global context. For every spatial FoR, there is a coordinate system (a larger global concept) composed of several smaller conceptual constituents including reference object, figure object, viewer, etc. (Levinson, 2003). Therefore, the expectation of the weak central coherence hypothesis for spatial FoRs is that autistic individuals may focus on the reference object, a concrete entity with specific features (e.g., its front and back), activating the intrinsic FoR. Meanwhile, this population may ignore the coordinate system of relative FoR, which depends on the relationship between the reference object and the viewer. On the other hand, there will be a different expectation with regard to theory-of-mind deficit. The theory-of-mind deficit, based on the idea that autistic individuals are impaired in understanding other persons' perspectives, indicates that this population may disregard the perspective of reference object (especially the one bearing [+ social]), which is essential to the activation of intrinsic FoR. Thus, the expectation with regard to theory-of-mind deficit is that autistic individuals may have difficulties with the activation of intrinsic FoR. This population may be egocentric in encoding spatial relationships between objects, giving rise to the activation of relative FoR (more precisely, the translation variant). Hence, it remains uncertain which theory (the weak central coherence vs. the theory-of-mind deficit) is the deciding factor in the activation of spatial FoR(s) in ASD in the context where the reference object has inherent orientation.

Therefore, the current study aimed to examine the activation of spatial FoR(s) in Mandarin-speaking autistic and non-autistic children in two conditions. In one condition, reference objects that bore the feature [+ social] were employed; in the other condition, the reference objects were nonsocial but had inherent fronts and backs. This study would address four questions: (1) whether Mandarin-speaking non-autistic children and autistic children without intellectual disability (ID) matched on receptive language ability are able to spontaneously activate both intrinsic and relative FoR, and, if not, (2) whether the intrinsic FoR is dominant when the reference object has inherent orientation in the two groups of children, (3) whether the activation of intrinsic FoR is affected by the feature [± social] of the reference object, and (4) whether the activation of intrinsic FoR is associated with ToM.

4.2 Method

4.2.1 Participants

Participants were 24 autistic children without ID and 25 non-autistic children who had taken part in the experiment presented in Chapter 3. In order to examine whether the participants were able to activate both relative and intrinsic FoRs, an identifiable preference for the relative FoR's variant was required for data analyses (see subsection 4.2.3 Data Analysis for more details). Three participants from the autistic group and one from the non-autistic group did not show reliable evidence of preference for any variant of the relative FoR. Therefore, there were 21 autistic and 24 non-autistic children left for further analyses. The overview of autistic and non-autistic participant characteristics is presented in Table 4.1. A Mann-Whitney *U*-test was performed to compare the two groups of participants' chronological age, since their chronological age was not normally distributed (Shapiro-Wilk test: $p < .05$). The result of the Mann-Whitney *U*-test showed the autistic group was significantly older than the non-autistic group ($U = 590.50$, $p = .014$). The two groups of participants were sampled from normal distributions with equal variances in terms of receptive language ability, so a two-sample t-test was conducted to compare the receptive language ability of the two groups. No significant difference was detected between the two groups in receptive language ability ($t = 1.24$, $p = .222$).

Table 4.1. Description of autistic and non-autistic participants.

	Autistic (n = 21)	Non-autistic (n = 24)
Sex (boys：girls)	18：3	13：11
Chronological age (SD)	7.89 (1.07)	7.28 (.83)
Receptive language ability (SD)	116.90 (15.13)	122.27 (13.67)
IQ (SD)	93.42 (11.16)	N.A.

In addition, the 23 adults who had finished the relative FoR test participated in the task regarding the spatial terms in this study.

Ethical approval for the study was obtained from the Human Subjects Ethics Subcommittee at the Hong Kong Polytechnic University.

4.2.2 Tasks

The present study consisted of four tests: the multiple spatial FoRs test, the receptive language ability test, the intelligence quotient test, and the ToM test. Autistic participants were tested individually in a quiet room at training centers for children with special needs, while non-autistic participants were tested in the resource rooms of primary schools. The tests were administered in a fixed order: first, the intelligence quotient test (optional); second, the receptive language ability test; third, the multiple spatial FoRs test; and fourth, the ToM test.

4.2.2.1 The Intelligence Quotient Test

The Wechsler Intelligence Scale for Children (Chinese version) (4th ed.; WISC-IV (CN); Zhang, 2008) was administered to measure autistic participants' IQ. Autistic participants with IQ < 70 were not allowed to proceed to the multiple spatial FoRs test, as IQ < 70 indicates ID. WISC-IV (CN) is a norm-referenced intelligence test for mainland Chinese children who are six years old or above. Please see subsection 3.2.2.1 for a detailed introduction of the subtests of WISC-IV (CN).

4.2.2.2 The Receptive Language Ability Test

The Peabody Picture Vocabulary Test-Revised (PPVT-R; Sang & Miao, 1990) was administered to measure participants' receptive language ability. It is a norm-referenced standardized language test for children aged between three years six months and nine years 11 months in mainland China. The test would yield receptive language ability for every participant based on their raw score and his/her chronological age (see subsection 3.2.2.2 for details of the test).

4.2.2.3 The Multiple Spatial Frames of Reference Test

The multiple spatial FoRs test was used to examine whether participants activate both intrinsic and relative FoRs when interpreting projective spatial terms in the context where the reference object had inherent orientation. The test has three versions, since there are three variants of the relative FoR (translation, reflection, and rotation). For every participant, it was determined which version would be implemented based on their performance in the previous experiment, which examined relative FoR preference (see Chapter 3). The three versions of this test are similar in procedure, and only differ in data coding. For each trial of the test, participants saw a photograph displaying two objects. At the same time, they heard a pre-recorded sentence describing the position of one object in reference to the other object in the photograph. Participants had to rate the acceptability of the sentence.

The test made use of 16 photographs. Every photograph contained a ball as the figure object and another object (a boy-like doll, a girl-like doll, a wardrobe, or a chair) as the reference object. The reference object faced or faced away from the participants with the figure object near the reference objects' faces or backs. Thus, there were four different configurations for each reference object, as shown in Figure 4.2.

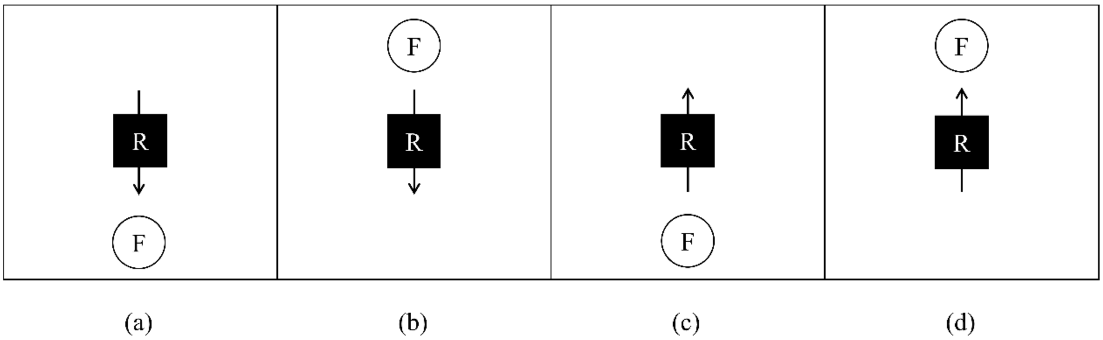


Figure 4.2. Four configurations used in the multiple spatial FoRs test.

Note: F = figure object; R refers to the reference object with inherent orientation. The arrow tip indicates the front side of the reference object. Configuration (a): the reference object faces participants while the figure object is near the reference object's face; Configuration (b): the reference object faces participants while the figure object is near the reference object's back; Configuration (c): the reference object faces away while the figure object is near the reference object's back; Configuration (d): the reference object faces away while the figure object is near the reference object's face.

Every photograph would appear twice accompanied by two different sentences, which described the position of the figure object in relation to the reference object using "front" or "behind". As there were 16 photographs, participants would receive 32 picture-sentence pairs in total. Some picture-sentence pairs were appropriate for the intrinsic/relative FoR, and some were inappropriate. Take the test version for the participants who showed a preference for the reflection variant of the relative FoR.

Table 4.2 shows the appropriateness of every picture-sentence pair coded for the intrinsic and the relative FoRs in this version.

Table 4.2. Appropriateness of picture-picture pair coded for the intrinsic FoR and the relative FoR.

	Reference object faces participants		Reference object faces away	
Picture				
Sentence 1 containing “front”	小球在女孩的前面。 The ball is in front of the girl.	小球在女孩的前面。 The ball is in front of the girl.	小球在女孩的前面。 The ball is in front of the girl.	小球在女孩的前面。 The ball is in front of the girl.
Appropriateness	Intrinsic (√) Reflection (√)	Intrinsic (×) Reflection (×)	Intrinsic (×) Reflection (√)	Intrinsic (√) Reflection (×)
Sentence 2 containing “behind”	小球在女孩的后面。 The ball is behind the girl.	小球在女孩的后面。 The ball is behind the girl.	小球在女孩的后面。 The ball is behind the girl.	小球在女孩的后面。 The ball is behind the girl.
Appropriateness	Intrinsic (×) Reflection (×)	Intrinsic (√) Reflection (√)	Intrinsic (√) Reflection (×)	Intrinsic (×) Reflection (√)

At the start of the multiple spatial FoRs test, participants were informed there was a cartoon character that was learning Mandarin. The cartoon character was observing the picture and trying to describe it. Participants were required to rate how well the cartoon character had done using a five-point scale. The best description should be given a score of five and the worst one should be assigned a score of one. The picture-sentence pairs were presented in random order using the computer software E-Prime 2.0. Participants gave responses by pressing the numeric keys on a keyboard, under no time pressure.

Before testing, the participants were invited to play with the actual objects that were used as reference objects for a while to familiarize themselves with the different sides of the reference objects. After the multiple spatial FoRs test, a follow-up test was used to test whether participants were able to identify the forward direction of the reference objects. For each trial, an object (boy-like doll, girl-like doll, wardrobe, or chair) was placed on a table in front of the participants. The object faced or faced away from the participants, and at the same time, they were required to indicate which side the object was facing. There were eight trials, with two for each reference object. None of the participants had difficulties with this follow-up task.

4.2.2.4 The ToM Test

Participants' ToM was assessed using two second-order ToM tasks: the look-predication task (Perner & Wimmer, 1985) and the say-prediction task (Sullivan et al., 1994). There were three test questions for each task. The participants were credited with one point if they gave the correct answer for one question, so the maximum score for the ToM test was six. Please see subsection 3.2.2.4 for a detailed introduction to the two ToM tasks.

4.2.3 Data Coding and Analysis

To determine whether Mandarin-speaking non-autistic children and autistic children without ID could activate both intrinsic and relative FoRs when judging the spatial description of a scene, the acceptability rating of every picture-sentence pair was encoded twice: once for examining the activation of the intrinsic FoR, and once for examining the activation of the relative FoR (Surtees et al., 2012). Aiming at investigating whether the intrinsic FoR was activated, the trials of picture-sentence pairs were coded as appropriate or inappropriate for the intrinsic FoR. According to Surtees et al. (2012), the evidence for spontaneous activation of intrinsic FoR is the significantly higher acceptability rating of picture-sentence pairs that are appropriate for the intrinsic FoR, compared with those inappropriate for the intrinsic FoR. Therefore, two-way Appropriateness (appropriate vs. inappropriate) × Group (autistic child vs. non-autistic child vs. adult) repeated measures ANOVAs were conducted to examine the activation of intrinsic FoR in the three groups of participants. If the statistical analyses revealed a significant main effect of Group or interaction effect, post hoc pairwise comparisons were performed with Bonferroni adjustment using the lsmeans package (Lenth, 2016). Likewise, all the trials of picture-sentence pairs were coded again based on their appropriateness for the relative FoR so as to examine the activation of this spatial FoR. As participants varied in relative FoR preference, the trials were coded for each participant individually. If participants preferentially adopted the reflection variant of the relative FoR, the picture-sentence pairs that were appropriate for the reflection variant were coded as appropriate for the relative FoR for these participants, and those inappropriate for the reflection variant were coded as inappropriate for the relative FoR. For participants who showed a preference for the translation variant, the picture-sentence pairs that were appropriate/inappropriate for the translation variant were coded as appropriate/inappropriate for the relative FoR, respectively. According to Table 3.5 in Chapter 3, some participants preferentially adopted both reflection and translation variants. Their responses were coded twice: once when they were regarded as having a preference for the translation variant, and once when they were regarded as preferring the reflection variant, giving rise to two sets of data (data A and data B). Based on data A, 2 × 3 repeated measures ANOVAs were conducted with Appropriateness for the relative FoR (appropriate vs. inappropriate) as within-subject, and Group (autistic child vs. non-autistic child vs. adult) as between-subjects factors. If the acceptability ratings of picture-sentence pairs that were appropriate for the relative FoR were significantly higher compared with those inappropriate for the relative FoR, it would be conclude that the data showed evidence of spontaneous activation of the relative FoR; otherwise, the participants failed to activate the relative FoR when the reference object had inherent orientation (Surtees et al., 2012). Additional repeated measures ANOVAs were run based on data

B, and similar results were found. Therefore, only the results of data A were reported in the following subsection. For the results of data B see Supplementary Material 1.

To determine whether the intrinsic FoR was the dominant spatial FoR in the context where the reference objects had inherent orientation, comparisons were performed between the acceptability ratings of picture-sentence pairs that are appropriate for the intrinsic FoR and those appropriate for the relative FoR. 2 × 3 repeated measures ANOVAs were conducted with Type (intrinsic vs. relative) as within-subject factor, and Group (autistic child vs. non-autistic child vs. adult) as between-subjects factor. Post hoc pairwise comparisons were performed with Bonferroni adjustment using the lsmeans package (Lenth, 2016) when necessary. If the intrinsic FoR is the dominant spatial FoR for the reference objects with fronts and backs, the acceptability ratings of the descriptions appropriate for the intrinsic FoR will be significantly higher, compared with those appropriate for the relative FoR.

Aiming at examining the influence of the reference object's feature [± social] in the activation of intrinsic FoR, another repeated measures ANOVA was undertaken with Feature (social vs. nonsocial) and Appropriateness for the intrinsic FoR (appropriate vs. inappropriate) as within-subject, and Group (autistic child vs. non-autistic child vs. adult) as between-subjects factors. Post hoc pairwise comparisons were performed where necessary, using the lsmeans package (Lenth, 2016) with Bonferroni adjustment. If the social reference objects (the boy- and the girl-like dolls), which may trigger social information, do put the autistic participants at a disadvantage in activating the intrinsic FoR, there would be a significant interaction of Feature × Appropriateness in the autistic group. Specifically, when the reference objects are social, the difference between the descriptions appropriate and inappropriate for the intrinsic FoR in acceptability ratings will be smaller, compared with when the reference objects are nonsocial (i.e., the chair and the wardrobe).

Another set of analyses was conducted to examine the role of ToM in the activation of intrinsic FoR in autistic and non-autistic children. First, cognitive profiles of the autistic participants were sketched by comparing their performance with that of non-autistic participants in the ToM test. Next, linear regression models were constructed to examine whether ToM affected the activation of intrinsic FoR when interpreting the projective spatial terms. Linear mixed-effect models were not used because the inclusion of random effect Subject was not justified by a lower AIC value (312.38 > 308.17). It began with a linear regression model with chronological age and receptive language ability as control factors. If receptive language ability or chronological age did not have an effect on the activation of intrinsic FoR, the factor(s) would be removed from the model one by one, starting with the effect with larger *p*-value. Next, the model was fit with ToM * Group (autistic vs. non-autistic) * Appropriateness (appropriate vs. inappropriate) to analyze the acceptability ratings of spatial descriptions. The two categorical factors (Appropriateness and Group) were deviation-coded. Therefore, the contrasts between levels of the factors were represented as -.5s and .5s, so as to test main effect of ToM rather than the effect of

ToM within a baseline condition. If ToM does play a role in the activation of intrinsic FoR, there will be a significant interaction of ToM × Appropriateness: that is, the participants with a high ToM ability would give high scores to the descriptions appropriate for the intrinsic FoR, while the effect of ToM on the acceptability ratings of descriptions inappropriate for the intrinsic FoR would be weak or even opposite.

4.3 Results

4.3.1 Activation of Intrinsic and Relative FoRs in Autistic and Non-Autistic Children

The current study examined the activation of intrinsic and relative FoRs in autistic and non-autistic participants in the context where the reference object had inherent orientation. First, it focused on whether the intrinsic FoR was activated; the spatial descriptions were coded as appropriate or inappropriate for the intrinsic FoR, whose average ratings of acceptability in the autistic child, the non-autistic child, and the adult groups are shown in Table 4.3. In general, ratings of acceptability were higher when spatial descriptions were appropriate for the intrinsic FoR compared with those that were inappropriate for the intrinsic FoR among the three groups of participants.

Table 4.3. Average acceptability ratings for the descriptions appropriate and inappropriate for the intrinsic FoR.

Group	Appropriate	Inappropriate
Autistic child	4.09 (1.53)	1.86 (1.48)
Non-autistic child	4.25 (1.51)	1.85 (1.48)

Adult	4.65 (0.91)	1.42 (1.00)

Statistical analysis revealed significant interaction of Appropriateness × Group ($F(2, 65) = 7.08$, $p = .002$, $\eta^2_G = .14$) and main effect of Appropriateness ($F(1, 65) = 507.97$, $p < .001$, $\eta^2_G = .85$), while the main effect of Group did not reach a significant level ($F(2, 65) = .38$, $p = .685$, $\eta^2_G < .01$). For the main effect of Appropriateness, the participants gave significantly higher scores to the spatial descriptions that were appropriate for the intrinsic FoR than to those inappropriate for the intrinsic FoR, which was further analyzed under different groups. The appropriate-inappropriate difference was observed in the three groups: autistic child ($t = 10.67$, $p < .001$, $SE = 0.21$), non-autistic child ($t = 12.29$, $p < .001$, $SE = 0.20$), and adult ($t = 16.19$, $p < .001$, $SE = 0.20$). The results suggest that the intrinsic FoR was activated in all three groups of participants. The interaction of Appropriateness × Group occurred because the effect of Appropriateness was greater in the adult group.

Turning to the activation of the relative FoR, the same set of spatial descriptions were coded based on the appropriateness for the relative FoR this time, rather than the intrinsic FoR. Table 4.4 shows the average ratings of acceptability of spatial sentences appropriate/inappropriate for the relative FoR in the three groups of participants. In general, the average ratings of acceptability were close to three regardless of the appropriateness for the relative FoR among all groups of participants. Statistical analyses did not detect a significant main effect of Appropriateness ($F(1, 65) = 2.58$, $p = .113$, $\eta^2_G = .02$) or Group ($F(2, 65) = .38$, $p = .685$, $\eta^2_G < .01$), and there was no significant interaction effect either ($F(2, 65) = .24$, $p = .788$, $\eta^2_G = .01$). The results did not support the activation of the relative FoR in the three groups of participants.

Table 4.4. Average acceptability ratings for the descriptions appropriate and inappropriate for the relative FoR.

Group	Appropriate	Inappropriate
Autistic child	3.08 (1.88)	2.87 (1.87)
Non-autistic child	3.13 (1.92)	2.97 (1.91)
Adult	3.06 (1.90)	3.00 (1.86)

In addition, to examine whether the intrinsic FoR was the dominant spatial FoR when the reference objects had inherent orientation, comparisons were made between the acceptability ratings of picture-sentence pairs that were appropriate for the intrinsic FoR and those appropriate for the relative FoR. A 2 × 3 ANOVA with Type (intrinsic vs. relative) as within-subject, and Group (autistic child vs. non-autistic child vs. adult) as between-subjects factors revealed a significant main effect of Type ($F(1, 65) = 303.79$, $p < .001$, $\eta^2_G = 0.65$, intrinsic > relative). Besides, there was a significant interaction of Type × Group ($F(2, 65) = 6.06$, $p = .004$, $\eta^2_G = .07$) and a significant main effect of Group ($F(2, 65) = 3.34$, $p = .041$, $\eta^2_G = .06$). For the main effect of Group, post hoc pairwise comparisons showed that compared with adults, autistic children gave lower scores to the spatial descriptions that were appropriate for the intrinsic or the relative FoR ($t = -.28$, $p = .038$, $SE = .11$), while non-autistic children did not differ from autistic children or adults in the acceptability ratings for these spatial descriptions (*p*s ⩾ .372). The interaction effect of Type × Group was analyzed under different groups to examine whether the acceptability ratings of descriptions appropriate for the intrinsic FoR were higher than those of descriptions appropriate for the relative FoR within each group. Post hoc pairwise comparisons revealed that the descriptions appropriate for the intrinsic FoR generated a much higher acceptability rating than the descriptions appropriate for the relative FoR for the autistic child group (t = 8.00, p < .001, SE = .13), the non-autistic child group (t = 9.29, p < .001, SE = .12), and the adult group (t = 12.99, p < .001, SE = .12). These results, together with the results of the ANOVAs on the activation of intrinsic/relative FoR, suggest that Mandarin-speaking autistic and non-autistic children do not spontaneously activate both intrinsic and relative FoRs when encoding the position of an object in relation to another object with inherent orientation, but preferentially adopt the intrinsic FoR, as has been observed in Mandarin-speaking adults.

4.3.2 Role of Reference Object Feature in the Activation of Intrinsic FoR in Autistic and Non-Autistic Children

The study examined whether the activation of intrinsic FoR was influenced by the feature of reference object [± social] in autistic and non-autistic participants. ANOVA with Feature (social vs. nonsocial) and Appropriateness for the intrinsic FoR as within-subject, and Group (autistic child vs. non-autistic child vs. adult) as between-subjects factors revealed a significant two-way interaction of Feature × Appropriateness (F(1, 65) = 4.32, p = .042, η^2_G = .01). The effect of Appropriateness (appropriate > inappropriate) was present for both social and nonsocial reference objects but was greater when the reference objects were social (estimate = 2.75, t = 22.12, $p < .001$, SE = .12) than when the reference objects were nonsocial (estimate = 2.49, t = 17.85, $p < .001$, SE = .14). This suggests that the participants exhibited higher sensitivity to the intrinsic FoR when the reference objects were social compared with nonsocial reference objects.

4.3.3 Role of ToM in the Activation of Intrinsic FoR in Autistic and Non-Autistic Children

Table 4.5 reports the performance of autistic and non-autistic participants in the ToM test (maximum = six). As the Shapiro-Wilk tests revealed that the data regarding ToM were not normally distributed (ps < .05), the median was reported in addition to the mean. Next, a Mann-Whitney U-test was performed to compare the two groups of participants in terms of ToM. The results showed that relative to non-autistic participants, autistic participants performed significantly worse in the ToM test (U = 274.50, $p < .001$).

Table 4.5. Performance of autistic and non-autistic participants in the ToM test.

Group	ToM test
Autistic (n = 21)	1.24 (SD = .89; median = 1)
Non-autistic (n = 24)	4.12 (SD = 1.75; median = 4.5)

Linear regression models were constructed to examine the role of ToM in the activation of intrinsic FoR in the autistic and the non-autistic groups. The inclusion of control factors (receptive language ability and chronological age) was checked first. The results showed that neither receptive language ability nor chronological age had a significant effect on the activation of intrinsic FoR ($p \geqslant .254$). Therefore, the model was fit with ToM * Group (autistic vs. non-autistic) * Appropriateness for the intrinsic FoR as fixed factors. The model revealed a significant main effect of Appropriateness ($t = 7.09$, $p < .001$, $SE = .28$; appropriate > inappropriate) and interaction of Group × Appropriateness ($t = 2.67$, $p = .009$, $SE = .53$), consistent with the results reported in Subsection 4.3.1. Besides, there was a significant interaction of ToM × Group × Appropriateness ($t = -3.94$, $p < .001$, $SE = .23$), which is illustrated in Figure 4.3. In the autistic group, the participants with high ToM would give high scores to the spatial descriptions that were appropriate for the intrinsic FoR, while giving low scores to the spatial descriptions that were inappropriate for the intrinsic FoR. This suggests that ToM ability facilitates the activation of intrinsic FoR in autistic participants. For non-autistic participants, the effect of ToM in the acceptability ratings of descriptions appropriate or inappropriate for the intrinsic FoR was weak.

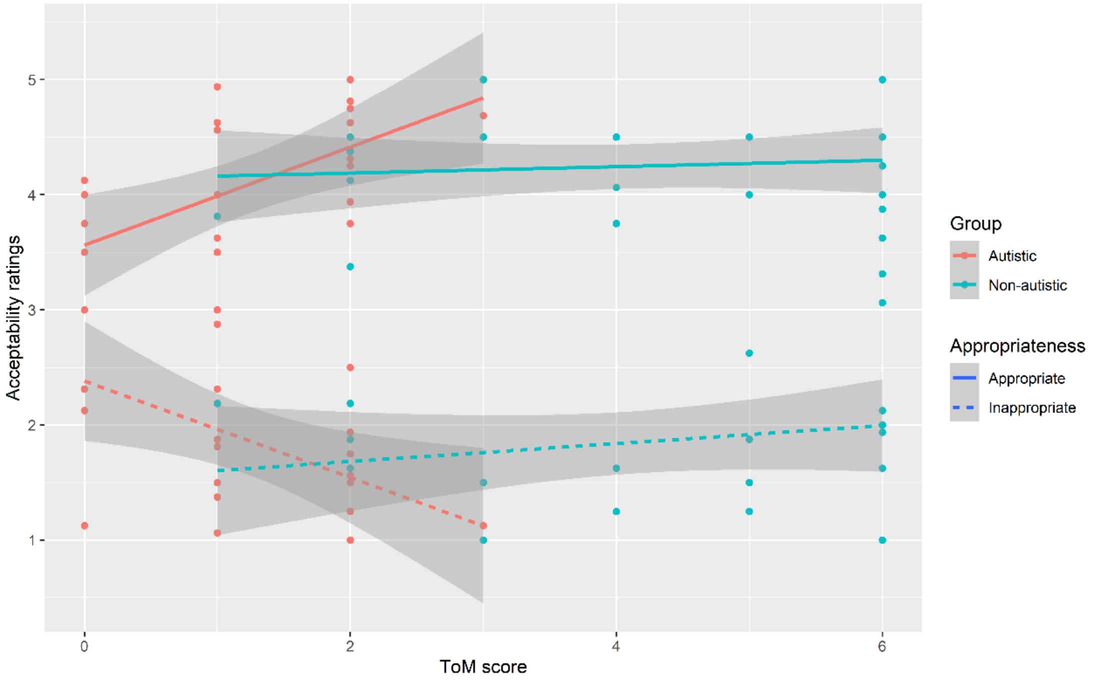


Figure 4.3. Relationship between ToM and acceptability ratings of spatial descriptions appropriate or inappropriate for the intrinsic FoR in autistic and non-autistic children.

4.4 Discussion

The study in this chapter examined the intrinsic FoR underlying the interpretation of projective spatial terms (“front” and “behind”) when locating an object in relation to an object with inherent orientation in Mandarin-speaking autistic children without ID, compared to Mandarin-speaking non-autistic children matched on receptive language ability.

4.4.1 Activation of Intrinsic FoR in Autistic and Non-Autistic Children

The activation of intrinsic FoR was observed in both autistic and non-autistic children; however, they did not activate the relative FoR when the reference objects had inherent fronts and backs. Specifically, the two groups of participants rated the spatial descriptions that were appropriate for the intrinsic FoR to be significantly better than those inappropriate for the intrinsic FoR, suggesting they were relying on the intrinsic FoR to encode space. By contrast, ratings of spatial descriptions that were appropriate for the relative FoR did not differ from those inappropriate on this dimension, indicating that neither autistic nor non-autistic participants showed sensitivity to the relative FoR in this context. The results did not converge with the previous finding that English-speaking neurotypical children were able to spontaneously activate both relative and intrinsic FoRs when evaluating location descriptions in relation to an object with inherent orientation (Surtees et al., 2012). In Surtees et al. (2012), the participants were required to judge whether the sentences were good spatial descriptions, and they rated the sentences that were appropriate for the intrinsic FoR or the relative FoR to be significantly better than those inappropriate for the intrinsic FoR or the relative FoR, respectively, reflecting the activation of both intrinsic and relative FoRs. While the results are not consistent with Surtees et al.'s (2012) finding in English-speaking neurotypical children, the data fit with previous evidence from neurotypical speakers of Mandarin that the orientational features of reference objects only trigger the intrinsic FoR (Deng & Yip, 2016). In Deng and Yip (2016), the participants in different age groups were required to judge whether sentences correctly described the position of an object in relation to a cow. More than 85% of the participants aged between three and six years judged the sentences relying on the intrinsic FoR to be correct, and judged the sentences relying on other spatial FoRs to be incorrect. To explain the divergence between the neurotypical speakers of English and Mandarin in the activation of both intrinsic and relative FoRs, it is useful to go back to the relative FoR underlying their space encoding. When the reference object did not have inherent orientation, the speakers of Mandarin were found to rely on both translation and reflection variants of the relative FoR (Deng & Yip, 2016; Guo, 2004, 2008), while the speakers of English exclusively adopted the reflection projection strategy (Cox, 1981). It means that, for the speakers of Mandarin, the front can be assigned to the space beyond the featureless reference object or the space between the featureless reference object and themselves, giving rise to uncertainty in using the projective spatial terms "front" and "back". The orientational features of the reference object may help to solve this uncertainty. Thus, when the reference object has inherent orientation, speakers of Mandarin are more likely to rely on the intrinsic FoR since this spatial FoR helps them encode the space more effectively.

The absence of activation of relative FoR in Mandarin speakers may also be ascribed to cultural influence/orientation. The relative FoR is a type of spatial FoR derived from the observer's own "self" perspective/orientation. When the reference objects have inherent orientation, it becomes feasible to generate a spatial coordinate system centered on the reference object, independent of the observer's perspective/orientation. In such case, speakers of Mandarin no longer activated the relative FoR. This phenomenon has been described as "losing one's self in space" since the relative FoR is linked to one's own "self" perspective (Surtees et al., 2012). Speakers of Mandarin living in collectivistic cultures (Chiu & Kosinski, 1995;

Greenfield et al., 2003) are reported to have interdependent selves (Shweder & Bourne, 1982). The cultural patterns of interdependence, which focus attention on others, may contribute to Mandarin speakers' "losing their self in space". Due to the influence of collectivistic cultures, Mandarin speakers may become less likely to derive a spatial FoR from their own perspective, resulting in an absence of relative FoR activation.

In addition, the activation of both intrinsic and relative FoRs observed in English-speaking children was limited to a certain context (Surtees et al., 2012). Surtees et al. (2012) made use of two types of featured reference objects: social and nonsocial. When the two types of reference objects were, instead of mixed, presented in separate blocks, the English-speaking children only relied on the intrinsic FoR to interpret the projective spatial terms "front" and "behind", while the relative FoR was no longer activated. The finding suggests that the intrinsic FoR is the dominant spatial FoR when the reference object bears orientational features, which is also confirmed by the result of comparing the acceptability rating of descriptions appropriate for the intrinsic FoR with those appropriate for the relative FoR. The results showed that the participants, regardless of diagnosis of ASD, rated the former significantly better than the latter.

The finding that autistic children were able to activate the intrinsic FoR seems to stand in contrast to the literature showing a deficit in perspective taking in autistic individuals (Hamilton et al., 2009; Ni et al., 2021; Pearson et al., 2013; Yirmiya et al., 1994). This population is often reported to encounter problems with understanding how the same object could appear differently from another perspective. The activation of intrinsic FoR has been argued to require viewers to consider the perspective of the reference object, which seems difficult for autistic individuals. The study instead found the activation of intrinsic FoR in the autistic group. One potential explanation for the finding is that the autistic participants compensated by focusing on the orientational features of reference objects (Frith, 1989; Frith & Happé, 1994; Happé, 1994), instead of rotating their mental position — a strategy that can be used in the perspective taking task, which facilitates the activation of the intrinsic FoR. A similar result was found by Bochyńska, Coventry, et al. (2020) who examined the intrinsic FoR in autistic and non-autistic individuals from Norway. The Norwegian participants were required to judge the descriptions of a ball's position in relation to a toy car as true or false, with the descriptions that were appropriate for the intrinsic FoR coded as true. Both autistic and non-autistic participants made judgments from the perspective of the car, and their scores were almost at ceiling. The result indicates that the activation of intrinsic FoR is preserved in autistic individuals, and that this population, like their non-autistic peers, will rely on the intrinsic FoR when the reference object has inherent orientation. While the activation of the intrinsic FoR appears to involve self-projection, autistic individuals, who are frequently reported to have difficulties with self-projection, can activate this spatial FoR, fitting with the evidence that the activation of intrinsic FoR may not necessarily require self-projection (Kessler & Thomson, 2010; Surtees & Apperly, 2012).

4.4.2 Factors Related to the Activation of Intrinsic FoR

As reported earlier, the intrinsic FoR was the dominant spatial FoR underlying Mandarin-speaking autistic and non-autistic children's use of projective spatial terms when the reference object had inherent orientation. This study further investigated whether and how the feature [± social] of reference object affected the activation of intrinsic FoR in the two groups of children. The results showed that both autistic and non-autistic participants rated the spatial descriptions that were appropriate for the intrinsic FoR to be significantly better than those inappropriate for the intrinsic FoR (appropriate > inappropriate), when the reference object, whether social or nonsocial, had inherent orientation. The appropriate-inappropriate difference was significantly larger when the reference object was social than when it was nonsocial, which is consistent with the previous findings in neurotypical English-speaking children (Surtees et al., 2012). The current suggestion is that the influence of the feature [± social] of the reference object may be due to the criterion used to distinguish the front and the back, which varies from case to case (Levinson, 2003). For social objects (i.e., humans and animals), the front refers to the side with the main perceptual organs (e.g., eyes), while for nonsocial objects, the assignment of the front can rely upon function, shape, etc. (Levinson, 1994). The orientational features of nonsocial objects seem more complex than those of social objects. Thus, forming a spatial coordinate system based on the orientational features of social reference objects may be less effortful, compared with nonsocial reference objects. This may help to explain why participants showed higher sensitivity to the intrinsic FoR when the reference objects were social, compared to when the reference objects were nonsocial.

The finding of positive influence of the social reference object in autistic children's activation of intrinsic FoR seems to contradict a previous report regarding social deficit in autistic individuals (American Psychiatric Association, 2013). The social reference objects used in the current study (i.e., humanoid dolls) may trigger socially relevant information. As autistic individuals with social deficits usually disregard the gaze direction of human reference objects, they are supposed to have difficulties in activating the intrinsic FoR when the reference object bears a social feature. The study instead found autistic participants, like their non-autistic peers, showed higher sensitivity to the intrinsic FoR when the reference objects were humanoid dolls. One possible explanation for this finding is that generating a spatial coordinate system centered on a human reference object may not require social interaction with the reference object. Thus, the influence of social deficits on the activation of intrinsic FoR is weak.

In addition to the external factor (i.e., the reference object's features), the study investigated whether and how the participants' ToM affected the activation of intrinsic FoR. The results showed that the effect of ToM ability on the sensitivity to the intrinsic FoR was larger in the autistic group than in the non-autistic group. Specifically, autistic participants who performed better in the ToM test tended to give higher scores to the spatial descriptions that were appropriate for the intrinsic FoR and lower scores to the spatial descriptions inappropriate for the intrinsic FoR than those who did not perform well in the ToM test. This finding suggests that Mandarin-speaking autistic children with higher ToM ability are more likely to rely upon the intrinsic FoR when encoding space in the context where the reference object has inherent orientation. For non-autistic participants, ToM ability had a weak effect on their sensitivity to the intrinsic FoR. To explain the different findings regarding the role of ToM in the autistic group and the non-autistic group, it is useful to go back to the relative FoR underlying their space encoding. When the reference object did not have inherent front and back, autistic children were found to preferentially adopt the translation variant of relative FoR. When a reference object with inherent orientation had its front toward the autistic participants, those who tried to use the translation strategy just as they did in situations with featureless reference objects might feel an inner conflict: that is, the intrinsic front of the reference object was on the near side, whereas the translation strategy assigned the front to the far side of the reference object. ToM ability would help these participants understand the perspective/orientation of the reference object could differ from their own, solving the inner conflict that might have a negative effect on the activation of intrinsic FoR. For non-autistic children, the conflict was not sharp when the reference object faced them, because they mainly relied on the reflection strategy, which assigned the front to the space between the reference object and themselves (i.e., the near side). In another situation where the featured reference object faced away from the observer (participant), there was no conflict between the perspective of the participant and that of the reference object. Therefore, no strong effect of ToM was found on non-autistic children's sensitivity to the intrinsic FoR.

4.5 Conclusion

The present study investigated the intrinsic FoR and the relative FoR underlying the interpretation of projective spatial terms when the reference objects had inherent orientation in Mandarin-speaking non-autistic children and autistic children without ID matched on receptive language ability. The activation of intrinsic FoR was observed in both autistic and non-autistic children; however, they did not activate the relative FoR when the reference objects had inherent fronts and backs, showing that they were "losing their self in space". In addition, when the reference objects bore the feature [+ social], both autistic and non-autistic children were more likely to rely on the intrinsic FoR when interpreting the projective spatial terms. This suggests that autistic children do not have difficulties with reference objects bearing socially relevant information when encoding space. Furthermore, the autistic children's sensitivity to the intrinsic FoR was found to be influenced by their ToM ability.

Chapter 5. Spatial Demonstrative Interpretation Based on Deictic Frame of Reference in Mandarin-Speaking Autistic and Non-Autistic Children

5.1 Introduction

The spatial FoRs proposed by Levinson and colleagues are mainly related to projective spatial terms, such as “front” and “behind”, and “left” and “right” (Levinson, 2003; Levinson et al., 2002; Levinson & Wilkins, 2006). However, Diessel (2014) pointed out that a class of spatial terms has been ignored in their research: that is, spatial demonstratives (e.g., “this” and “that”, and “here” and “there”). This class of spatial terms invokes a deictic FoR, which should not be disregarded when examining spatial reasoning (Diessel, 2014). The commonly used spatial demonstratives in Mandarin include 这 “this”, 那 “that”, 这里 “here”, and 那里 “there”.

Spatial demonstratives have been observed in the speech of Mandarin-speaking non-autistic toddlers around two years of age (Kong & Chen, 1999; Zhang & Wu, 2007), consistent with the findings of studies examining toddlers speaking other languages (e.g., English, Japanese, Italian; Boyd, 1914; Clark & Sengul, 1978; Grant, 1915; Nice, 1915). As these terms require an understanding of the speaker’s position for their interpretation, Mandarin-speaking non-autistic toddlers aged three years still experience difficulties interpreting spatial demonstratives (Zhao, 2007; Zhu et al., 1986). Similarly, de Villiers and de Villiers (1974), examining the interpretation of spatial demonstratives in English-speaking non-autistic toddlers, found three-year-old participants made errors frequently. In these studies, the participants in older age groups exhibited the ability to take the speaker's perspective and performed better in interpreting spatial demonstratives (de Villiers & de Villiers, 1974; Zhao, 2007; Zhu et al., 1986). The development of spatial demonstratives seems consistent across languages.

However, non-autistic children speaking English and those speaking Mandarin differ in which member of a spatial demonstrative pair is acquired earlier, "here" vs. "there", and "this" vs. "that". Two case studies recording the use of spatial demonstratives in Mandarin-speaking toddlers reported 这 "this" appeared earlier than 那 "that" (Kong & Chen, 1999; Zhang & Wu, 2007). Zhao (2007) examined the comprehension of spatial demonstratives in Mandarin-speaking children. Her results showed that the participants performed better in the comprehension of 这 "this" than the comprehension of 那 "that" (Zhao, 2007). By contrast, Tfouni and Klatzky (1983) found it was more difficult to comprehend "this" and "here" than "that" and "there" for English-speaking neurotypical children. Tfouni and Klatzky (1983) proposed one explanation for their finding: in the two pairs of spatial demonstratives, "this" and "here" are marked while "that" and "there" are unmarked, and the unmarked members are usually learned before the marked members (Donaldson & Balfour, 1968; Klatzky et al., 1973). One criterion for determining which member of a pair is marked and which is unmarked is the generality of distribution. The unmarked members are characterized by greater generality of distribution. An asymmetry has been found between 这 “this” and 那 “that” in their usages, with 那 “that” having a broader possibility of application than 这 “this” (Wu, 2004). In addition to being a deictic term, 那 “that” also appears in idiomatic expressions (see sentence 1 below), has a usage in euphemism (see sentence 2), and a conjunctive usage as in (3). The wider usage of 那 “that” in Chinese is supposed to contribute to a better mastery of 那 “that” compared with 这 “this”. However, Zhao (2007) reported an opposite finding that her participants performed better in comprehending 这 “this” than 那 “that”, suggesting that the wider usage of 那 “that” does not facilitate the mastery of its deictic usage for space.

(1)	Na	dangran!							
	that	of course							

“Of course!” (Xun et al., 2016)

(2)	…you	juede	jiang	de	guohuo	ye	bu	da	nage, …
	…but	think	reward	DE	overly	also	NG	quite	“nage”

“…but thought over reward was also quite — you know what I mean…” (Xun et al., 2016)

(3)	Ruguo	renren	dou	neng	jieyue	yi	di	shui,
	If	everyone	all	can	save	QN	CL	water,

na 13yi di shui jiu hui huicheng heliu.

then QN CL water ADP will converge river.

"If everyone saves a drop of water, 1.3 billion drops of water will converge into a river." (Xun et al., 2016)

The conflicting findings of Zhao (2007) and Tfouni and Klatzky (1983) may be attributed to task design. The task of both studies is to ask the participants to act out movements according to the instructions of experimenter(s), which contain spatial demonstratives referring to proximal or distal objects (e.g., "put that elephant in the black zoo"), but there were three different conditions. First, the same perspective condition: the participant as addressee was seated beside the experimenter; second, the opposite perspective condition: the participant as addressee was seated opposite the experimenter; third, the spectator perspective condition: the participant was in a spectator position with two experimenters sitting opposite one another. Although the third condition is named the spectator perspective condition, the participants needed to place the objects according to the experimenters' instructions, instead of solely watching. Young children showed a tendency to choose objects close to themselves, so they would perform better on instructions with "this" or "here" in the same perspective condition while they would perform better on instructions with "that" and "there" in the opposite perspective condition. The same and the opposite perspective conditions were employed by Zhao (2007), while the study by Tfouni and Klatzky (1983) consisted of the opposite and the spectator perspective conditions, but not the same perspective condition. Therefore, employing the opposite perspective condition and not employing the same perspective condition in Tfouni and Klatzky (1983) might be one possible explanation for their finding that the participants were more accurate at interpreting “that” and “there” than “this” and “here”.

In addition, there is some discrepancy in the degree of difficulty in interpreting spatial demonstratives in different conditions. Tfouni and Klatzky (1983) found their participants performed better in the opposite perspective condition than in the spectator perspective condition (i.e., opposite > spectator). However, the opposite results were found in Zhu et al.’s (1986) study of Mandarin-speaking non-autistic children. Zhu et al. (1986) employed all the three conditions, and their results showed that the degree of difficulty of the three conditions from easiest to hardest were same > spectator > opposite perspective conditions.

The instructions of experimenter(s) used in these previous studies might account for the random variation in the findings of participants’ performance in spatial demonstrative interpretation. For each instruction, there was only one spatial demonstrative, which would give rise to ambiguity in a testing situation (Diessel, 2012; Hobson, García-Pérez, et al., 2010; Levinson, 2004; Lyons, 1975; Tfouni & Klatzky, 1983). Take “this” as an example. Even when the speaker and the addressee have opposite perspectives, “this” could mean both close to the speaker and close to the addressee in a small-scale setting. The experiments of the three studies (Tfouni & Klatzky, 1983; Zhao, 2007; Zhu et al., 1986) were implemented on a table, which is a typical small-scale setting. In such case, “this” would trigger an ambiguous representation for the participants in the opposite perspective condition. Specifically, "this" could mean both close to the experimenter and close to the participants because of the small-scale setting, even though the experimenter and the participants are completely opposite to each other in perspective. The ambiguous instructions were believed to have confounding effects on participants' performance in comprehending spatial demonstratives (Hobson, García-Pérez, et al., 2010; Tfouni & Klatzky, 1983). To avoid ambiguity, it has been suggested to establish a deictic contrast, which can be achieved by using a pair of spatial demonstratives when giving one instruction. This will be adopted in the current study to address the inconsistent findings of children's comprehension of spatial demonstratives in the three perspective conditions. As previous studies found the successful interpretation of spatial demonstratives was no earlier than four years old, and more than one spatial demonstrative would be used in the current study, the youngest children to be recruited was four years old.

As for spatial demonstratives, a pragmatic aspect of language, it is supposed that autistic individuals may encounter difficulties, since they often show pragmatic dysfunction (Baron-Cohen, 1988; Loukusa & Moilanen, 2009; Philofsky et al., 2007; Swineford et al., 2014; Whyte & Nelson, 2015). Autistic pragmatic deficits are consistently reported for turn-taking (e.g., Capps et al., 1998; Eales, 1993), topic management (e.g., Tager-Flusberg & Anderson, 1991; Volden & Lord, 1991), the comprehension of figurative language, such as simile (e.g., Cheung et al., 2020), metaphor (e.g., Kalandadze et al., 2019), irony (e.g., Deliens et al., 2018), and idiom (e.g., Whyte et al., 2014), and the use of deictic expressions, such as personal pronoun (e.g., Overweg et al., 2018) and spatial demonstrative (e.g., Friedman et al., 2019).

The research on deictic expressions in autistic children mainly focused on personal pronouns (Arnold et al., 2009; Baltaxe, 1977; Charney, 1980; Fay, 1979; Hobson, Lee, et al., 2010; Jordan, 1989; Lee et al., 1994; Naigles et al., 2016; Oshima-Takane & Benaroya, 1989; Overweg et al., 2018a). One typical example of deictic dysfunction in ASD is personal pronoun reversal: that is using the second personal pronoun “you” to refer to oneself and/or using the first personal pronoun “I” to refer to the addressee (Kanner, 1943, 1944). Besides, autistic individuals were found to avoid using personal pronouns, showing a greater tendency to use proper names for themselves and the addressees (Baltaxe, 1977; Jordan, 1989; Tager-Flusberg et al., 1990).

Regarding spatial demonstratives in ASD, much attention has been focused on autistic individuals’ production of these terms (Friedman et al., 2019; Hobson, García-Pérez, et al., 2010; Landry & Loveland, 1989; Loveland & Landry, 1986; Tager-Flusberg et al., 1990). In a series of studies by Loveland and Landry, the production of spatial demonstratives was examined in English-speaking children with ASD and language-delayed controls aged between five and 13 years through videotaping (Landry & Loveland, 1988, 1989; Loveland & Landry, 1986). They found autistic children were less likely to be spontaneous in producing “this” and “that”, and “here” and “there”, relative to the control group. A longitudinal study by Tager-Flusberg et al.

(1990) compared spontaneous utterances in two clinical groups, autistic and Down syndrome, by following six English-speaking autistic children and six English-speaking children with Down syndrome over a period of time ranging from 12 to 26 months. The two groups of children were matched on chronological age (range: three to six years old) and mean length of utterance at the starting point. When the participants' mean length of utterance did not exceed three, autistic participants were found to use significantly fewer spatial demonstratives relative to participants with Down syndrome. In another study (Hobson, García-Pérez, et al., 2010), the spatial demonstrative production of English-speaking autistic children and adolescents was compared with that of children with intellectual disability (ID), and the two groups of participants were matched on both receptive language ability and chronological age (age range: five to 14 years old). The results showed that only participants in the autistic group referred to a location that was distal to themselves by using “this” or “here”. Friedman et al. (2019) examined spatial demonstrative production during a semi-structured conversation in adolescents with fragile X syndrome who also received a co-diagnosis of ASD (mean age = 12.79 years), compared to chronological-age-matched idiopathic autistic adolescents (mean age = 13.16 years). The results showed that adolescents with fragile X syndrome and co-diagnosis of ASD produced a larger proportion of appropriate spatial demonstratives than autistic adolescents. In short, autistic individuals produced a larger proportion of inappropriate spatial demonstratives or fewer spatial demonstratives overall, relative to individuals suffering from various conditions, including developmental language delay, ID, Down syndrome, and fragile X syndrome.

However, to the best knowledge, there is only one empirical study that investigated the comprehension of spatial demonstratives in autistic individuals (Hobson, García-Pérez, et al., 2010). This study compared the performance of autistic individuals aged between eight and 14 years with that of individuals with ID matched on chronological age and verbal mental age. The participants' understanding of spatial demonstratives was measured by an act-out task. The task involved two experimenters sitting opposite each other. In front of the two experimenters, there were two chairs 1.5 meters apart from each other. Two toy fields created with plastic fences were each placed on a chair. The two experimenters took it in turns to communicate with the participant that he/she should put objects into a certain field denoted by spatial demonstratives, like "put an object in this field, and put an object in that field". This task could assess the participants' ability to understand that "this/here" denotes a place that is closer to the person who uttered the term while "that/there" denotes a place that is more distal. The results showed the autistic group made more errors in responding to the experimenters' instructions containing spatial demonstratives than the control group, suggesting that autistic individuals are less capable of interpreting spatial demonstratives than those with ID. Hobson, García-Pérez, et al. (2010) did not compare participants' performance in comprehending "that" and "there" (distal type) with that in comprehending "this" and "here" (proximal type), leaving it unsettled as to which member of a pair of spatial demonstratives is mastered better by autistic individuals. In addition, as only one condition (the spectator perspective condition) was employed by Hobson, García-Pérez, et al. (2010), autistic individuals' comprehension of spatial demonstratives in the other two conditions (same and opposite) remains unclear. Therefore, the current study will address the gaps by comparing autistic children's performance in comprehending different types of spatial demonstratives (proximal vs. distal) in different perspective conditions (i.e., same, opposite, and spectator).

With regard to the finding of autistic individuals misinterpreting spatial demonstratives, one possible explanation is their deficit in ToM, defined as the cognitive ability to infer one's own and other people's mental states (Baron-Cohen et al., 1985; Premack & Woodruff, 1978). Autistic individuals' pragmatic dysfunction is often attributed to this cognitive inability (Cardillo et al., 2021). For instance, Taiwanese-speaking autistic individuals (age range: seven to 12 years) who did not pass the task assessing ToM performed significantly worse than those who passed the ToM task in comprehending figurative language, including metaphor, irony, indirect reproach, and sarcasm (Huang et al., 2015). A study examining the comprehension of personal pronoun by Dutch-speaking autistic children aged between six and 12 years found that autistic participants with low ToM ability made more errors when interpreting personal pronouns than those with a high ToM ability. In addition, previous studies found that ToM was associated with the ability to take people's perspective to observe the world (Aichhorn et al., 2006; Pearson et al., 2013), which has been believed to be significant for interpreting spatial demonstratives (de Villiers & de Villiers, 1974). The role of ToM in spatial demonstrative interpretation has been corroborated by empirical studies in non-autistic children (Chu & Minai, 2014, 2018). Chu and Minai (2014, 2018) examined whether ToM had an impact on the comprehension of spatial demonstratives in English-speaking non-autistic children (age range: three to six years) and Chinese-speaking non-autistic children (age range: four to six years). ToM was assessed using a hide-and-seek task that tapped into the participants' understanding that seeing leads to knowing. In the hide-and-seek task, an object was hidden by character A in one of three identical containers with covers, and this process was being watched by character B while character C was wearing a blindfold. Meanwhile, the participants were not allowed to watch the hiding event. The participants were then required to guess which container had the hidden object with the help of character B and character C: that is, characters B and C would point to the box that they each thought contained the object. The correct response was to select the box pointed to by character B, which reflects the ability to infer the knowledge state of others. The comprehension of spatial demonstratives was measured by a judgment task, where participants were required to judge whether a picture matched a sentence containing spatial demonstratives. In the picture, there was a person on the right-hand side of the picture and two white objects to the left of the person, with one placed next to the person and the other placed apart from the person. The person in the picture would utter "paint this object blue", and then the color of one object became blue. The correct response is to judge the picture with the blue object next to the person as matching, and the picture with the blue object apart from the person as mismatched. The results showed that participants' ToM task score was positively associated with their performance in comprehending spatial demonstratives, regardless of language background (English vs. Chinese), indicating that ToM plays a role in spatial demonstrative comprehension by non-autistic children speaking English or Chinese. However, there has been no empirical study examining the relationship between ToM and comprehension of spatial demonstratives in autistic children. Pearson et al. (2013) proposed that autistic children, lacking ToM, had difficulty in observing the world from other people's perspectives. If a hearer fails to take the speaker's perspective, the hearer will interpret spatial demonstratives incorrectly when the hearer and the speaker differ in perspective. Therefore, there is reason to hypothesize that autistic children's ToM deficit may account for their poor performance in the comprehension of spatial demonstratives. Thus, the current study will examine this assumption.

An alternative explanation for autistic individuals' difficulty with spatial demonstrative comprehension is their executive dysfunction. EF refers to a set of cognitive abilities that coordinate thoughts and actions, and direct them to the attainment of future goals (Best & Miller, 2010; Diamond, 2013; Miyake et al., 2000). The role of EF in autistic individuals' pragmatic abilities has been examined in other aspects of pragmatics, such as personal pronouns, which has been found to be influenced by working memory, a subcomponent of EF (Overweg et al., 2018a). Working memory refers to the capacity system that temporarily stores received information and manipulates it (Diamond, 2013; Miyake et al., 2000). Autistic individuals with a lower working memory showed poorer performance in understanding personal pronouns, as these terms have been argued to require sufficient cognitive recourse for their interpretation (Overweg et al., 2018a). There is evidence from non-autistic adults that the interpretation of scalar implicatures draws on working memory resources because processing scalar implicatures involves consideration of a rich array of linguistic (e.g., the literal meaning of the utterance) and extra-linguistic information (e.g., the speaker's epistemic state and the purpose of the utterance). Previous studies showed that young non-autistic children performed poorly in the comprehension of spatial demonstratives uttered by a speaker whose perspective differed from the children's (Clark & Sengul, 1978; Webb & Abrahamson, 1976), because more information must be maintained in working memory to process different perspectives. Therefore, autistic individuals' difficulty with spatial demonstratives might be attributed to their low working memory (see Lai et al., 2017 for a meta-analysis of autistic individuals' working memory). Another subcomponent of EF, mental flexibility, has been found to assist the comprehension of spatial demonstratives in non-autistic children (Chu & Minai, 2014, 2018). Mental flexibility involves a capacity to think in multiple ways such as switching between dimensions and considering other people's perspectives (Zelazo, 2015). The task used to assess the ability to comprehend spatial demonstratives has been introduced in the previous paragraph. To measure mental flexibility, the authors adopted the Dimensional Change Card Sort (DCCS) task, which consists of cards depicting a blue rabbit or a red boat. Participants were required to sort the cards according to one dimension (e.g., shape: rabbit shape vs. boat shape), and then according to another dimension (e.g., color: blue vs. red). The DCCS task assessed whether the participants were able to inhibit the first dimension and switch to the second dimension. The results of studies by Chu and Minai (2014, 2018) showed that participants' score on the DCCS task was positively associated with their performance in comprehending spatial demonstratives, suggesting the role of mental flexibility in spatial demonstrative comprehension. It is well known that mental flexibility is impaired in autistic individuals (Demetriou et al., 2018; Hill, 2004; Lai et al., 2017), and this might account for their poor performance in the comprehension of spatial demonstratives. The study also aimed at scrutinizing this assumption.

To conclude, this study will investigate the comprehension of two pairs of spatial demonstratives by Mandarin-speaking autistic children without ID and non-autistic children in three conditions, and the possible factors that have influence on spatial demonstrative comprehension (ToM and EF) to address the following questions:

(1) In which condition do the two groups of children perform better in comprehending spatial demonstratives: the same, opposite, or spectator perspective conditions?

(2) Which member of a spatial demonstrative pair (“this” vs. “that”; “here” vs. “there”) is mastered better by the two groups of children?

(3) Do Mandarin-speaking autistic children without ID have difficulty comprehending spatial demonstratives relative to language-ability-matched non-autistic children?

(4) Do ToM and EF have any influence on the two groups of children’ comprehension of spatial demonstratives in the three conditions.

5.2 Method

5.2.1 Participants

Autistic group. Thirty-five Mandarin-speaking autistic children were recruited through the Xiaohaixing Service Center for Special Children and the Yuxing Training School for Autistic Children, Xiamen, China. To participate in this study, all children in the autistic group had to have received an official clinical diagnosis of ASD by a pediatrician or a clinical psycholinguist, either in public hospitals or in child assessment centers using the criteria of the fourth (American Psychiatric Association, 2000) or fifth (American Psychiatric Association, 2013) edition of the Diagnostic and Statistical Manual of Mental Disorders. Autistic individuals without ID are those with an intelligence quotient (IQ) score not lower than two standard deviations below the population mean (American Psychiatric Association, 2013). The Wechsler Preschool and Primary Scale of Intelligence (Chinese version) 4th ed.; the WPPSI-IV (CN), Li

& Zhu, 2014) was administered to measure the IQ of autistic children aged six years 11 months or below, while for those who were seven years old or above the Wechsler Intelligence Scale for Children (Chinese version) 4th ed.; WISC-IV (CN); Zhang, 2008) was used prior to the tests. The autistic participants with IQ < 70 were not allowed to proceed to the actual test, as such individuals are classified as having ID. Two participants from the autistic group were excluded because their IQ scores were lower than 70, with one girl scoring 68 and one boy scoring 58. To ensure the children could fully understand the task instructions, only those who scored above cut-off levels on the standardized language test, the Peabody Picture Vocabulary Test-Revised (Sang & Miao, 1990), were included. Five autistic participants scored below cut-off levels. In addition, one boy failed to finish all the tasks. Therefore, 27 autistic children were left for further analyses.

Non-autistic group. Twenty-eight Mandarin-speaking non-autistic children were recruited via advertisements posted on the WeChat social media platform or flyers sent to the Golden Coast Kindergarten, or via word of mouth. Regarding the exclusion criteria for the non-autistic group, if, according to their legal guardians or teachers, the applicants received a diagnosis of or were suspected of having a language or mental health disorder or a learning disability, they were rejected. None of the non-autistic participants scored below cut-off levels on the Peabody Picture Vocabulary Test-Revised (Sang & Miao, 1990).

Table 5.1 presents descriptive characteristics (means and standard deviations) of the two groups of children. As the two groups of participants' chronological age was not normally distributed according to the results of the Shapiro-Wilk tests (*p*-values < .05), a Mann-Whitney *U*-test was conducted to compare their chronological age and found autistic participants were significantly older than non-autistic participants (U = 978.50, p < .001). The groups of participants were sampled from normal distributions with equal variances in terms of receptive language ability. Therefore, a two-sample t-test was used to compare receptive language ability in the two groups and detected no significant difference in receptive language ability (t = .67, p = .506).

Table 5.1. Description of autistic and non-autistic participants.

	Autistic (n = 27)	Non-autistic (n = 28)
Sex (boys：girls)	22：5	20：8
Chronological age (SD)	6.88 (1.22)	5.83 (.58)
Receptive language ability (SD)	114.48 (15.02)	117.14 (14.45)
IQ (SD)	95.67 (10.99)	N.A.

The study also recruited 24 Mandarin-speaking adults (age range: 22 to 38 years, mean age = 30.13 years). They only participated in the task assessing spatial demonstrative comprehension. Their correct rates of spatial demonstrative comprehension were at ceiling (mean = 98.18%; SD = 3.55%).

Ethical approval for the study was obtained from the Human Subjects Ethics Subcommittee at the Hong Kong Polytechnic University. All child participants' legal guardians and adult participants provided informed consent before the start of the tests.

5.2.2 Tasks

The present study involved six tests: the spatial demonstrative comprehension test, the working memory test, the mental flexibility test, the ToM test, the receptive language ability test, and the intelligence quotient test. Children were tested individually in a quiet room at the centers for special children or at the Golden Coast Kindergarten. The tests were administered in Mandarin, and the order of the tests was fixed: first the intelligence quotient test (for autistic children only); second, the receptive language ability test; third, spatial demonstrative comprehension test; fourth, the ToM test; fifth, the working memory test; and sixth, the mental flexibility test.

5.2.2.1 The Intelligence Quotient Test

The WPPSI-IV (CN; Li & Zhu, 2014) was administered to measure the IQ of autistic children aged six years 11 months or below, while for those who were seven years old or above the WISC-IV (CN; Zhang, 2008) was used. Autistic participants with IQ $<$ 70 were not allowed to proceed to the spatial demonstrative comprehension test, as IQ $<$ 70 indicates ID. The WPPSI-IV (CN) is a norm-referenced standardized intelligence test for children aged four years to six years 11 months in mainland China. It consists of 15 subtests, and the full-scale IQ is based on six subtests measuring abilities from five aspects: verbal comprehension, visuospatial ability, fluid reasoning, working memory, and processing speed. For verbal comprehension, two subtests were administered: the Similarities subtest and the Information subtest. The former assesses children's ability to identify similarities between two objects and the latter required children to answer questions on various topics based on general factual knowledge. Visuospatial ability was assessed using the Block Design subtest where children had to put blocks together according to an intact pattern, while fluid reasoning was measured using the Matrix Reasoning subtest, which required children to complete 2 × 2 or 3 × 3 picture matrices with one picture missing for each matrix. Working memory was measured using the Picture Memory subtest where children were required to view a stimulus page showing several pictures for five seconds and then choose same pictures on the response page, which contained target pictures and distractors. Processing speed was assessed using the Bug Search subtest, where target bugs were presented, and then children were asked to mark the target bugs as quickly as possible in search groups. For the WISC-IV (CN) designed for children who are six years old or above, please see subsection 3.2.2.1 for a detailed introduction of its subtests

5.2.2.2 The Receptive Language Ability Test

The Peabody Picture Vocabulary Test-Revised (Chinese version; PPVT-R; Sang & Miao, 1990) was administered to measure participants' receptive language ability. It is a norm-referenced standardized language test for children aged three years six months to nine years 11 months in mainland China. Please see subsection 3.2.2.2 for a detailed introduction.

5.2.2.3 The Spatial Demonstrative Comprehension Test

The Spatial demonstrative comprehension test was used to assess the participants' understanding of spatial demonstratives. The test made use of two pairs of spatial demonstratives (这 "this" and 那 "that", and 这里 "here" and 那里 "there"). The participants were required to arrange objects in certain places, according to the instructions of experimenter(s). There were three conditions: the same perspective condition, the opposite perspective condition, and the spectator perspective condition. Figure 5.1 showed the positions of participants and experimenter(s), and the arrangement of experimental materials in the three conditions. In each condition, the experimenter(s) gave four sets of instructions. Every set included two instructions, with each instruction containing a pair of contrasting demonstratives. In total, participants received 24 instructions, eight per condition. This is an example of a set of instructions: "child's name, 请把苹果放进这个篮子，请把橘子放进那个篮子" "please put an apple in this basket, and put an orange in that basket"; "child's name, 请把草莓放进那里，请把香蕉放进这里" "please put a strawberry there, and put a banana here". As shown in Figure 5.1, two experimenters were involved in the spectator perspective condition. In this condition, two experimenters took it in turns to communicate to the participant that he/she should place an object in one location. The order of the condition was fixed: first same perspective condition; second, the opposite perspective condition; and third, the spectator perspective condition. To avoid non-verbal cues, the experimenters were trained to look at the objects they mentioned rather than the places (e.g., basket for the example above) when delivering instructions, and no gestures were allowed, such as nodding towards, pointing to, etc.

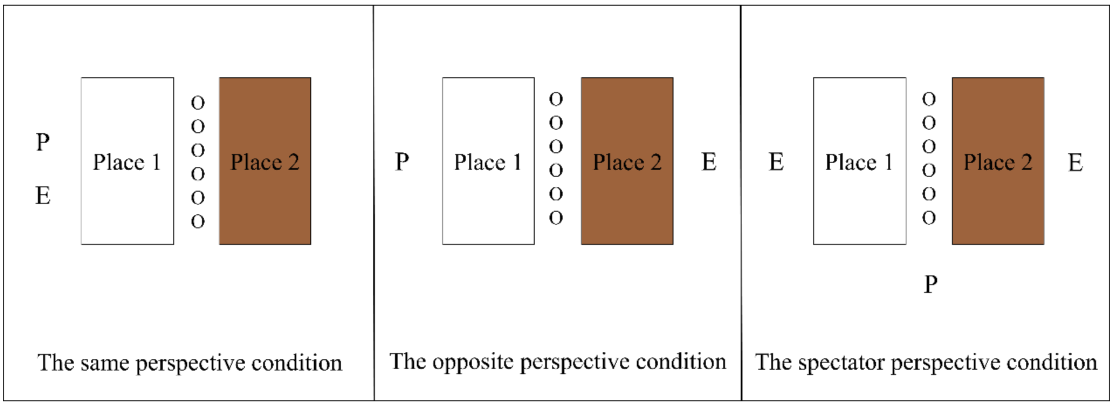


Figure 5.1. Positions of participants and experimenter(s) and arrangement of materials in the three conditions.

Note: P = participant; E = experimenter; O = objects (i.e., toy animals/fruits); Place 1 = white field/basket; Place 2 = brown field/basket.

The test on spatial demonstrative comprehension has been proven valid for Mandarin-speaking children. A similar task has been used in the study by Zhu et al. (1986), which examined the comprehension of spatial demonstratives in Mandarin-speaking children between the ages of three and seven years. One difference between Zhu et al. (1986) and the current study is that every instruction in Zhu et al. (1986) contained only one spatial demonstrative, while a pair of spatial demonstratives was involved in the current study. The main reason for having the experimenter(s) refer to two objects using two demonstratives every time rather than one is that only involving one demonstrative is ambiguous (Diessel, 2012; Levinson, 2004; Lyons, 1975; Tfouni & Klatzky, 1983). Hobson, García-Pérez, et al. (2010) proposed that using a pair of demonstratives would establish a deictic contrast, eliminating the ambiguity.

Considering that using two spatial demonstratives increases the degree of difficulty of the task, a screening test was included before the main test to ensure the participants were able to deal with the task demands. The screening test consisted of eight trials where the instructions were similar in form to those used in the main test, but no spatial demonstratives were involved (e.g., “child’s name, 请把苹果放进白色篮子，请把香蕉放进棕色篮子” “please put an apple in the white basket and put a banana in the brown basket”).

For the screening test and the three conditions of the main test, two sets of experimental materials were used: one set consisted of six types of plastic fruit (a banana, an apple, a strawberry, an orange, a pear, and a peach) and two baskets; the other set consisted of six plastic toy animals (a pig, a dog, a cat, a chicken, a rabbit, and a sheep) and two fields. Before the test, the experimenter asked every participant to name all the types of fruits and animals. The objects that could not be named by the participants would be replaced with spare objects, including litchi, longan, mango, and lemon for fruits; and a cow, a horse, a tiger, and a panda for animals.

For each trial in the screening test and the three conditions of the actual test, the objects moved by participants would be placed back before the experimenter gave the next instruction. Participants who moved the right animal to the right field obtained a score of one. As the screening test and every condition of the main test consisted of eight instructions and every instruction involved two objects, the maximum score of the screening test and every condition is 16.

5.2.2.4 The ToM Test

Participants' ToM understanding was assessed using four first-order ToM tasks: two unexpected content tasks (Perner et al., 1987) and two change-in-location tasks (Wimmer & Perner, 1983). Aggregating multiple tasks has been proven to be the most reliable measure of ToM abilities (Hughes et al., 2000). Previous studies revealed that first-order ToM understanding developed around age of four and understanding of second-order ToM was no earlier than six years old, and autistic children have demonstrated a delayed or even impaired ToM understanding. Therefore, first-order ToM tasks were considered suitable for participants aged around five to six years in the current study. In the two unexpected content tasks, participants were required to infer another person's false belief about what was inside a container. In this task, participants were introduced to a clearly identifiable container (e.g., a candy box) with an unexpected object inside (e.g., an eraser). With participants themselves knowing what the object inside the container was, a new character (a boy- or girl-like doll) was introduced as never having looked inside the container. During the presentation, participants received two control questions to check their attention and memory as well as a test question about the false belief of the character ("what does the boy/girl think is in the box?"). The correct response to the test question should be "candy" rather than the real content "eraser". In the two change-in-location tasks, participants were asked to infer another person's false belief about the location of an object. In this task, a simple story was enacted for participants with supporting puppets. In each story, one character (A) moved an object from place A to place B while another character (B), who had placed the object in place A, was absent. During the presentation of each story, participants received two control questions to check their story understanding and one test question ("where will character B look for the object?"). The test question was about the false belief of character B who did not know about the change in location of the object, and the correct answer should be place A instead of place B. For the four ToM tasks, the participants who gave correct responses to the control as well as the test questions were considered as having passed the task and would score one for passing one task.

5.2.2.5 The Working Memory Test

A word span task was administered to assess the participants' working memory (Joseph & Tager-Flusberg, 2004). There were two conditions: the forward and backward conditions. In both conditions, the participant would hear several sequences of words at the rate of one word per second. Every word sequence was preselected from nice concrete nouns with high usage frequency, all of which were two-syllable and ended with 子 ("zi") (see Supplementary Material 2). Before testing, all participants were assessed as to whether they knew the nine nouns. For each noun, participants were presented with a 3 × 3 matrix containing the figures of nine corresponding nouns. None of the participants had any problems with the nouns. After hearing a word, they were required to point to the figure the word described. In the forward condition, after hearing a word sequence, participants were immediately presented with a 3 × 3 matrix containing the figures of nice corresponding nouns, and were required to point to the figures in the same order as the spoken sequence. Following the forward condition, all participants proceeded to the backward condition. It is similar to the forward condition, but in the backward condition, the participants were required to point to the figures in the reverse order from the words they heard. For both conditions, the word sequence length ranged from two to eight words. Participants received two different trials for each sequence length, resulting in 14 trials per condition. Testing would stop when the participants gave incorrect responses to both trials of one sequence length. A correct response to each trial would score one, and the sum was calculated as a measure of working memory.

5.2.2.6 The Mental Flexibility Test

To assess participants' mental flexibility, the shape-color switch task of Diamond and Kirkham (2005) was adapted to make it more similar to the Dimensional Change Card Sort task (DCCS; Zelazo, 2006). In the shape-color switch task, participants saw pictures depicting a blue rabbit or a yellow boat on the computer screen and had to press the left or right key on the keyboard to report the color or shape of every picture; these are referred to as the color game and the shape game, respectively. For each trial, participants would see and hear the cue that indicates what (color or shape) they should report. Participants completed 72 practice trials prior to the test blocks, with 16 for the color game, 16 for the shape game, and 40 for the mixed game. They received feedback for half the practice trials, leaving the other half without feedback, which was intended to help the participants familiarize themselves with the test blocks where no feedback would be provided. There were seven test blocks, among which Block #1, Block #3, and Block #6 used one soring criterion, while Block #2, Block #5, and Block #7 used another criterion. In Block #4, two sorting criteria were mixed, consisting of 13 nonswitch trials and seven switch trials. Except for Block #4 that consisted of 20 trials, the other six blocks consisted of 10 trials. Participants' error rate and reaction time were recorded using E-Prime software. The measures of mental flexibility were error rate switch cost and reaction time switch cost (de Vries & Geurts, 2012). The former was measured by subtracting the mean error rate on Block #1-#3 and #5-#7 from the mean error rate on Block #4, and the latter was measured by subtracting the mean reaction time on Block #1-#3 and #5-#7 from the mean reaction time on Block #4. Larger switch cost means switching between different sorting criteria produces more cognitive cost, reflecting low mental flexibility.

5.2.3 Data Analysis

Consistently with the research aims, several sets of analyses were performed. The first focused on comparing the degree of difficulty of comprehending spatial demonstratives in the three conditions for autistic and non-autistic children.

Specifically, a linear model was fit on correct rates of spatial demonstrative comprehension with the lme4 package in R. Before fitting the linear model, it was checked whether including a random effect, Subject, was justified by comparing the AIC of the baseline model without random effect to the AIC of the model with random effect. The results showed that the AIC of the model with random effect was larger, which indicated the inclusion of the random effect was not justified. Thus, random effect was not included, and a linear model was used in the current study. The linear model was built with the Group factor (two levels: autistic, non-autistic), the Condition factor (three levels: same perspective, opposite perspective, and spectator perspective), and their two-way interaction. Post-hoc pairwise comparisons were conducted by using the lsmeans package with Bonferroni adjustment (Lenth, 2016) to compare the degree of difficulty in the three conditions. In addition, post-hoc pairwise comparisons were performed to examine the group differences within each condition, so as to address the third research question: whether Mandarin-speaking autistic children without ID have difficulty in comprehending spatial demonstratives relative to language-ability-matched non-autistic children.

Regarding the aim of comparing performance in comprehending two members of a spatial demonstrative pair, a Type factor (two levels: proximal vs. distal) was added to the linear model. "This" and "here", used to refer to a place that is near to the speaker were coded as proximal type, while "that" and "there", used to denote a more distant place were coded as distal type.

Another set of analyses was conducted to examine the role of cognitive abilities (ToM and EF) in spatial demonstrative comprehension in the two groups of participants. First, cognitive profiles of autistic participants were sketched by comparing their performance with that of non-autistic participants in the ToM test, the working memory test, and the mental flexibility test. Mann-Whitney *U*-tests were used because the data were not normally distributed (p-values < .05). Next, linear models were built to examine the potential variables contributing to the autistic and non-autistic participants' spatial demonstrative comprehension. Hypothesized predictors include the score of the ToM test, the scores of the working memory test's forward and backward conditions, and two measures of mental flexibility (error rate switch cost and reaction time switch cost). Besides, receptive language ability and chronological age would be considered. It began with a modal with Group, and receptive language ability and chronological age mean-centered and additionally included in the model. If receptive language ability or chronological age did not have an effect on the correct rate of spatial demonstrative comprehension, the factor(s) would be removed from the model one by one, starting with the effect with the larger p-value. The five hypothesized predictors were examined as main effects and in interaction with Group (autistic vs. non-autistic groups) in separate analyses to decide which predictors to be retained. The hypothesized predictors with (main or interaction) effects on spatial demonstrative interpretation were combined along with receptive language ability and/or chronological age to evaluate effects of predictors adjusted for one another, while those with no effect were removed ($p \geq 0.05$).

5.3 Results

5.2.1 Performance in the Comprehension of Spatial Demonstratives

The current study examined the performance of autistic and non-autistic participants in the comprehension of spatial demonstratives in the three conditions (same, opposite, and spectator). Table 5.2 shows the correct rates of autistic and non-autistic children in each condition.

Table 5.2. Correct rates of spatial demonstrative comprehension in autistic and non-autistic children in the three conditions.

Condition	Autistic group (SD)	Non-autistic group (SD)
Same perspective condition	84.26% (22.49%)	90.84% (17.05%)
Opposite perspective condition	32.41% (30.23%)	73.21% (29.60%)
Spectator perspective condition	62.04% (19.30%)	84.36% (20.16%)

The linear model on correct rates in the spatial demonstrative comprehension test yielded a significant two-way interaction of Group × Condition ($F(2, 159) = 7.20$, $p = .001$), which was further analyzed under different groups using post-hoc pairwise comparisons with Bonferroni adjustment. In the non-autistic group, participants' performance in the same perspective condition was significantly better than that in the opposite perspective condition ($\beta = .18$, $SE = .06$, $t = 2.79$, $p = .018$), but similar to that in the spectator perspective condition ($\beta = .06$, $SE = .06$, $t = 1.02$, $p = .923$). Their performance in the latter two conditions did not differ from one another ($\beta = -.11$, *SE*

= .06, t = -1.76, p = .238). In the autistic group, participants' performance in the same perspective condition was significantly better than that in the spectator perspective condition (β = .22, SE = .06, t = 3.45, p = .002), which was better than that in the opposite perspective condition (β = .30, SE = .06, t = 4.60, $p < .001$).

To compare the comprehension of spatial demonstratives in the two groups of participants in the three conditions, the significant two-way interaction of Group × Condition was analyzed under different conditions. In the same perspective condition, autistic and non-autistic participants performed comparably in comprehending spatial demonstratives (β = .07, SE = .06, t = 1.03, p = .304). In the opposite perspective condition, participants in the autistic group performed significantly worse than those in the non-autistic group in comprehending spatial demonstratives (β = .41, SE = .06, t = 6.39, $p < .001$). Such a group difference was also observed in the spectator perspective condition (β = .22, SE = .06, t = 3.50, p = .001).

Next, to compare the performance in comprehending the two members of a spatial demonstrative pair, the Type factor (proximal vs. distal) was added to the linear model. After adding Type and a three-way interaction of Type × Group × Condition, the result showed there was no significant improvement over the model without Type (F = .36, d.f. = 6, p = .905). This suggests that in all three conditions, participants' performance in comprehending the proximal type ("this" and "here") is similar to their performance in comprehending the distal type ("that" and "there") regardless of their diagnosis, as shown in Figure 5.2.

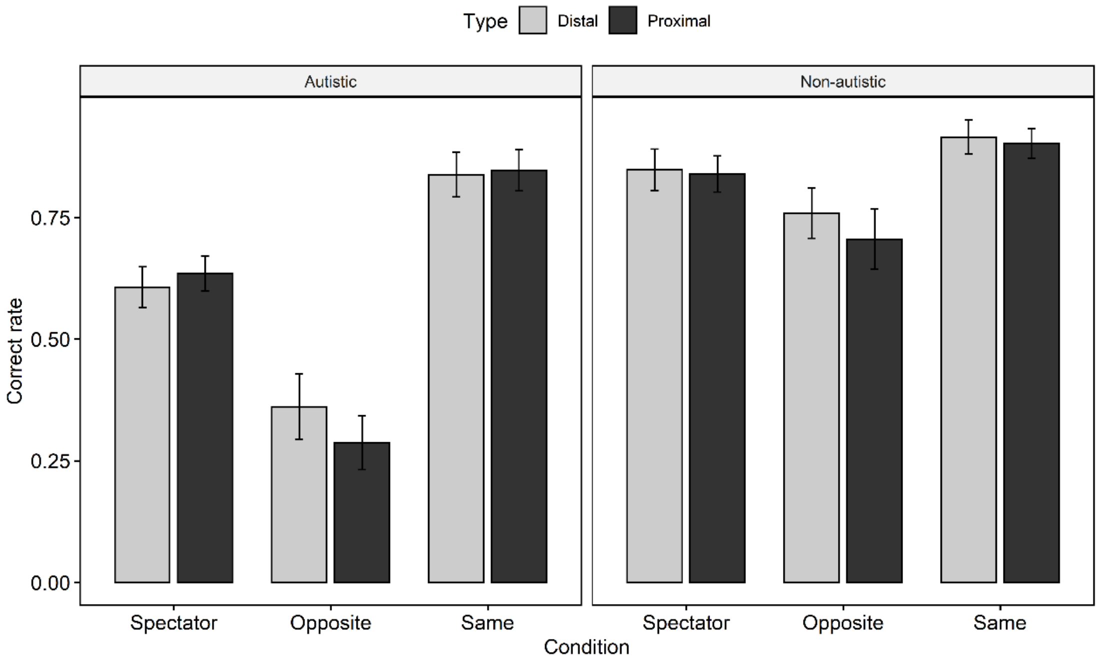


Figure 5.2. Autistic and non-autistic participants' performance in comprehending the two members of a pair of spatial demonstratives in the three conditions.

Note: Proximal type = "this" + "here"; distal type = "that" + "there". Error bars: ± 1 standard error.

5.2.2 Role of ToM and EF in the Comprehension of Spatial Demonstratives

Table 5.3 reports the performance of autistic and non-autistic participants in the tests assessing ToM and EF, including the ToM test, the working memory test, and the mental flexibility test. The ToM test consisted of four first-order false-belief tasks: two unexpected content tasks and two change-in-location tasks. Scores from the four tasks were totaled into a composite score for ToM (maximum = four), since the result of Spearman correlation analysis revealed that the participants' performance in the unexpected content tasks highly correlated with their performance in the change-in-location tasks (r = .69, $p < .001$). Spearman correlation was used because the data were not normally distributed according to the results of the Shapiro-Wilk tests (*p*-values < .05). In addition, the Shapiro-Wilk tests revealed that the data regarding EF were not normally distributed, so the median as well as the mean were reported. Next, Mann-Whitney *U*-tests were conducted to compare the two groups of participants in ToM and EF. *P*-values for the two conditions of the working memory test and the two measures of the mental flexibility test were corrected with the Bonferroni method. The results showed that autistic participants performed significantly worse than non-autistic participants in the ToM test ($U = 483.00$, $p < .001$). The difference between the two groups of participants in terms of working memory assessed in the backward condition was approaching significance after correction ($U = 635.00$, $p = .064$). The two groups of participants performed comparably in the forward condition of the working memory test ($U = 851.50$, $p = .168$) and the mental flexibility test (error rate switch cost: $U = 781.00$, $p = .673$; reaction time switch cost: $U = 697.00$, $p = .642$).

Table 5.3. Performance of autistic and non-autistic participants in the tests assessing cognitive abilities.

	Autistic (n = 27)	Non-autistic (n = 28)
ToM	0.48 (SD = 1.19; median = 0)	2.86 (SD = 1.46; median = 4)
Working memory (forward condition)	4.70 (SD = 1.17; median = 4)	4.00 (SD = 1.12; median = 4)

Working memory (backward condition)	1.33 (SD = 1.62; median = 0)	2.29 (SD = 1.67; median = 2)
Mental flexibility (error rate switch cost)	9.30% (SD = 16.53%; median = 8.00%)	5.37% (SD = 8.22%; median = 4.00%)
Mental flexibility (reaction time switch cost)	342 ms (SD = 477 ms; median = 404 ms)	480 ms (SD = 307 ms; median = 364 ms)

Linear models were built to examine whether the participants' comprehension of spatial demonstratives in different conditions were influenced by their ToM or EF (working memory or mental flexibility). As mentioned, every participant got two scores for their working memory, with one for the forward condition of the working memory test (WM-F) and the other for the backward condition of the working memory test (WM-B). In addition, there were two measures for participants' mental flexibility: error rate switch cost (MF-ER) and reaction time switch cost (MF-RT). In total, there were five measures of cognitive abilities. Besides, the participants' receptive language ability and chronological age were considered.

In the same perspective condition, the linear model showed main effects of chronological age (β = .01, *SE* = .002, *t* = 4.89, *p* < .001) and receptive language ability (β = .01, *SE* = .001, *t* = 3.99, *p* < .001). Therefore, it started from a model with chronological age, receptive language ability, and Group, which accounted for 39.76% of variance in the spatial demonstrative comprehension dependent variable (*F*(3, 51) = 12.88, *p* < .001). Next, the five measures of cognitive abilities were examined one by one as main effects and in interaction with Group in five separate analyses to investigate which cognitive abilities were associated with spatial demonstrative comprehension in the same perspective condition. Specifically, after adding a two-way interaction of Group × ToM and a main effect of ToM, the result showed there was no significantly improved fit over the previous model (F = 2.07, d.f. = 2, p = .137). Similarly, adding WM-F*Group did not lead to a significantly improved fit over the previous model (F = .30, d.f. = 2, p =.744), neither did the inclusions of WM-B*Group (F = 1.66, d.f. = 2, p = .200), MF-ER*Group (F = 0.10, d.f. = 2, p = 0.905), or MF-RT*Group (F = 1.17, d.f. = 2, p = 0.319).

In the opposite perspective condition, the linear model showed main effect of receptive language ability (β = .01, SE = .003, t = 2.20, p = .032), while no effect of chronological age was found (β = -.002, SE = .004, t = -.65, p = .518). Thus, it started from a model with receptive language ability and Group, which explained 36.39% of variance in the spatial demonstrative comprehension dependent variable ($F(2, 52)$ = 16.44, p < .001). After adding a main effect of ToM and its interaction with Group, the result showed there was a significantly improved fit over the previous model (F = 9.20, d.f. = 2, p < .001). In addition, adding WM-B*Group led to a significant improvement over the previous model (F = 3.33, d.f. = 2, p = .044), and so did the inclusion of MF-RT*Group (F = 7.18, d.f. = 2, p = .002). However, adding WM-F*Group (F = 1.02, d.f. = 2, p = .367) or MF-ER*Group (F = .05, d.f. = 2, p = .459) did not lead to a significantly improved fit over the model without the effect in question. Therefore, ToM*Group, WM-B*Group, and MF-ER*Group were combined along with receptive language ability to evaluate effects of predictors adjusted for one another on the comprehension of spatial demonstratives in the opposite perspective condition. The final model showed a significant main effect of ToM ($\beta < .01$, $SE < .01$, $t = 2.23$, $p = .031$), and marginally significant interaction effects of Group × WM-B ($\beta < .01$, $SE < .01$, $t = 1.74$, $p = .088$) and Group × MF-RT ($\beta < .01$, $SE < .01$, $t = -1.89$, $p = .065$). The median split method was adopted to illustrate significant interaction effects. For the interaction effect of Group × WM-B, participants were divided into two groups based on a median split on the score of the working memory test (backward condition). As the median score was two, the participants who scored two or below were labeled “low WM-B”, while those who scored above two were labeled “high WM-B”. Figure 5.3 showed the correct rates of spatial demonstrative comprehension per diagnosis group (autistic vs. non-autistic) and WM-B group (high vs. low). It can be seen from the figure that working memory measured in the backward condition had a larger effect on spatial demonstrative comprehension in the opposite perspective condition in non-autistic children than in autistic children.

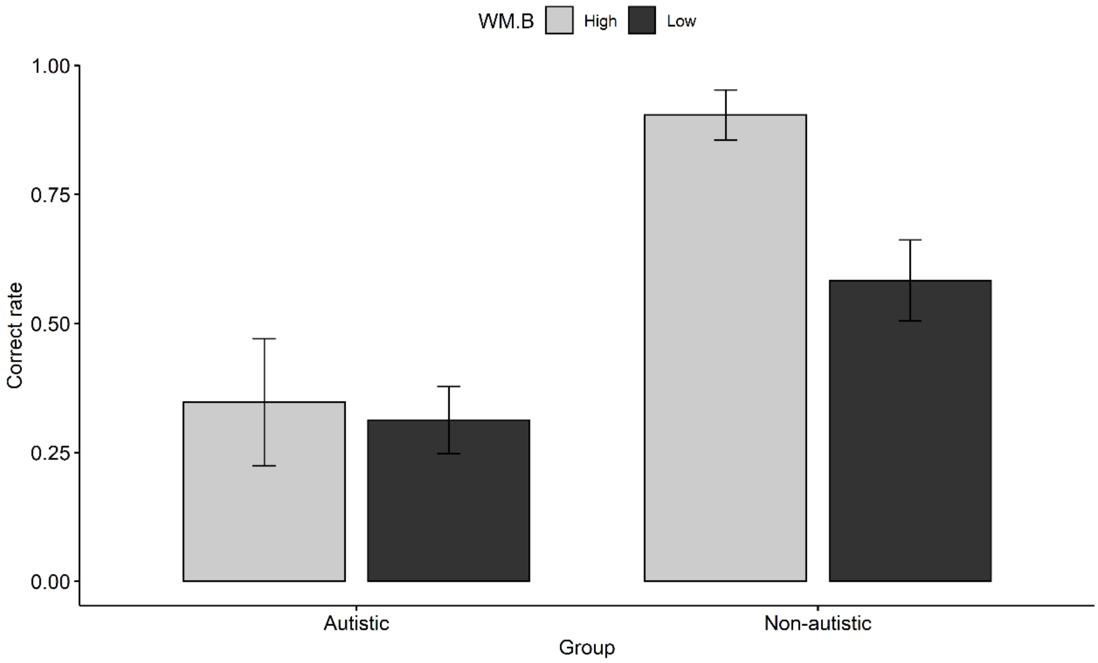


Figure 5.3. Correct rates in the opposite perspective condition of the spatial demonstrative comprehension test per group.

Note: low working memory: ≤ median; high working memory: > median; median = 4.

For the interaction effect of Group × MF-RT, the participants were divided into two groups based on a median split on the reaction time switch cost. Larger switch cost means switching between different dimensions causes more cognitive cost, that is, low mental flexibility. The participants whose switch cost measured by reaction time was smaller than or equal to the median 364 ms were labeled “high mental flexibility”, while those whose switch cost was larger than 364 ms were labeled “high mental flexibility”. As shown in Figure 5.4, mental flexibility had a larger effect on spatial demonstrative comprehension in the opposite perspective condition in non-autistic children than in autistic children.

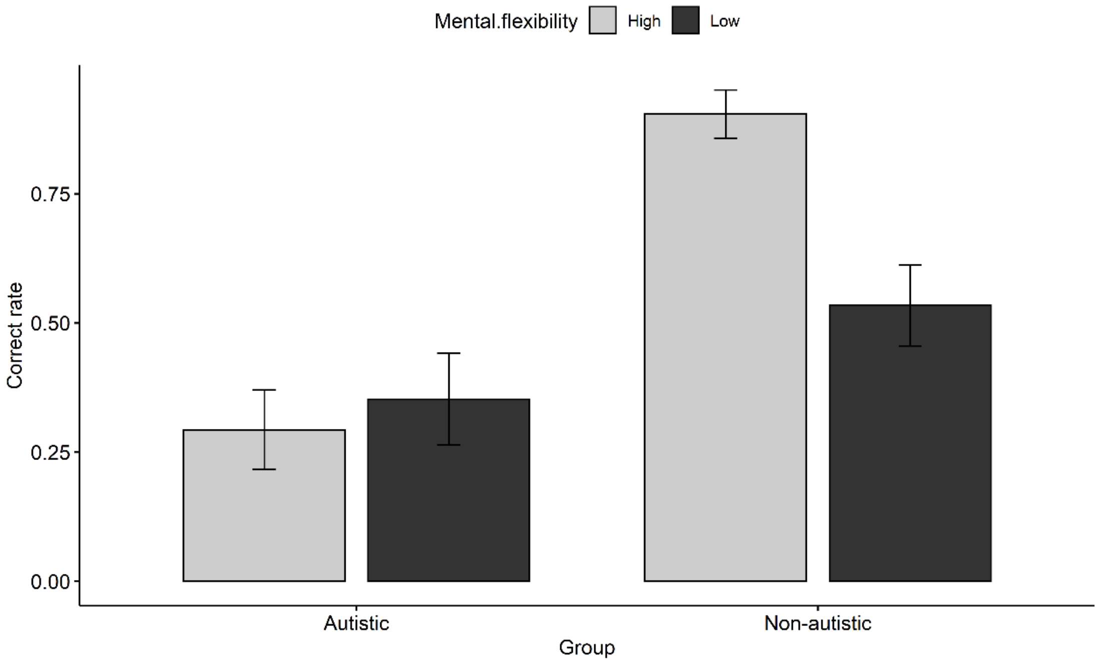


Figure 5.4. Correct rates in the opposite perspective condition of the spatial demonstrative comprehension test per diagnosis group.

Note: high mental flexibility: ≤ median; low mental flexibility: > median; median = 364 ms.

The final model for the opposite perspective condition accounted for 55.08% of variance in the demonstrative comprehension dependent variable ($F(8, 46) = 9.28$, $p < 0.001$).

In the spectator perspective condition, the linear model showed main effect of receptive language ability ($\beta = .005$, $SE = .002$, $t = 2.82$, $p = .007$), while no effect of chronological age was found ($\beta = .002$, $SE = .002$, $t = .90$, $p = .373$). Thus, it started from a model with receptive language ability and Group, accounting for 31.92% of variance in comprehending spatial demonstratives ($F(2, 52) = 13.66$, $p < .001$). After adding ToM*Group, the result showed there was a significantly improved fit over the model without ToM*Group (F = 6.52, d.f. = 2, p = .003). In addition, the inclusion of WM-B*Group led to a significant improvement over the previous model (F = 6.64, d.f. = 2, p = .003), and so did the inclusion of MF-RT*Group (F = 5.25, d.f. = 2, p = .009). However, the inclusion of WM-F*Group did not lead to a significantly improved fit over the previous model (F = 2.53, d.f. = 2, p = .090), neither did the inclusion of MF-ER*Group (F = .35, d.f. = 2, p = .705). Thus, ToM*Group, WM-B*Group, and MF-ER*Group were added to the model with receptive language ability. The final model showed a significant interaction effect of Group × WM-B (β < .01, SE < .01, t = 2.49, p = .017). The median split method was adopted to plot accuracy of spatial demonstrative comprehension per diagnosis group (autistic vs. non-autistic) and WM-B group (low WM-B: ≤ 2 vs. high WM-B: > 2) to illustrate the direction of the interaction effect. As shown in Figure 5.5, working memory measured in the backward condition had a larger effect on non-autistic children's performance in comprehending spatial demonstratives in the spectator perspective condition than on autistic children's. The final model for the spectator perspective condition explained 50.37% of the variability in comprehending spatial demonstratives (F(8, 46) = 7.85, p < 0.001).

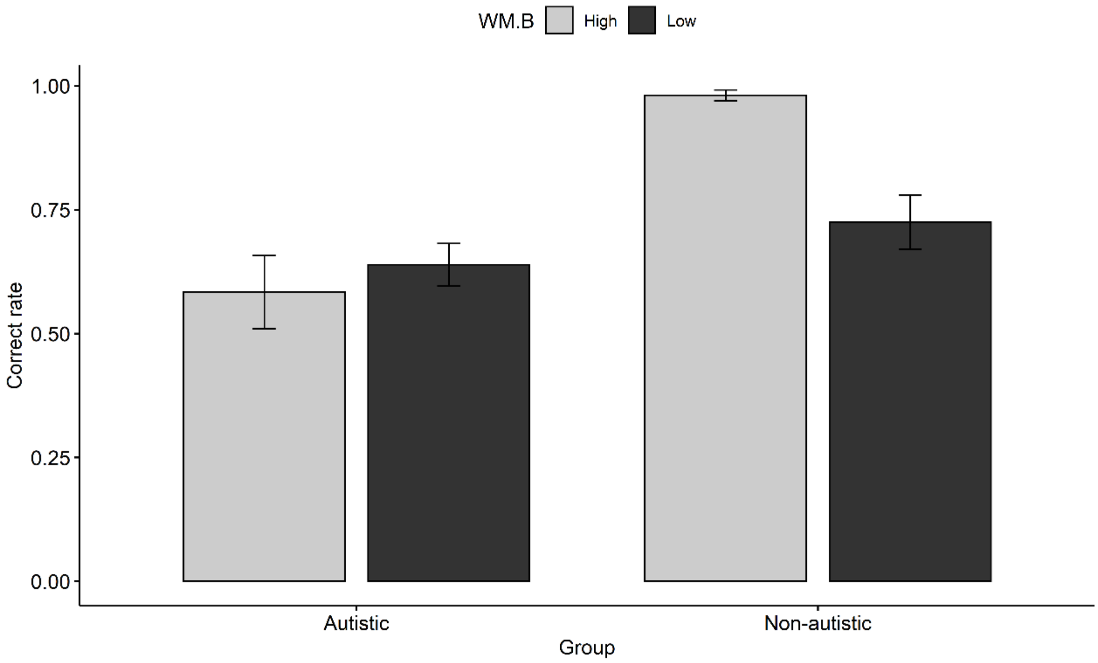


Figure 5.5. Correct rates in the spectator perspective condition of the spatial demonstrative comprehension test per group.

Note: low working memory: ≤ median; high working memory: > median; median = 4.

5.4 Discussion

The current study in this chapter examined the comprehension of two pairs of spatial demonstratives (“this” and “that”, and “here” and “there”) by Mandarin-speaking autistic children without ID in three conditions (same, opposite, and spectator), compared to Mandarin-speaking non-autistic children matched on receptive language ability.

5.4.1 Comparison Between two Members of a Spatial Demonstrative Pair

The study investigated which member (proximal vs. distal) of a spatial demonstrative pair was mastered better by Mandarin-speaking autistic children without ID and non-autistic children. The participants' performance in comprehending the distal terms ("that" and "there") was not significantly better than their performance in comprehending the proximal terms ("this" and "here"), and vice versa. The findings do not lend support to the markedness explanation (Clark, 1973; Donaldson & Balfour, 1968; Klatzky et al., 1973; Tfouni & Klatzky, 1983). This account predicts that the unmarked members ("that" and "there") will be mastered better than the marked members ("this" and "here"), considering the greater generality of distribution of the unmarked members. Specifically, the unmarked member of the spatial demonstrative pair in Chinese (i.e., 那) can appear in a euphemism and an idiomatic expression, and as a conjunction. However, the participants did not perform better in the comprehension of 那 "that" than that of 这 "this". This suggests that the wider usage of 那 "that" does not facilitate the mastery of its deictic usage for space.

The absence of a difference between the two members in comprehension accuracy is also not consistent with previous studies (Tfouni & Klatzky, 1983; Zhao, 2007). Tfouni and Klatzky (1983) found English-speaking neurotypical children were more accurate at interpreting "that" than "this" in the opposite perspective condition, while in the same perspective condition Zhao (2007) observed an opposite finding in Mandarin-speaking neurotypical children. In the current study, no such asymmetry in the comprehension of two members of a demonstrative pair was found. Mandarin-speaking autistic and non-autistic children seem to acquire the two members at the same time. Some of them reversed the meanings of 这 “this” and 那 “that”, that is, if they interpreted “this” as if it referred to the place distal to the speaker, they also interpreted “that” as if it referred to the place near to the speaker. In other words, some participants might know the proximal-distal distance contrast between the two members of a spatial demonstrative pair without knowing exactly which one denotes a proximal distance from the speaker and which one denotes a distal distance. This finding is consistent with results from a study of how Mandarin-speaking children acquire another pair of spatial terms, “front” vs. “behind” (Li, 1988). Specifically, his participants did not respond to 前 “front” more correctly than to 后 “behind”, nor did they perform better in interpreting 后 “behind” than 前 “front”, suggesting that Mandarin-speaking children master these two projective spatial terms at the same time (Li, 1988). The current study extended this literature to the comprehension of spatial demonstrative pairs in Mandarin-speaking autistic as well as non-autistic children.

5.4.2 The Degree of Difficulty of Comprehending Spatial Demonstratives in the Three Conditions

Regarding the aim of comparing the degree of difficulty of comprehending spatial demonstratives in the three conditions, autistic participants performed significantly better in the same perspective condition than they did in the spectator perspective condition (same > spectator), where the performance was significantly better than that in the opposite perspective condition (spectator > opposite). One possible explanation is that the roles of children in the three conditions placed different demands on the process of interpreting spatial demonstratives. It was easiest when there was only one perspective for a spatial demonstrative to refer to, and this occurred when participants and experimenter sat side by side (i.e., the same perspective condition). In the spectator and the opposite perspective conditions, the perspectives of both self and speaker(s)/experimenter(s) needed to be considered, if spatial demonstratives were to be fully understood. Thus, the process of interpreting demonstratives would be harder in these two conditions. Regarding the discrepancy noted between the harder conditions (i.e., opposite vs. spectator), it seems more difficult to inhibit one's own perspective and shift to a totally opposite perspective in the opposite perspective condition. In the spectator perspective condition, by contrast, the participants' own perspective had a low possibility of causing interference to the interpretation of spatial demonstratives since the two places referred to by the experimenters were the same distance from the participants, so inhibition might not necessarily be required. Therefore, more errors were observed in the opposite perspective condition than in the spectator perspective condition. Another possibility is that, in the spectator perspective condition, there were two experimenters giving instructions on alternative trials, which might serve as a cue that different perspectives were involved. Thus, autistic participants became aware that there was a need to take other people's perspectives for interpreting spatial demonstratives.

Concerning cross-condition comparisons within the non-autistic group, the non-autistic children's mean correct rate of spatial demonstrative comprehension in the same perspective condition was higher than that in the spectator perspective, but statistical analysis did not reveal a significant difference between the performances in the two conditions. This suggests that although non-autistic children were slightly more accurate at interpreting the spatial demonstratives when their perspective was the same as that of the speaker (experimenter), they could deal with the situation where the experimenter's perspective was not the same as their own. In other words, non-autistic children seemed able to take the perspectives that differ from their own when interpreting spatial demonstratives. However, non-autistic participants performed significantly worse in the opposite perspective condition than they did in the same perspective condition, confirming a previous finding by Zhu et al. (1986) in Mandarin-speaking non-autistic children. The lower mean correct rate in the opposite perspective condition might be due to the difficulty in inhibiting one's own perspective and taking an opposite perspective (Zhu et al., 1986).

5.4.3 Comparison Between Autistic and Non-Autistic Children in Comprehending Spatial Demonstratives

Turning to the research aim regarding the comparison between autistic and non-autistic children in comprehending spatial demonstratives, Mandarin-speaking autistic children without ID were found to exhibit comparable performance in the same perspective condition to the language-ability-matched non-autistic children. However, autistic children made more errors in the opposite and the spectator perspective conditions relative to non-autistic children. That is, in the opposite perspective condition, the autistic participants would put objects in the place close to themselves when the experimenter gave instructions containing “this” or “here”. The response was incorrect because the place that was near the participants was far away from the experimenter, while “this” or “here” in the experimenter’s instructions referred to the place near the experimenter. Likewise, autistic participants would put objects in the place that was far away from themselves but near the experimenter when the experimenter’s instructions contained “that” or “there”. These responses indicated that autistic participants interpreted spatial demonstratives wrongly from their own perspective rather than from the perspective of the speaker (experimenter). In the spectator perspective condition, there were two speakers (experimenters) opposite each other, and they took it in turns to give instructions. Autistic participants were found to focus on one experimenter’s perspective, neglecting the other experimenter’s. Thus, these participants would respond correctly to the instructions delivered by the former experimenter, whereas they made errors when the latter experimenter gave instructions. The finding that autistic children had difficulties with spatial demonstratives is consistent with a previous finding by Hobson, García-Pérez, et al., (2010). These authors examined the comprehension of spatial demonstratives in English-speaking autistic individuals and non-autistic individuals with ID in the spectator perspective condition. Although the two groups of participants were matched on receptive language ability, participants in the autistic group were found to make more errors compared with non-autistic participants with ID. One possible explanation of the findings is that autistic individuals have difficulty with visuospatial perspective-taking, which is believed to be vital to success in interpreting spatial demonstratives especially in the spectator and the opposite perspective conditions. Failing to take the speaker’s perspective that differs from their own, autistic individuals would reverse the meanings of the spatial demonstratives: that is, they would interpret “this” and “here” as if they referred to the place distal to the speaker, and “that” and “there” as if they referred to the place near the speaker.

5.4.4 Role of ToM and EF in Spatial Demonstrative Comprehension

As reported earlier, the performances of autistic and non-autistic children varied according to condition, and autistic children performed significantly worse than non-autistic children in two of the three conditions. The study further investigated whether and how working memory, mental flexibility, and ToM understanding affected the two groups of children’s comprehension of spatial demonstratives in the three conditions. In the same perspective condition, the participants’ chronological age and receptive language ability had a significant effect on the comprehension of spatial demonstratives. Specifically, older participants were more accurate in their interpretation of spatial demonstratives than younger participants, and participants with higher receptive language ability performed better than participants with lower receptive language ability. After controlling for the effect of chronological age and receptive language ability, neither ToM nor EF (working memory and mental flexibility) had significant influence on the comprehension of spatial demonstratives by autistic or non-autistic children in the same perspective condition. In the opposite perspective condition, receptive language ability was found to have a significant effect on the comprehension of spatial demonstratives. After controlling for this effect, ToM understanding, WM-B, and MF-RT were found to affect spatial demonstrative comprehension. When these effects were adjusted for one another, ToM understanding was a significant predictor of correct interpretation of spatial demonstratives in both autistic and non-autistic children. Furthermore, non-autistic children's WM-B and MF-RT were predictive of comprehending spatial demonstratives. In the spectator perspective condition, receptive language ability had significant influence on spatial demonstrative comprehension. When this influence was controlled for, ToM understanding, WM-B, and MF-RT were found to have effects on the comprehension of spatial demonstratives. When their effects on demonstrative comprehension were adjusted for one another, the result showed that the effect of WM-B remained significant in the non-autistic group.

The finding of the role of ToM understanding in spatial demonstrative comprehension in the opposite and the spectator perspective conditions converges with previous findings that neurotypical children's comprehension of spatial demonstratives was associated with their ToM ability when their perspective differed from the speaker's (Chu & Minai, 2014, 2018). The current study extended this literature by finding a similar relationship in autistic children. This also fits with previous evidence that autistic children's pragmatic difficulties were associated with their poor ToM abilities, such as their difficulties with the comprehension of personal pronouns (Overweg et al., 2018a), figurative language (Kalandadze et al., 2018), etc. The results showed that autistic and non-autistic children with poorer ToM ability were less accurate at interpreting spatial demonstratives than those with better ToM ability in the opposite and the spectator perspective conditions. One possible explanation for this finding is that when hearer and speaker do not share the same perspective, spatial demonstratives require an understanding of the position/perspective of the speaker (experimenter) for their correct interpretation, which is related to ToM understanding, an ability to understand others' mind (Chu & Minai, 2014, 2018; de Villiers & de Villiers, 1974). ToM ability will help children understand the position/perspective of the speaker (experimenter) and translate from their own point of view to the experimenter's when locating the places referred to by the experimenter using spatial demonstratives.

Apart from ToM ability, Chu and Minai (2014, 2018) claimed that the correct comprehension of spatial demonstratives required another cognitive ability, mental flexibility, in the situation where the speaker's perspective was different from the hearer's. This was confirmed by their finding that neurotypical children were more accurate at interpreting spatial demonstratives as their correct responses for the task assessing mental flexibility increased, regardless of receptive language ability. In the current study, similarly, non-autistic participants' interpretation of spatial demonstratives in the opposite perspective condition was found to be influenced by their mental flexibility, assessed by reaction time after controlling for the effect of receptive language ability. One way to explain the role of mental flexibility, as Chu and Minai (2014, 2018) suggested, is that to locate the place referred to by the speaker (experimenter) using spatial demonstratives, the hearer (participant) needs to disengage himself/herself from his/her own perspective and switch to the speaker's, for which mental flexibility, the cognitive ability to switch between different perspectives, is needed.

However, the effect of mental flexibility on autistic children's comprehension of spatial demonstratives was weak, which is consistent with results from some studies examining the role of mental flexibility in autistic individuals' pragmatic abilities (Akbar et al., 2013; Landa & Goldberg, 2005; Overweg et al., 2018a). For instance, in a study of personal pronouns, Overweg et al. (2018) reported that autistic individuals' interpretation of personal pronouns was not associated with their mental flexibility. Perhaps a relationship between pragmatic abilities and mental flexibility was not found in autistic individuals because some autistic individuals showed enhanced performance on the mental flexibility task (Landa & Goldberg, 2005). In the current study, the switch cost of reaction time of autistic children was slightly smaller than that of non-autistic children: that is, autistic children had slightly higher mental flexibility. However, they did not enjoy superiority in the comprehension of spatial demonstratives. One possible explanation for these findings is that the stimuli used in the mental flexibility task did not involve socially relevant information, whereas the spatial demonstrative comprehension task required participants to consider other persons' perspectives. Therefore, it is not surprising that although autistic children were cognitively flexible, they had difficulties in spatial demonstrative comprehension. An alternative explanation for the weak effect of mental flexibility in the autistic group is that the measure of mental flexibility, reaction time, was not that reliable for participants in this group. They are often reported to exhibit high levels of inattention and hyperactivity-impulsivity symptoms, which may contribute to high variability in reaction time (Geurts et al., 2008). Thus, the lack of mental flexibility effect in the autistic group must be interpreted with caution.

As for another subcomponent of EF — working memory, the results suggest that autistic children's poor performance in comprehending spatial demonstratives may be due to their low working memory measured in the backward condition (WM-B). Specifically, autistic participants received significantly lower scores on the backward condition of the working memory test than their non-autistic peers, and they also made more errors in the opposite and the spectator perspective conditions of the spatial demonstrative task. This indicated that spatial demonstrative comprehension might be associated with WM-B, which is consistent with results from a study of the relationship between personal pronoun comprehension and working memory in Dutch-speaking autistic and non-autistic children (Overweg et al., 2018a). The authors reported that autistic children with low working memory assessed using the n-back task (Owen et al., 2005) frequently reversed the meanings of personal pronouns, “I” and “you”, that is, they interpreted “I” as if it meant “you” and “you” as if it meant “I”, resulting in pronoun reversals. One possible explanation of this finding, as Overweg et al. (2018a) suggested, is that autistic children have difficulty in keeping the perspective of the speaker in mind due to low working memory, which made it hard for them to take the correct perspective to comprehend personal pronouns.

Nevertheless, a relationship between spatial demonstrative comprehension and working memory measured in the forward condition (WM-F) was not found. According to Redick and Lindsey (2013), although the two conditions of the working memory test are both considered measures of working memory, the forward condition assesses maintenance while the backward condition assesses manipulation in addition to maintenance. In other words, the forward condition of the working memory test does not require manipulation of the stored information (Overweg et al., 2018b). The test in the forward condition might not capture working memory to the extent needed in interpreting spatial demonstratives in the opposite and the spectator perspective conditions. When interpreting spatial demonstratives in these two conditions, both one’s own and the experimenters’ perspectives must be considered. To process such complex information, manipulation is believed to be more essential than maintenance (Overweg et al., 2018b). This may help to explain why spatial demonstrative comprehension in the opposite and the spectator perspective conditions was associated with WM-B, which involved manipulation instead of WM-F. The divergence between the roles of WM-F and WM-B had been detected in other aspects of language (de Ruiter et al., 2018; Overweg et al., 2018b). Specifically, the performance in the working memory test that did not involve manipulation was not associated with the comprehension of temporal conjunctions (de Ruiter et al., 2018), whereas Overweg et al. (2018b), whose working memory test measured manipulation found, a significant effect of working memory on the interpretation of complex sentences containing temporal conjunctions.

5.5 Conclusion

The present study investigated the comprehension of two pairs of spatial demonstratives (“this” and “that”; “here” and “there”) by Mandarin-speaking autistic children without ID and non-autistic children matched on receptive language ability. Mandarin-speaking children, whether autistic or non-autistic, seemed to master the two members of a demonstrative pair at the same time in terms of their usage in encoding space. Autistic children performed significantly better in the same perspective condition than they did in the spectator perspective condition, where their performance was significantly better than that in the opposite perspective condition. As for non-autistic children’s comprehension of spatial demonstratives, a significant difference was only observed between the same and opposite perspective conditions, with the performance in the former condition being better than that in the latter condition. Additionally, autistic children’s performance in the opposite and spectator perspective conditions were significantly worse than those of non-autistic children matched on receptive language ability. Autistic children's difficulties with demonstratives in the two conditions may be due to their poor ToM understanding and low working memory, suggesting that these cognitive abilities likely contribute to the mature comprehension of spatial demonstratives in situations where the hearer and the speaker do not share the same perspective. Specifically, sufficient working memory allows children to maintain and manipulate different perspectives involved in the opposite and the spectator perspective conditions, and good ToM understanding helps children consider other persons' perspective and shift to that perspective, which is essential to correct interpretation of demonstratives when children do not share the same perspective with the speaker.

Chapter 6. General Discussion

The present dissertation is concerned with the interpretation of spatial terms in Mandarin-speaking autistic children without ID, compared to non-autistic children. Spatial terms allow people to translate visuospatial perception into linguistic representations (Laeng et al., 2003; Levinson & Wilkins, 2006; Talmy, 1983). Atypical visuospatial processing is frequently reported in autistic individuals (overview in Mitchell & Ropar, 2004; Muth et al., 2014; Samson et al., 2012). There is reason to hypothesize that the typical use of spatial terms might be altered in this population. Previous research on spatial terms mainly focused on individuals from western countries, and since the interpretation of some spatial terms is subjective to cross-cultural variations (Beller et al., 2015; Levinson, 2003; Majid et al., 2004), this dissertation aimed to examine the interpretation of spatial terms in Mandarin-speaking non-autistic children and autistic children without ID, and the factors related to the spatial term interpretation.

6.1 Interpretation of Spatial Terms in Non-Autistic Mandarin Speakers

There are different types of spatial FoRs underlying the use of spatial terms, including the relative FoR and the intrinsic FoR underlying the use of projective spatial terms, and the deictic FoR underlying the use of spatial demonstratives (Diessel, 2014; Levinson, 1996). Projective spatial terms can provide directional information, while spatial demonstratives can be used to indicate distance between the figure object and the reference object (usually the speaker; Anderson & Keenan, 1985). For the use of projective spatial terms, when the reference object does not have inherent front and back, only the relative FoR is applicable. Three variants of relative FoR have been proposed — reflection, translation, and rotation (Levinson, 2003). Previous studies suggest that across languages, people differ in the variants of relative FoR they preferentially adopt when interpreting projective spatial terms (Beller et al., 2015; Majid et al., 2004). For instance, a preference for the reflection variant of the relative FoRs has been found in neurotypical adults speaking English, German, and Norwegian, whereas a preference for the translation variant has been found in neurotypical adults speaking Hausa, Mandarin, and Tongan (Beller et al., 2015; Bennardo, 2000; Bochyńska, Coventry, et al., 2020; Hill, 1982). In line with the findings, Mandarin-speaking neurotypical adults in the first study of this dissertation indeed preferentially adopted the translation variant of the relative FoR when interpreting projective spatial terms in the context of a featureless reference object (see Table 3.4 and Table 3.5). Notably, in the same context, Mandarin-speaking non-autistic children tended to rely upon the reflection variant of relative FoR. This finding fits with previous evidence that neurotypical children speaking Mandarin frequently adopted the reflection projection strategy to interpret “front” and “behind” (Deng & Yip, 2016; Li, 1988). The present suggestion is that young children’s interpretation of projective spatial terms may be influenced by the canonical encounter (Clark, 1973). According to the concept of canonical encounter, two persons will face each other during most daily interactions, which may have an influence on the projection of the front/back axis. To be more specific, during normal interactions, which are usually carried out face-to-face, “front”, which is interpreted to mean near the face, will be assigned to the space between the two interlocutors, that is, near their faces, and “behind”, which is interpreted to mean near the back, will be assigned to the far side for each interlocutor, that is, near their backs. Thus, Mandarin-speaking non-autistic children, affected by the canonical encounter, exhibited a tendency to adopt the reflection projection strategy to interpret projective spatial terms.

Although Mandarin-speaking adults showed a preference for the translation variant, they were found to accept the use of projective spatial terms based on both translation and reflection variants (Deng & Yip, 2016; Guo, 2004). Converging with the previous findings in adults, the current study extended this literature by finding the acceptance of multiple variants of the relative FoR (usually translation and reflection) in Mandarin-speaking non-autistic children aged around seven years. Additionally, even the rotation variant was found to be accepted by the adult participants to a small extent, confirming the finding by Beller et al. (2015). The substantial flexibility in adopting different variants of the relative FoR may be attributed to cultural influence (Beller et al., 2015). Speakers of Mandarin living in collectivistic cultures (Chiu & Kosinski, 1995; Greenfield et al., 2003) are reported to have interdependent selves (Shweder & Bourne, 1982). It has been found that the cultural patterns of interdependence, which focus attention on other people, enable Mandarin speakers to flexibly switch between their own perspective and that of others (Wu & Keysar, 2007).

Therefore, even though Mandarin-speaking individuals have a preferentially adopted variant of the relative FoR when encoding space, they are capable of switching to other variants if needed, so as to facilitate communication.

In the context where the reference object has inherent front and back, the intrinsic FoR as well as the relative FoR are applicable for the encoding of space using projective spatial terms. In such a context, English-speaking neurotypical adults and children were found to be able to activate the intrinsic FoR and the relative FoR (reflection variant) simultaneously (Bialystok & Codd, 1987; Cox, 1981; Harris & Strommen, 1972; Surtees et al., 2012). The activation of dual types of spatial FoR was not observed in Mandarin-speaking neurotypical adults or children, who mainly adopted the intrinsic FoR to encode space when the reference object had inherent front and back (see Table 4.3 and Table 4.4). The data fit with previous evidence from neurotypical speakers of Mandarin that the orientational features of reference objects only trigger the intrinsic FoR (Deng & Yip, 2016). To explain the absence of the activation of dual types of spatial FoRs in speakers of Mandarin, it is useful to go back to the relative FoR underlying their space encoding. When the reference object did not have inherent orientation, Mandarin speakers accepted both translation and reflection variants of the relative FoR (Deng & Yip, 2016; Guo, 2004, 2008). Therefore, "front" can be interpreted as the space beyond the featureless reference object or the space between the featureless reference object and themselves, giving rise to uncertainty in using the projective spatial terms "front" and "back" in

Mandarin speakers. The uncertainty can be solved by the orientational features of the reference object. In other words, in the context of a reference object with identifiable orientation, the intrinsic FoR could help Mandarin speakers encode the space more effectively. This might be one of the reasons why they rely on the intrinsic FoR when it was applicable.

While people across languages differ in the preferentially adopted spatial FoR when interpreting projective spatial terms, the spatial FoR underlying the use of spatial demonstratives is universal (Anderson & Keenan, 1985; Diessel, 2005; Kornfilt, 1997). Spatial demonstratives will invoke a deictic FoR, which is speaker-anchored (Fillmore, 1975). Almost all languages have at least a pair of spatial demonstratives that can differentiate between places at different distances from the origin, which is usually centered on the speaker, such as “here” and “there” in English (Diessel, 1999). According to the Semantic Feature Hypothesis (Clark, 1973), the spatial demonstratives specifying a distal location (the distal terms, like “that”) are unmarked, while those specifying a near location (the proximal terms, like “this”) are marked, like unmarked vs. marked adjectives — far vs. near. The unmarked members are usually grasped before the marked members (Donaldson & Balfour, 1968; Klatzky et al., 1973); this has been corroborated by Tfouni and Klatzky (1983) in English-speaking children’s acquisition of spatial demonstratives, with the distal terms (“there” and “that”) mastered better than the proximal ones (“here” and “this”). In the current study, however, no such asymmetry in the comprehension of distal and proximal terms was found: that is, Mandarin-speaking non-autistic children showed comparable performance in comprehending the two types of terms (see Figure 5.2). This finding is consistent with results from a study of how Mandarin-speaking children acquire another pair of spatial terms, “front” vs. “behind” (Li, 1988). Although the Semantic Feature Hypothesis claims that children should master “front” (the unmarked or positive term), before “behind” (the marked or negative term), Li (1988) found Mandarin-speaking children acquired the two terms at the same time. The current study extended this literature to the comprehension of spatial demonstrative pairs. Specifically, some participants who made errors when interpreting spatial demonstratives might have understood the proximal-distal distance contrast between the proximal and the distal terms while not knowing exactly which one denotes a proximal distance from the speaker and which one denotes a distal distance. In addition, Mandarin-speaking non-autistic children had more difficulty interpreting spatial demonstratives when their perspective was the opposite of the speaker’s (the experimenter’s) than when their perspective was the same as the experimenter’s, confirming previous findings (Tfouni & Klatzky, 1983; Zhao, 2007; Zhu et al., 1986). When the participant and the experimenter were opposite to each other in perspective, the correct interpretation of spatial demonstratives required the participant’s inhibition of his/her own perspective and a switch to the speaker’s perspective. This seemed harder than the condition where the participant and the experimenter shared the same perspective.

6.2 Interpretation of Spatial Terms in Mandarin-Speaking Autistic Children

This dissertation revealed *selective* abnormalities in the spatial language domain in Mandarin-speaking autistic children without ID, consistent with the uneven linguistic and nonverbal profiles in autism. Although autistic children are characterized by impairment in social communication/interaction (American Psychiatric Association, 2013), they appear to have overall enhancement in the nonverbal domain (Happé, 1994; Joseph et al., 2002). Notwithstanding the asymmetry between verbal and nonverbal abilities, it does not seem appropriate to treat the impairment and strength in autistic children so categorically. For example, while autistic individuals are frequently reported to have superior performance in some nonverbal tasks, such as the Embedded Figure task and the Block Design task (see Muth et al., 2014), they do not seem to enjoy such superiority in a range of nonverbal skills, like visual perspective-taking (see Ni et al., 2021). Regarding the verbal domain, while problems with pragmatic abilities have been consistently reported across the autistic spectrum (Loukusa & Moilanen, 2009), their acquisition of grammatical aspects of language seems to follow the same developmental path as their neurotypical peers (Tager-Flusberg et al., 1990).

In the current project, it was also found that autistic children showed comparable performance to non-autistic children in some subdomains of spatial language while differing from their non-autistic peers in other subdomains. As for the use of projective spatial terms in the context of the reference object with inherent front and back, autistic children, like non-autistic children, were found to mainly rely on the forward direction of reference object and adopted the intrinsic FoR to interpret these spatial terms (see Table 4.3). The finding is consistent with that of previous study in Norwegian autistic children and adults (Bochyńska, Coventry, et al., 2020), suggesting that the activation of intrinsic FoR is preserved in autistic individuals. By contrast, in the context of the featureless reference object, Bochyńska, Coventry, et al. (2020) observed that autistic individuals differed from their non-autistic peers in the choice of variants of the relative FoR. In line with this study, while Mandarin-speaking non-autistic children were found to show preference for the reflection variant of the relative FoR, Mandarin-speaking autistic children preferentially adopted the translation variant (see Table 3.4 and Table 3.5). Autistic children's preference for the translation variant may be attributed to their egocentrism. The translation projection strategy underlying the use of projective spatial terms "front" and "behind" is in accordance with one's own perspective: that is, the reference object is viewed as aligned in the same direction as oneself, so the translation variant has been linked to egocentrism in the literature (Deng & Yip, 2016; Li, 1988). Therefore, it is not surprising to find that Mandarin-speaking autistic children exhibited a preference for the translation variant when interpreting projective spatial terms. In addition, Mandarin-speaking autistic children did not take kindly to the spatial descriptions that did not rely on the variant they preferentially adopted (i.e., the translation variant), compared with their non-autistic peers. This might be because autistic children engaged in restricted and repetitive verbal as well as nonverbal behaviors (American

Psychiatric Association, 2013). With such a characteristic, this population would be obsessive about one variant when using spatial terms to encode space and reject other variants. With regard to the interpretation of spatial demonstratives, Mandarin-speaking autistic children were found to exhibit comparable performance in the same perspective condition to the receptive-language-ability-matched non-autistic children. However, autistic children had more difficulties with spatial demonstrative comprehension in the opposite and the spectator perspective conditions relative to non-autistic children. In these two conditions, the hearer (participant) and the speaker (experimenter) did not share the same perspective, which means the spatial demonstratives required an understanding of the experimenter's perspective for their interpretation. This may put autistic children at a disadvantage since this population is known to have poor understanding of other people's mind (Baron-Cohen, 2001; Baron-Cohen et al., 1985). See the next subsection for details of factors that influence autistic children's difficulties with spatial demonstrative comprehension in the opposite and the spectator perspective conditions.

6.3 Factors Related to the Atypical Use of Spatial Terms in Mandarin-Speaking Autistic Children

Autistic children's atypical performance in the verbal domain has been found to be associated with their autistic traits, ToM understanding, and/or EF (Cardillo et al., 2021; Friedman & Sterling, 2019; Zhao et al., 2021). The studies in this dissertation also observed connection between autistic traits and spatial term interpretation in autistic children. Autistic traits were assessed using one of the widely used scales — the Autism Spectrum Quotient-Chinese's Version (AQ-C; Auyeung et al., 2008). The lower AQ-C score indicates less autistic-like behavior. Autistic participants were found to have a significantly higher AQ-C score, exhibiting stereotyped and repetitive patterns of behaviors, e.g., "prefers to do things the same way", "gets strongly absorbed in one thing", etc. With these autistic traits, it seemed difficult for them to divert attention from one variant of spatial FoR to other variants when encoding space. This could help explain why the autistic participants solely relied on one variant of the relative FoR to interpret projective spatial terms and did not take kindly to others.

As for the role of ToM in spatial terms, participants with poor performance in the ToM test were found to tend to rely upon one variant of the relative FoR and reject other variants when interpreting projective spatial terms. In order to accept the spatial descriptions made by someone relying on a different variant, one needs to switch from his/her own perspective to that person's to understand why he/she encodes space in that way. This seems related to ToM understanding, a capacity of predicting other people's behaviors based on their minds that may differ from one's own (Baron-Cohen et al., 1985; Perner & Wimmer, 1985). Autistic children performed significantly worse in the ToM test. With low ToM ability, autistic children might have difficulty in taking different perspectives, and thus did not take kindly to relying on different variants of the relative FoR to interpret the projective spatial terms. In addition to the projective spatial terms, ToM ability was found to affect autistic children's comprehension of spatial demonstratives. Autistic children with a lower ToM ability than those in the non-autistic group also made more errors when interpreting spatial demonstratives in the opposite and the spectator perspective conditions compared with the non-autistic group. In these two conditions where the hearer and the speaker do not share the same perspective, spatial demonstratives require an understanding of the position/perspective of the speaker (experimenter) for their correct interpretation, for which ToM ability seems to be required (Chu & Minai, 2014, 2018; de Villiers & de Villiers, 1974). Specifically, ToM ability will help children understand the position/perspective of the speaker (experimenter) and translate from their own point of view to the experimenter's when locating the places referred to by the experimenter using spatial demonstratives. Therefore, it is not surprising that autistic children with a low ToM ability had difficulty in comprehending spatial demonstratives when they did not share the same perspective with the speaker.

Autistic children's difficulties with spatial demonstrative comprehension in the opposite and the spectator perspective conditions might also be attributed to their executive dysfunction — low working memory. In the two conditions, the positions/perspectives of both self and speaker(s)/experimenter(s) as well as the distance information indicated by the spatial demonstratives needed to be considered, if spatial demonstratives were to be correctly understood. The process of interpreting spatial demonstratives in such complex conditions seems to require sufficient capacity of processing considerable information. Autistic children performed significantly worse in the backward condition of the working memory test, which assessed the capacity of maintaining incoming information and manipulating the maintained information. Low working memory might contribute to autistic children’s difficulty in comprehending spatial demonstratives in the conditions where the speaker’s perspective was not the same as their own.

Chapter 7. Conclusion

7.1 Summary of Findings

The main purpose of this dissertation was to investigate the spatial language (projective spatial terms and spatial demonstratives) in Mandarin-speaking autistic children without ID, compared with language-ability-matched non-autistic children.

When the reference object did not have inherent front and back, Mandarin-speaking autistic children without ID preferentially adopted the translation strategy to interpret the projective spatial terms, including “front”, “behind”, “left”, and “right”, while their non-autistic peers showed a preference for the reflection strategy. Autistic children did not take kindly to accepting the use of projective spatial terms that did not rely on the variant they preferentially adopted. Compared with autistic children, non-autistic children were more likely to accept different variants in addition to the one preferentially adopted. The acceptance of multiple variants of the relative FoR was found to positively correlate with ToM understanding.

In the context of the reference object with inherent orientation, autistic children, like their non-autistic peers, mainly relied on the intrinsic FoR to interpret the projective spatial terms and no longer activated the relative FoR. The two groups of children showed higher sensitivity to the intrinsic FoR when the reference object bore the feature [+ social] (e.g., human) than when the reference object bore the feature [- social] (e.g., chair). In addition, autistic children with higher ToM abilities were more sensitive to the intrinsic FoR when interpreting the projective spatial terms than those with lower ToM abilities.

Turing to the interpretation of spatial demonstratives, autistic children had more difficulties in the opposite perspective condition than in the spectator perspective condition, where they performed worse than they did in the same perspective condition. In addition, compared with non-autistic children, autistic children made more errors in interpreting spatial demonstratives in the two harder conditions (i.e., opposite and spectator). The difficulty with spatial demonstrative comprehension in these two conditions might be attributed to low ToM abilities and executive dysfunction.

7.2 Significance

Research on the use of spatial terms in Mandarin-speaking autistic children is still in its infancy. Most of what is known about autistic people comes from studies in Indo-European speakers, whose preferences for the spatial FoRs underlying the use of spatial terms differ from those of Mandarin speakers. The findings of the present dissertation can facilitate a better understanding of the use of spatial terms in ASD. First, this dissertation is the first to examine Mandarin-speaking autistic children's use of projective spatial terms ("front", "behind", "left", and "right") when locating an object in relation to another object without inherent orientation where the underlying spatial FoR is the relative FoR. There are three variants of relative FoR: translation, reflection, and rotation. The reflection variant has been equated with the relative FoR in some standardized development tests and spatial language tests, disregarding the other two variants (Bochyńska, Coventry, et al., 2020; Edwards et al., 2011). With three variants taken into consideration, the current dissertation enables us to obtain a clearer picture of the relative FoR underlying the use of projective spatial terms in autistic people. Second, this dissertation is the first to examine the activation of multiple spatial FoRs when interpreting projective spatial terms in autistic children from an Eastern country. Third, the investigation of spatial demonstratives, whose use is based on the deictic FoR, employed a modified experimental design to remove the possible ambiguity caused by methods of previous studies (Chu & Minai, 2014, 2018; Tfouni & Klatzky, 1983; Zhao, 2007; Zhu et al., 1986). Furthermore, this is the first study that investigates whether autistic children's interpretation of spatial terms is associated with their ToM abilities and EF. The findings of relationships between spatial term comprehension and these two cognitive abilities enrich the existing knowledge about the role of ToM abilities and EF in non-autistic children's interpretation of spatial terms.

The present dissertation offers evidence of selective atypical uses of spatial terms in Mandarin-speaking autistic children that were previously overlooked, but that could influence daily communication and social development. The use of spatial terms is a key element of communicative interaction, where it can assist in a range of communicative functions, such as expressing where someone or something is or which direction the person or the thing is moving. Atypical use of spatial terms may contribute to inefficient communication in autistic individuals, which perhaps results in a vicious circle whereby an autistic person's low conversation skills hamper his/her acceptance within a community, which in turn heightens the deficiency in communication (Hamilton et al., 2009; Wallace et al., 2011). Therefore, awareness of the profile of spatial term interpretation in ASD should be raised. Practically, the findings of this dissertation in regard to mainland Chinese autistic children's spatial terms will be useful for clinicians and speech-language pathologists to develop intervention strategies and assistive tools that are tailored to autistic children in mainland China. These efforts will help to enhance autistic children's interpretation and representation of spatial relationships. In addition, the findings suggest the intervention programs targeting speech in ASD should go beyond linguistic abilities and include cognitive aspects such as ToM understanding and EF.

7.3 Limitations and Future Directions

The present dissertation has several limitations that deserve attention. First, while here the studies in this dissertation focused on autistic children without ID who were matched with non-autistic children on receptive language ability but not on chronological age, the current findings do not necessarily extend to other autistic subgroups, such as those who have comparable receptive language ability to chronological-age-matched non-autistic children. Considering large amounts of heterogeneity within the autistic spectrum, future research with autistic and non-autistic children matched on receptive language ability in addition to chronological age would allow to uncover the spatial terms in ASD more comprehensively. Additionally, IQ, serving as an inclusion criterion for autistic children, was not measured in non-autistic children. The observed differences between autistic and non-autistic children might be attributed to their possible difference in IQ level. Future studies with IQ tested in both groups will help to address this issue.

Second, the present study solely focused on the interpretation of projective spatial terms under the ordinary condition where the viewer was static, and the figure object was not covered by the reference object. In such a condition, the use of projective spatial terms is subjective to cross-linguistic variations, while the cross-linguistic differences are neutralized under some special circumstances (Deng & Yip, 2016; Hill, 1982). For instance, in the circumstance where the figure object is covered by the reference object (e.g., a ball lies behind a tree), Hausa neurotypical speakers who normally adopt the translation strategy will shift to the reflection strategy to encode the spatial relationships between the two objects. English neurotypical speakers who prefer the reflection strategy under ordinary conditions tend to adopt the translation strategy when they, as reviewers, are in motion. These findings suggest the use of projective spatial terms by non-autistic people under certain circumstances is governed by some universal perceptual constraints (Deng & Yip, 2016; Hill, 1982). Given atypical perceptual processing is frequently reported in autistic individuals, an investigation of this population's use of projective spatial terms under special circumstances would be an important addition to future research exploring spatial terms in ASD.

Third, the discussion of how collectivistic cultures and interdependence could be shaping our findings of acceptance of less-preferred variants of relative FoRs by Mandarin speakers is pure speculation. In order to test this hypothesis, more precise data on the cultural factors is needed. Future studies with comparison between speakers of collectivistic and individualistic cultures would allow to more comprehensively uncover the cultural influence on the acceptance of multiple variants.

Supplementary Material

Supplementary Material 1. Examining the Activation of the Relative FoR Based on Data B.

To determine whether Mandarin-speaking non-autistic children and autistic children without ID could activate the relative FoRs when locating an object in relation to another object with inherent orientation, the trials of picture-sentence pairs were coded as appropriate or inappropriate for the relative FoR. As the participants varied in relative FoR preference, the trials were coded for each participant individually. For instance, if the participant preferentially adopted the reflection variant of the relative FoR in the relative FoR test (see Subsection 3.2.2.3), the picture-sentence pairs that were appropriate for the reflection variant were coded as appropriate for the relative FoR for this participant, and those inappropriate for the reflection variant were coded as inappropriate for the relative FoR. There were some participants who preferentially adopted both reflection and translation variants. Their responses were coded twice: once when they were regarded as having a preference for the translation variant, and once when they were regarded as preferring the reflection variant, giving rise to two sets of data (Data A and Data B). Repeated measures ANOVAs were run based on Data A to examine the activation of the relative FoR, and the results have been reported in Subsection 4.4.1. Table S1 shows the average ratings of acceptability of spatial sentences appropriate/inappropriate for the relative FoR in the three groups of participants when Data B was used: the autistic child, the non-autistic child, and the adult groups. Statistical analyses did not detect a significant main effect of Appropriateness or Group, and there was no significant interaction effect either (p > .05). Whether based on Data A or B, the results did not support the activation of the relative FoR in any group of participants.

Table S1. Average acceptability ratings for the descriptions appropriate and inappropriate for the relative FoR in the autistic child, non-autistic child, and adult groups.

Group	Appropriate	Inappropriate
Autistic child	3.14 (1.87)	2.81 (1.86)
Non-autistic child	3.11 (1.92)	2.98 (1.91)
Adult	3.04 (1.90)	3.03 (1.86)

Supplementary Material 2. The Items and Materials of the Working Memory Test

Item	Trial	Test	Response	Score
1	1	勺子-桌子		
	2	椅子-裤子		
2	1	裙子-叉子-桌子		
	2	椅子-袜子-杯子		
3	1	勺子-桌子-帽子-叉子		
	2	杯子-椅子-裤子-勺子		
4	1	叉子-桌子-裙子-杯子-椅子		
	2	袜子-勺子-桌子-帽子-叉子		

5	1 2	裤子-杯子-椅子-裙子-勺子-桌子 袜子-叉子-桌子-帽子-杯子-椅子		
6	1 2	裙子-勺子-裤子-桌子-袜子-椅子-叉子 帽子-桌子-杯子-袜子-椅子-勺子-裙子		
7	1 2	勺子-袜子-杯子-袜子-裙子-桌子-椅子-裤子 叉子-椅子-裤子-袜子-帽子-杯子-勺子-椅子		

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