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# Linguistic markers of psychosis in Mandarin Chinese: Relations to theory of mind

Han Zhang [a,*], Alberto Parola [b,c], Yuan Zhou [d], Huiling Wang [e], Vibeke Bliksted [c,f], Riccardo Fusaroli [b,c,g], Wolfram Hinzen [a,h]

[a] *Department of Translation and Language Sciences, Universitat Pompeu Fabra, Carrer de Roc Boronat, 138, Barcelona 08018, Spain*
[b] *Department of Linguistics, Semiotics and Cognitive Science, Aarhus University, Aarhus, Denmark*
[c] *The Interacting Minds Centre, Institute of Culture and Society, Aarhus University, Aarhus, Denmark*
[d] *Institute of Psychology, Chinese Academy of Sciences, Beijing, China*
[e] *Department of Psychiatry, Renmin Hospital of Wuhan University, Wuhan, China*
[f] *Psychosis Research Unit, Department of Clinical Medicine, Aarhus University, Aarhus, Denmark*
[g] *Linguistic Data Consortium, University of Pennsylvania, Philadelphia, USA*
[h] *Catalan Institute for Advanced Studies and Research (ICREA), Barcelona, Spain*

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ABSTRACT

Disorganized and impoverished language is a key feature of schizophrenia (Sz), but whether and which linguistic changes previously observed in Indo-European languages generalize to other languages remains unclear. Targeting Mandarin Chinese, we aimed to profile aspects of grammatical complexity that we hypothesized would be reduced in schizophrenia in a task of verbalizing social events. 51 individuals with Sz and 39 controls participated in the animated triangles task, a standardized measure of theory of mind (ToM), in which participants describe triangles moving in either a random or an 'intentional' condition. Results revealed that clauses embedded as arguments in other clauses were reduced in Sz, and that both groups produced such clauses and grammatical aspect more frequently in the intentional condition. ToM scores specifically correlated with production of embedded argument clauses. These results document grammatical impoverishment in Sz in Chinese across several structural domains, which in some of its specific aspects relate to mentalizing performance.

## 1. Introduction

Anomalies in speech production manifesting forms of disorganization and impoverishment are a prominent feature in patients diagnosed with schizophrenia, which carries clinical importance (DeVylder et al., 2014; Harrow and Marengo, 1986; Maria-de-Gracia et al., 2010; Ortiz et al., 2013; Wilcox, 1990; Palaniyappan, 2022). Anomalies can be rated clinically using canonical rating schemes, where they are classed according to a number of clinical labels such as tangentiality, derailment, or poverty of content, characterized as 'formal thought disorder' (Andreasen,1986). A linguistic perspective on such anomalies can help to clarify which aspects of linguistic organization are specifically involved, and these in turn can help to inform neurocognitive hypotheses. A major current challenge in this regard is to demonstrate the universalizability of language changes in schizophrenia across languages, including those of other (in particular non-Indo-European) language families, which can differ radically in how grammatical relations are manifest morphologically. The overarching goal of the present study was to profile language changes in schizophrenia in Mandarin Chinese, at a specific level of linguistic organization, which was targeted with a view to relating linguistic variables at this level to theory of mind (ToM) performance in the same sample.

While ToM capacity is doubtlessly involved in the social-communicative use of language (Achim et al., 2022; Bosco et al., 2019), evidence suggests that it is also related to language at the syntactic level, i.e. its structural organization at the level of phrases and sentences. A reduction in syntactic complexity in spontaneous connected speech has been studied in schizophrenia groups in a number of studies, which have used relatively coarse-grained measures such as sentence length in words or part-of-speech (PoS) tagging (e.g. nouns, verbs, pronouns) (De Boer et al., 2020; Marini et al., 2008; Tang et al., 2021); and Corcoran et al. (2020), Haas et al. (2020) for computational

* Corresponding author.
*E-mail address:* han.zhang@upf.edu (H. Zhang).

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studies in groups at clinical high risk involving similar measures). This reduction has recently been confirmed at the level of syntactic networks as well (Ciampelli et al., 2023). Little is known for the case of Chinese at any level of linguistic organization, though see Shi et al. (2021) for an experimental study of the (mis-)use of classifiers in a Mandarin-speaking schizophrenia group and Agurto et al. (2023) for a computational discrimination of Mandarin-speaking youths at clinical high risk of psychosis based on a number of measures across the acoustic, PoS, and semantic levels.

Results on more specific aspects of syntactic complexity, such as the production of embedded clauses, are currently ambiguous, even in English. Unlike a measure such as sentence length, embedding indicates syntactic complexity in the hierarchical sense: one clause (e.g. *while he was eating*) is not syntactically independent but appears as a part of another (e.g. *He smoked while he was eating*). Some studies found that clausal embedding differentiates schizophrenia groups from healthy controls in English (Cokal et al., 2018; Fraser et al., 1986; DeLisi et al., 1997), while others found no difference, in Spanish (Sevilla et al., 2018) and English (DeLisi, 2001). Embedded clauses are also often introduced by specific word types such as *that* or *which* (in one of their uses), and studies have found that the use of these decreases in clinical high-risk groups (Bedi et al., 2015; Corcoran et al., 2018).

A reduction (or at least shift) in grammatical complexity has also been found in the domain of noun phrases (NPs), specifically pronouns and determiners such as *the* or *a*, which in English function so as to determine the referential use of NPs – e.g. whether a specific individual is referenced (e.g. *the man with the accent*), or not (e.g. *a man was here*) (Harvey, 1983; Rochester and Martin, 1979). Recent work in this direction has documented changes in the quantitative distribution of grammatically different NP types, particularly a decrease in the use of definite-specific reference in the sense above, and more anomalies in the use of them in patients with formal thought disorder, across a number of languages (English: Cokal et al., 2018; peninsular Spanish: Sevilla et al., 2018; Chilean Spanish: Palominos et al., 2023; Turkish: Cokal et al., 2022).

For the present study of Chinese, we focused on syntactic complexity in the domain of the verb phrase (VP), specifically on embedded clauses, verbal Aspect, and VP-adjoined adjuncts (as explained below). This was motivated by our specific research questions as well as the nature of our data, which came from the animated triangles task (Abell et al., 2000). In this task, participants are asked to describe animated clips in which two triangles are observed to move either randomly or else in an apparently intentional way. In describing such events, relevant aspects of VP-related complexity have to be selected by speakers, which serves to index the complexity of the ways in which they represent the events. Embedded clauses are a case in point: Thus, an intrinsic feature of a linguistic representation of the form *The small triangle is upset* is that it represents a fact; but as occurring in *The large triangle thinks the small triangle is upset*, that same structure does not do that, representing a mental content instead. This turns such a complex structure technically into a *meta*representation: in addition to representing a fact (about the large triangle thinking something), it is also representing a representation (namely the large triangle's thought that the small one is upset). Simply in virtue of their form, therefore, such metarepresentations index a cognitively significant variable, *through* a specific aspect of syntactic complexity, thereby linking language and cognition in a clinically important way.

This aspect is grammatically precise, in that it concerns clauses functioning as syntactic *arguments* of an embedding verb phrase (VP), while clauses embedded as *adjuncts* do not exhibit this meta-representational feature. Thus, in *she laughed while/because he was reading)*, the embedded clause (underlined) functions as an adjunct, and it is clear that it does not function so as to represent a mental content. Arguments are different from adjuncts in that the latter can be dropped, while preserving grammaticality. Adjunct clauses nonetheless index another critical aspect of cognitive complexity, namely how a speaker cognitively relates two events to each another, e.g. presenting one as a part or cause of the other. In a task where participants are specifically asked to describe visually presented events, both argument and adjunct clauses are therefore likely to capture relevant cognitive complexity in how events are conceptualized or interpreted, though in different ways, and they were therefore distinguished here.

In line with the metarepresentational significance of embedded argument clauses, numerous studies using different methodologies in different populations (Schroeder et al., 2021; Steele et al., 2003; Tager-Flusberg and Joseph, 2005) have shown that the comprehension of embedded (argument) clauses relates to independent cognitive measures of metarepresentational capacities, including ToM (Durrleman et al., 2017; Boeg Thomsen et al., 2021). In clinical populations, most insight in this regard has come from cognitive development in children with autism spectrum disorders (ASD) (e.g. Schroeder et al. 2021). In the context of schizophrenia, pervasive ToM impairment (Dimopoulou et al., 2017; Frith, 2004; Harrington et al., 2005; Sprong et al., 2007), as well as deviance in the comprehension and production of embedded argument clauses (Cokal et al., 2018, 2019) have been documented. But the two have not been linked. We aimed to do this here, with a view to also clarifying inconsistencies in the previous literature as noted above. It seems likely that a major factor in these inconsistencies regarding embedded clauses is variability in (or lack of) technical definitions (e.g. DeLisi 2001, De Boer et al. 2020). Argument and adjunct clauses have also typically not been distinguished in previous studies (e.g. Sevilla et al., 2018), and some studies have used summary measures combining all clauses appearing as parts of other clauses (e.g. Tavano et al. 2008).

Another feature of the cognitive complexity involved in representing events is grammatical Aspect, which is defined as the grammatical specification of whether a given dynamic event is complete or incomplete in relation to a temporal point of reference, i.e. the point of speech – e.g., the morpheme *-ing* in English in *he is smoking* specifies the event of smoking as ongoing while the speech act takes place. Aspect therefore goes beyond conceptualizing events as such, insofar as it also concerned with embedding or anchoring such events in time and in relation to a speaker and his specific temporal perspective. Mandarin Chinese lacks inflectional morphology and is a 'tense-less' language in the sense that there are no overt morphological markers of past tense. Aspect (as specified through free morphemes) thus takes over some of the functions of tense, e.g. by indicating completeness and thereby that the event does not reach into the present as indexed by the point of speech (Li and Thompson, 1989).

Finally, verbal adjuncts were investigated, as they can be subcategorized in terms of their attachment sites in the syntactic hierarchy, and therefore provide an indirect index of complexity relating to the latter. In particular, an adjunct adjoining to a lexical verb (V), e.g., an action modifier (*The small triangle harshly pushed the big triangle.*), attaches to a syntactic constituent at a low level of the hierarchy, while an adjunct adjoining to a verb phrase (VP), e.g., a spatiotemporal adjunct, targets the hierarchy one level up (*At the beginning, the triangle was moving clockwise around the rectangle.*). In turn, affective or epistemic adverbs that express a speaker's attitudes or evaluations on a proposition adjoin to an entire clause, which is hierarchically higher than both a V and VP (*Probably, the two triangles are fighting with each other*). All of these variables at the clausal and VP levels reflect grammatical complexity indexing mentalizing as required by the task: e.g., a V-attached adverbial (*push harshly*) indicates thinking about the mental state behind a given action; likewise, VP-adjoined adjuncts such as spatiotemporal ones specify the logical sequence or the spatial property of an event, which can be crucial to the coherence of a social narrative; and epistemic adverbials express the speakers' subjective evaluation on what is going on in the animation. Although NPs are also a domain of considerable interest given its relevance to the referential function of language and previous studies of the latter in schizophrenia, we did not include variables from this domain in this analysis because of no evidence for expecting links between NP-structure and ToM, as well as because of the nature of our data, where referencing (to two triangles only) is too poor to generate rich enough data.

### 1.1. Current study

The present study had two main aims. The first was to profile syntactic complexity in Chinese speakers with schizophrenia, through variables in the verbal and clausal domains that we specifically hypothesized to linguistically index cognitive demands of a mentalizing task: Embedded argument and adjunct clauses; Aspect (Progressive and complete), and Adjuncts (V-adjoined, VP-adjoined, Epistemic). We predicted a general effect of group for these aspects of syntactic complexity, with a reduction in schizophrenia. A main effect of condition was also expected, in the sense that more complexity would be naturally expected in the more complex intentional rather than the random condition, particularly for embedded argument clauses; though such an effect might also be confined to the control group. Our second main aim was to investigate relations between these variables and standardized ToM scores, as well as available neurocognitive measures. Relations to cognitive scores are to be expected based on previous studies that have found linguistic differences in schizophrenia to be associated with deficits in ToM (Harrington et al., 2005; Gavilán and García-Albea, 2011) and executive dysfunction. In particular, Docherty et al. found correlations between referential communication disturbances and poor performance on tasks of immediate auditory memory and distractibility, working memory, sustained attention and sequencing (Docherty and Gordinier, 1999; Docherty 2005). In turn, Cokal et al. (2019) found correlations between schizophrenia patients' performance on sentence-picture matching tasks and all standardized neuropsychological measures from sentence comprehension, to executive function, visual semantic memory, and general IQ. A reduction in the dimension of syntactic complexity targeted here could therefore form part of a more general profile of cognitive impairment, which could in turn mediate the specific relation of linguistic variables to ToM performance as analyzed here.

## 2. Methodology

### 2.1. Participants

Participants data were obtained from previous studies using the same dataset (Beck et al., 2020; Parola et al., 2022). 51 people with schizophrenia and 39 healthy controls were included in the current study. All participants were native Chinese speakers, and were of Han Chinese ethnicity. The study was IRB approved and written informed consent was obtained from all participants. Detailed information on sociodemographics, verbal IQ, ToM, and neurocognitive measures is summarized in Table 1.

#### 2.1.1. Speech samples

Speech samples were collected using the Animated Triangles task (Abell et al., 2000; Castelli et al., 2000), which consists of eight short video clips representing two animated triangles moving around on a framed, white background. In four of the clips, the two triangles are moving randomly and apparently unintentionally (e.g., bouncing about), while in the remaining four clips the triangles are interacting intentionally, with one triangle trying to influence the mental state of the other (e.g., the large blue triangle trying to convince the small red triangle to come outside). The duration of each animation is approximately 40 s. After each animation, the participants were asked what they thought was going on in each animation and their answers were audio-recorded and then transcribed. All transcripts were double-checked against the audios by the first author of the present study.

**Table 1**
Sociodemographic and clinical characteristics of patients with schizophrenia (Sz) and healthy controls (HC).

| Characteristics | Sz ($n = 51$) Mean ± SD | HC ($n = 39$) Mean ± SD | P-value |
|---|---|---|---|
| Age (year) | 27.31 ± 7.15 | 29.76 ± 8.77 | 0.470 |
| Educational (year) | 12.67 ± 2.64 | 14.07 ± 2.39 | < 0.001 |
| Gender (n. of females and%) | 23 (45%) | 18 (46%) | 0.840 |
| Verbal IQ | 96.13 (16.74) | 102.21 (13.22) | 0.056 |
| Medication (Chlorpromazine equivalents) | 604.75 ± 389.67 | – | – |
| Illness duration (month) | 62.97 ± 7.3 | – | – |
| SANS global | 7.77 ± 2.87 | – | – |
| SAPS global | 7.38 ± 4.69 | – | – |
| PANSS positive symptoms | 16.25 ± 4.50 | – | – |
| PANSS negative symptoms | 16.95 ± 4.76 | – | – |
| Verbal memory | 37.34 (11.87) | 46.66(7.85) | < 0.001 |
| Working memory | 26.26(5.31) | 30.36(3.86) | 0.002 |
| Motor speed | 70.26(15.42) | 78.45 (10.01) | 0.010 |
| Verbal fluency | 29.32(11.06) | 41.42 (11.27) | < 0.001 |
| Attention | 46.29(11.38) | 62.94(8.67) | < 0.001 |
| Executive functions | 14.52(5.15) | 17.30(2.86) | 0.030 |
| ToM (triangles task) | 16.98 (7.01) | 23.26(5.95) | < 0.001 |
| ToM (Brüne) | 16.74 (3.81) | 20.37(3.00) | < 0.001 |

Note: Patients data came from two cohorts and were combined, where one cohort ($n = 31$) had the SANS (Scale for the Assessment of Negative Symptoms) and the SAPS (Scale for the Assessment of Positive Symptoms) data available, and another cohort ($n = 20$) had the PANSS (Positive and Negative Syndrome Scale) data available. The two scales were converted into a single measure using the method proposed in van Erp et al. (2014). Detailed clinical measures of the two cohorts are provided in the supplementary materials. Medication was computed from 27 patients whose data were available. We built regression models to examine the potential effects of illness duration and antipsychotic medication on the production of linguistic variables (see supplementary materials).

#### 2.1.2. Measures of ToM and neurocognition

The Animated Triangles task was also used to assess participants' ToM capacities in a standardized way. Answers were scored according to a target item as defined by Russel et al. (2006). indicating whether subjects were describing the correct degree of intentionality, range 0–1. An additional nonverbal ToM task was Brüne's picture sequencing task (Brüne, 2003), where participants are asked to arrange mixed-ordered cards in a logical sequence of events and are then asked between two and four questions for evaluating if they had understood the characters' mental state. The questions investigate comprehension of first-order, second-order and third-order false belief, with one point assigned for each correctly answered question. Neurocognition was accessed using the Chinese version of Brief Assessment of Cognition in Schizophrenia (BACS), a validated neurocognitive test battery containing six subtests to estimate verbal memory, working memory, motor speed, verbal fluency, executive functions, and attention and speed of processing.

### 2.2. Linguistic annotation

Transcripts for each video clip were imported to CLAN (Computerized Language Analysis) (MacWhinney, 2000), where the annotations of variables of interests were carried out manually. The basic unit of analysis was an utterance defined as a syntactically independent unit providing new information to the discourse. For each utterance, three linguistic domains were investigated, namely embedded clauses, Aspect, and non-clausal adjuncts. Embedded clauses were subcategorized as embedded argument and embedded adjunct clauses. The first of these subcategories consisted of five sub-variables: the first three of these were clauses whose matrix clause (the clause within which they are embedded) contained first-, second- or third-person subjects, respectively. This distinction was made since an accurate description of the animation requires use of third-person nouns (e.g. *the small triangle, the big triangle, they*) more than of first or second person nouns referring to either the subjects themselves or the interlocutor, suggesting deviance from the task. The other two variables under embedded argument clauses were VP-argument clauses, and the '*Ba*' or disposal construction in Mandarin. The former is any clause in which the main verb takes a VP argument, e.g., *the small triangle wants the big triangle to go out.* The latter is a special construction in Chinese involving the interaction of the subject and the object, which is a linguistic structure often employed in the ToM condition where the two triangles frequently interact with each other, e.g., *lanse sanjiaoxing ba hongse sanjiaoxing tuichu menwai le* (*The blue triangle pushed the red triangle out of the door*). The second subcategory of embedded clause was embedded adjunct clause, e.g., adjuncts clauses indicating causality, goal, or time. The second broad domain of interest was Aspect, including progressive and completeness markers. Chinese does not use the concept of formal tenses, employing grammatical aspect instead, through particles signaling how a given event relates to the speech time. The particles most often used to indicate aspect in Chinese are *progressive* markers 'zai', 'zhengzai', e.g., *liangge sanjiaoxing zai yundun* (*Two triangles are moving around*), and *completeness* markers 'le', 'guo', e.g.*, da sanjiaoxing daile yige xiao sanjiaoxing yiqi wan* (The big triangle brought a small triangle to play together). Lastly, we targeted non-clausal adjuncts, which were divided into three sub-categories: V-attached adverbial, VP-attached adjunct, and epistemic adverbs, attaching to constituents at different levels of the syntactic hierarchy. Fig. 1 is a schematic representation of the linguistic variables.

### 2.3. Reliability of coding

Following the annotation manual described above, the first author coded the entire samples in consultation with the senior author (WH). To establish the inter-rater reliability of coding, 10% of the data were randomly selected and recoded by an independent rater who was trained for the annotation manual. Independent rating samples were checked against the original ratings on a point-to-point basis and disagreements were attempted to be resolved by discussion to reach consensus from the two raters. Final reliability was calculated for all variables by dividing the total number of points the two ratings agreed by the sum of the total points possible. Mean agreement between raters was 91.8% for the schizophrenia group, 93.6% for the control group.

### 2.4. Statistical analysis

The analysis proceeded in two stages. First, to address our research questions about group differences and condition effects on each of the aspects of grammatical complexity investigated, we fitted a set of mixed effects negative binomial regression models using the glmmTMB package, version 1.0.2.1 (Brooks et al., 2017) in R to evaluate any potential group, condition, or interaction effects. Negative binomial regression is a generalization of Poisson regression. It has an advantage over Poisson regression in that it does not make the mean equal to variance assumption, and performs well in addressing overdispersion resulting from outliers or other factors (Payne et al., 2018). In each of the models, we defined *Group* and *Condition* as two categorical predictors, random intercepts and slopes for both subject and condition, and an offset term (widely used for modeling rate) containing the *total number of characters*, which was used to account for the possibility that each linguistic phenomenon was more or less present as an effect of variation in the number of characters produced by different participants. This offset term also served to convert the outcome of the predicted variable from a count into a rate (i.e., the incidence of linguistic variable per character). Education was included in each model as a covariate to account for the group difference in years of education. As there is a tendency for groups to differ in verbal IQ ($p = 0.056$), we therefore additionally added it as another covariate. The potential effects of antipsychotic medication and illness duration were checked through post-hoc analyses (see results and supplementary materials). Next, to address our second question regarding the relationship between linguistic measures and independent measures of ToM capacity and other neuropsychological measures, Spearman rank correlations were run to access the potential association between the production of each linguistic variable (a relative ratio calculated by dividing the total number of occurrences of this variable by the total number of characters) and measures of ToM from two tasks and six measures of neurocognition (verbal memory, working memory, motor speed, verbal fluency, executive functions, attention). For those significant correlations between language and ToM, we further ran partial correlations to control for the effect of neurocognition and verbal IQ. Additionally, correlational analyses were run in order to explore the relationships between clinical symptoms and linguistic variables. To account for multiple comparisons, we adjusted p values for both the regression models and the correlations using the false discovery rate (FDR) method (Benjamini and Hochberg, 1995) and the significance level was set to 0.05.

## 3. Results

Our first research question concerned group and condition effects on the nine linguistic variables. As seen from Table 2, there was a reduction of linguistic complexity in schizophrenia group regardless of condition, showing significantly lower rates in the use of embedded argument clauses and adjuncts at the non-clausal level. Specifically, the individuals with schizophrenia were 55% less likely to produce embedded argument clauses ($p = 0.026$), and 32% less likely to use non-clausal adjuncts compared to controls ($p = 0.026$). However, groups did not differ in the production of Aspect, whether in Progressive or Completeness. As for the effect of condition, results showed that the production of embedded argument clauses was 3.85 times higher in the intentional condition than in the random condition, for both groups ($p < 0.001$). The same pattern applied to Aspect production, with Aspect markers being 146% more likely to occur in the intentional condition than in the Random condition ($p < 0.001$). When zooming into the two sub-categories of Aspect, results showed that both groups had a tendency to produce more Progressive in the random compared to the

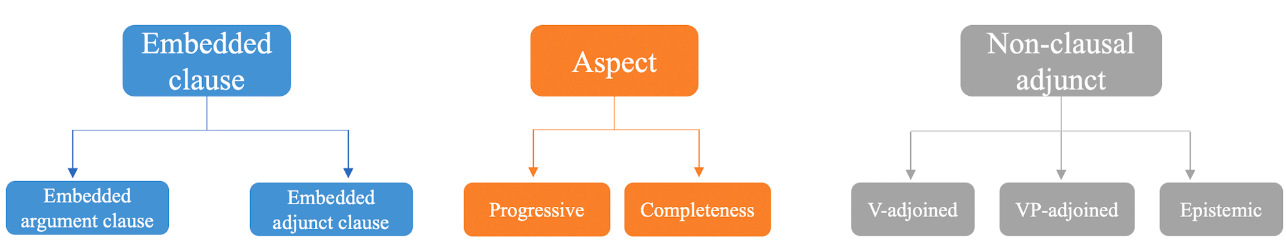


**Fig. 1.** A schematic representation of the linguistic variables.

**Table 2**
Statistical significance for group and condition effects on the nine linguistic variables.

| | Fixed effect | | | | | | Random Effect | |
|---|---|---|---|---|---|---|---|---|
| *Variable* | *Predictors* | *Incidence Rate Ratios* | *CI* | *Statistic* | *p-values* | *p-values adjusted* | $\sigma^2$ | $\tau_{00}$ |
| Embedded argument clause | Intercept | 0.01 *** | 0.00 – 0.05 | −6.88 | | | 3.91 | 0.09 |
| | Group (Sz) | 0.45 ** | 0.26 – 0.79 | −2.76 | **0.006** | **0.026** | | |
| | Condition (ToM) | 3.85 *** | 2.81 – 5.27 | 8.41 | **<0.001** | **<0.001** | | |
| | Group (Sz) * Condition (ToM) | 1.47 | 0.83 – 2.60 | 1.31 | 0.192 | 0.684 | | |
| Embedded adjunct clause | Intercept | 0.00 *** | 0.00 – 0.01 | −6.53 | | | 5.34 | 0.19 |
| | Group (Sz) | 0.64 | 0.34 – 1.19 | −1.41 | 0.157 | 0.283 | | |
| | Condition (ToM) | 1.37 | 0.93 – 2.00 | 1.6 | 0.11 | 0.165 | | |
| | Group (Sz) * Condition (ToM) | 1.04 | 0.55 – 1.98 | 0.13 | 0.898 | 0.898 | | |
| Aspect (all) | Intercept | 0.01 *** | 0.00 – 0.03 | −7.27 | | | 3.89 | 0.18 |
| | Group (Sz) | 1.24 | 0.85 – 1.79 | 1.11 | 0.266 | 0.343 | | |
| | Condition (ToM) | 1.46 ** | 1.16 – 1.83 | 3.23 | **0.001** | **0.004** | | |
| | Group (Sz) * Condition (ToM) | 0.84 | 0.60 – 1.18 | −1.01 | 0.311 | 0.684 | | |
| Progressive | Intercept | 0.00 *** | 0.00 – 0.06 | −4.03 | | | 5.59 | 0.74 |
| | Group (Sz) | 1.24 | 0.62 – 2.48 | 0.61 | 0.543 | 0.543 | | |
| | Condition (ToM) | 0.69 | 0.45 – 1.05 | −1.74 | 0.082 | 0.165 | | |
| | Group (Sz) * Condition (ToM) | 0.84 | 0.44 – 1.62 | −0.51 | 0.61 | 0.784 | | |
| Completeness | Intercept | 0.00 *** | 0.00 – 0.02 | −7.97 | | | 4.2 | 0.15 |
| | Group (Sz) | 1.21 | 0.79 – 1.85 | 0.87 | 0.384 | 0.432 | | |
| | Condition (ToM) | 1.92 *** | 1.45 – 2.54 | 4.59 | **<0.001** | **<0.001** | | |
| | Group (Sz) * Condition (ToM) | 0.83 | 0.55 – 1.26 | −0.88 | 0.38 | 0.684 | | |
| Adjunct | Intercept | 0.02 *** | 0.01 – 0.04 | −8.84 | | | | |
| | Group (Sz) | 0.68 ** | 0.52 – 0.88 | −2.88 | **0.004** | **0.026** | 3.64 | 0.04 |
| | Condition (ToM) | 0.91 | 0.75 – 1.11 | −0.92 | 0.355 | 0.400 | | |
| | Group (Sz) * Condition (ToM) | 1.19 | 0.86 – 1.64 | 1.03 | 0.302 | 0.684 | | |
| V-attached | Intercept | 0.00 *** | 0.00 – 0.00 | −6.74 | | | 6.09 | 0.00 |
| | Group (Sz) | 0.49 | 0.23 – 1.03 | −1.87 | 0.061 | 0.138 | | |
| | Condition (ToM) | 0.79 | 0.49 – 1.26 | −0.99 | 0.322 | 0.400 | | |
| | Group (Sz) * Condition (ToM) | 0.7 | 0.25 – 1.97 | −0.67 | 0.501 | 0.752 | | |
| VP-attached | Intercept | 0.01 *** | 0.00 – 0.03 | −7.75 | | | 3.91 | 0.06 |
| | Group (Sz) | 0.8 | 0.56 – 1.13 | −1.26 | 0.207 | 0.310 | | |
| | Condition (ToM) | 1.05 | 0.78 – 1.42 | 0.33 | 0.740 | 0.740 | | |
| | Group (Sz) * Condition (ToM) | 1.08 | 0.71 – 1.65 | 0.37 | 0.713 | 0.802 | | |
| Epistemic | Intercept | 0.03 ** | 0.00 – 0.28 | −3.03 | | | 5.9 | 0.37 |
| | Group (Sz) | 0.40 * | 0.20 – 0.81 | −2.54 | **0.011** | **0.033** | | |
| | Condition (ToM) | 0.65 | 0.40 – 1.08 | −1.67 | 0.094 | 0.165 | | |
| | Group (Sz) * Condition (ToM) | 1.76 | 0.75 – 4.12 | 1.3 | 0.194 | 0.684 | | |

Note: Total number of characters in Sz (Mean ± SD): 416 ± 295; in HC: 575 ± 318.

intentional condition (Intentional/Random = 0.69) prior to the p-value correction, while the rates of Completeness were significantly higher in the intentional than in the random condition (Intentional/Random = 1.92, $p < 0.001$). Post-hoc analyses showed that medication and duration of illness had no predictive effect on any of the linguistic variables (see supplementary materials).

Our second research question concerned the relationships between linguistic variables and independent measures of ToM, neurocognitive measures and clinical symptoms. Table 3 showed that the production of embedded clauses in the intentional condition, regardless of whether they were arguments or adjuncts, was significantly positively correlated with measures of degree of intentionality using standardized ratings of the animated triangles task. Additionally, there was a significant positive correlation between the production of embedded argument clauses and the scores obtained from Brüne's picture sequencing task. V-adjoined adjuncts were also found to be significantly correlated with the measures of degree of intentionality using standardized ratings of the animated triangles task. Except for embedded clauses and V-adjoined adjuncts, no other linguistic variables were found to be correlated with ToM measures. Post-hoc partial correlational analyses indicated that the previously observed significant correlation between embedded adjunct clauses and ToM measures was no longer present after accounting for the effects of neurocognition and verbal IQ, while the three other significant correlations remained unchanged (see Table 4).

There were weak and sparse significant correlations between linguistic and neurocognitive measures. Embedded adjunct clause was the only variable found to be significantly correlated to three of the six neurocognitive measures (motor speed, $r = 0.33$, $p < 0.005$; verbal fluency, $r = 0.48$, $p < 0.001$; and attention, $r = 0.32$, $p < 0.05$). Epistemic adjunct was significantly associated with executive function ($r = 0.35$, $p < 0.05$). Finally, no significant correlations were found between linguistic variables and general measures of clinical symptoms (see Table 5).

## 4. Discussion

The goal of this study was to assess, for the first time, specific aspects of syntactic complexity in Chinese-speaking patients with schizophrenia, which we hypothesized would distinguish groups in an event-description task designed to elicit mental state reasoning. Major findings can be summarized in three points. First, we found a reduction of syntactic complexity as indexed by our variables in schizophrenia, comprising embedded argument clauses and non-clausal adjuncts; second, the linguistic profile changes with task demands, but it does so in both groups, as both patients and controls responded to the ToM condition by increasing their production of embedded argument clauses and aspect markers (completeness). Third, embedded argument clause production was significantly and strongly correlated with standardized measures of ToM from both ToM tasks, whereas the correlations between linguistic and neurocognitive measures were weaker and sparser.

Regarding syntactic complexity, these findings from Chinese are consistent with previous studies in English finding reduced use of clausal embedding (Morice and Ingram, 1982; Cokal et al., 2018; DeLisi et al., 1997), though our study is not directly comparable insofar as it made a distinction between embedded argument and adjunct clauses, which patterned partially differently. Thus, the former showed a condition effect, the latter did not; and they did not correlate significantly with each other. This confirms that, while they both index relevant aspects of

**Table 3**
Correlation coefficients and significance levels between linguistic variables, neurocognition, ToM and Verbal IQ.

| | Adjunct clauses | Argument clauses | Completeness | Progressive | Aspect | V-adjoined | VP-adjoined | Epistemic | Adjunct | VM | WM | MS | VF | Attention | EF | ToM-Triangle | ToM-Brüne |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Adjunct clauses** | | | | | | | | | | | | | | | | | |
| **Argument clauses** | 0.21 | | | | | | | | | | | | | | | | |
| **Completeness** | −0.02 | 0.18 | | | | | | | | | | | | | | | |
| **Progressive** | −0.05 | 0.03 | 0.13 | | | | | | | | | | | | | | |
| **Aspect** | −0.07 | 0.13 | 0.90**** | 0.50*** | | | | | | | | | | | | | |
| **V-adjoined** | 0.43** | −0.04 | −0.16 | 0.01 | −0.11 | | | | | | | | | | | | |
| **VP-adjoined** | 0.12 | 0.14 | 0.26 | 0.16 | 0.23 | 0.1 | | | | | | | | | | | |
| **Epistemic** | 0.09 | 0.29 | −0.1 | 0 | −0.09 | −0.02 | 0.07 | | | | | | | | | | |
| **Adjunct** | 0.16 | 0.15 | 0.11 | 0.09 | 0.09 | 0.21 | 0.88**** | 0.41** | | | | | | | | | |
| **VM** | 0.25 | 0.22 | −0.03 | −0.02 | −0.07 | 0.25 | 0.03 | 0.11 | 0 | | | | | | | | |
| **WM** | 0.07 | 0.03 | 0.13 | 0.21 | 0.2 | 0.05 | 0.18 | 0.05 | 0.12 | 0.53*** | | | | | | | |
| **MS** | 0.33* | 0.22 | 0.26 | 0.15 | 0.28 | 0.19 | 0.16 | 0.13 | 0.11 | 0.2 | 0.36* | | | | | | |
| **VF** | 0.48*** | 0.2 | 0.01 | 0.04 | 0.01 | 0.15 | 0.02 | 0.12 | 0.03 | 0.23 | 0.18 | 0.24 | | | | | |
| **Attention** | 0.32* | 0.25 | −0.12 | 0.01 | −0.1 | 0.22 | 0.12 | 0.18 | 0.13 | 0.48*** | 0.54*** | 0.39* | 0.40** | | | | |
| **EF** | 0.09 | 0.05 | −0.07 | 0.08 | −0.04 | −0.05 | 0.08 | 0.35* | 0.18 | 0.35* | 0.56**** | 0.29 | 0.26 | 0.41** | | | |
| **ToM-Triangle** | 0.39** | 0.40** | −0.04 | −0.04 | −0.06 | 0.38* | 0.15 | 0.12 | 0.14 | 0.24 | 0.18 | 0.33* | 0.50*** | 0.41** | 0.21 | | |
| **ToM-Brüne** | 0.25 | 0.57**** | 0.15 | 0.13 | 0.15 | 0.19 | 0.2 | 0.18 | 0.14 | 0.48*** | 0.37* | 0.27 | 0.31 | 0.56**** | 0.32* | 0.47** | |
| **Verbal IQ** | 0.35* | 0.2 | 0.01 | 0.1 | 0.04 | 0.18 | 0.12 | 0.18 | 0.16 | 0.31 | 0.36* | 0.27 | 0.40** | 0.28 | 0.27 | 0.28 | 0.31 |

Abbreviations: VM: Verbal memory, WM: Working memory, MS: Motor speed, VF: Verbal fluency, EF: Executive function.
$p < 0.0001$ '****'; $p < 0.001$ '***', $p < 0.01$ '**', $p < 0.05$ '*'.

**Table 4**
Results of partial correlation between linguistic variables and ToM variables after controlling for neurocognition and verbal IQ.

| | ToM_Triangle_task | ToM_Brüne |
|---|---|---|
| **Adjunct clauses** | $r = 0.14$, $p = 0.275$ | |
| **Argument clauses** | $r = 0.29$, $p = \mathbf{0.029}$ | $r = 0.53$, $p < \mathbf{0.001}$ |
| **V-adjoined adjunct** | | $r = 0.30$, $p = \mathbf{0.024}$ |

cognitive complexity in representing dynamic events, they are different, with the metarepresentational content of argument clauses being more relevant to the demands of the task (intentional condition). While the lack of interaction effect between group and condition for argument clauses may be due to an insufficient sample size, it also suggests that the schizophrenia group succeeded to adapt its linguistic profile to the ToM-related task demands. Adjuncts other than clausal ones also showed group effects, however, and no condition ones, suggesting a reduction of syntactic complexity partially irrespective of how language adapts to the ToM demands. Crucially, adjuncts are grammatically optional, adding information to a linguistic representation that can as such function independently. Functioning therefore as *modifiers* of given event representations, they index cognitive processes going beyond identifying events and satisfying constraints of grammaticality as such, tapping into how we *transform* cognitive representations of events into more complex ones when making sense of them in the context of others. Intriguingly, a recent study using automatized natural language processing in Chinese (Agurto et al., 2023) found that a group of youths at high risk of schizophrenia were distinguishable through their use of 'localizers', which appear to strongly overlap with VP-adjoined adjuncts as defined here.

The schizophrenia group did not differ in terms of Aspect production indicating cognitive complexity in conceptualizing a given event as being complete or incomplete, with both groups showing the same tendency of increasing progressive markers in the random condition, while increasing completeness markers in the intentional condition. Aspect markers in Chinese are independent characters (free morphemes) that go immediately after the main verb, and are mostly mandatory elements to make a sentence grammatical, particularly in the case of progressive aspect. This may reduce their complexity with regards to both embedded clauses and adjuncts, which may partially explain why aspect markers did not show a group difference. This task effect in the absence of group effect again suggests that both groups respond to the heightened demands of the ToM condition by adapting their linguistic resources. In particular, in the non-intentional (random) condition, there is little to say about specific events, which simply follow one another. Increase of the use of Progressive in this condition may thus reflect that both groups merely reflect background ongoing actions.

As predicted, embedded clauses were significantly related to ToM, extending a pattern long seen in the context of ASD (Schroeder et al., 2021; Durrleman et al., 2017) to schizophrenia. This not only showed in condition effects for this type of embedded clause (but not adjunct embedded clauses), but also in small- to moderate correlations of both of these variables to standardized measures of ToM as provided by both the animated triangles and picture sequencing tasks. This may suggest that even apparently 'non-verbal' tasks tapping into one's meta-representational capacities may involve linguistic representations (of a specific metarepresentational form and content) at some level of processing, even if they do not involve *speech* production. This perspective is consistent with the recent finding by Paunov et al. (2022) that brain-language regions show robust tracking of non-linguistic stimuli if these are rich in mental state content. V-attached adjuncts were also correlated with ToM as standardly scored. This particular result may be explained by the fact that V-attached adjuncts like 'harshly', 'consistently' etc. are indeed related to reasoning about the event participants' intentionality. Overall, therefore, we conclude that this pattern of correlations with ToM scores further questions the initial

**Table 5**
Correlation coefficients and significance levels between linguistic variables and clinical symptoms.

| | Adjunct clauses | Argument clauses | Completeness | Progressive | Aspect | V-adjoined | VP_adjoined | Epistemic | Adjunct |
|---|---|---|---|---|---|---|---|---|---|
| SAPS global | −0.28 | −0.16 | −0.20 | −0.14 | −0.23 | 0.13 | −0.24 | −0.10 | −0.23 |
| SAPS global | 0.06 | 0.10 | 0.18 | −0.06 | 0.14 | 0.20 | 0.19 | −0.12 | 0.18 |
| PANSS positive | 0.03 | 0.11 | 0.22 | −0.09 | 0.15 | 0.25 | 0.14 | −0.09 | 0.13 |
| PANSS negative | −0.17 | −0.11 | −0.12 | −0.07 | −0.13 | 0.03 | −0.05 | −0.21 | −0.08 |

$p < 0.0001$ '****'; $p < 0.001$ '***', $p < 0.01$ '**', $p < 0.05$ '*'.

view of ToM as a language-independent or 'modular' cognitive construct, as also evidenced by Tang et al. (2022) that computational speech measures predicted mentalizing ability in schizophrenia. At a practical level, our findings may motivate moving from conventional ways of scoring ToM tasks to language-based assessments, which can in part be automatized as well.

While there was an absence of correlation for linguistic measures with symptoms, they sparsely and weakly correlated with several neurocognitive measures: embedded adjunct clauses showed significant associations with measures of motor speed, verbal fluency, and attention; epistemic adjuncts were significantly associated with executive function. This extended but sparse pattern may equally suggest the need to view language alterations in schizophrenia in the context of cognitive changes overall, rather than seeking to explain them as changes in an independent or specific capacity: unlike classical aphasic language impairments following strokes, which may leave crucial aspects of hierarchical grammatical complexity intact (Zhang and Hinzen, 2022), previous evidence from direct comparisons of language impairment in aphasia and schizophrenia (Little et al., 2019) suggest that language changes in schizophrenia index cognitive changes themselves (Bosco and Parola, 2017; Bosco et al., 2019). This may specifically concern aspects of cognition that we need language to execute, and which therefore decline in conjunction with language impairment.

## 5. Conclusions

This study documents widespread linguistic changes in the spontaneous speech of people with schizophrenia in Chinese relative to neurotypical speakers. It confirms, for a language typologically different from the relatively few languages investigated in this field so far, that schizophrenia affects linguistic variables capturing syntactic complexity that is specifically related to cognitive complexity involved in conceptualizing events. In part, these variables are affected differently depending on whether the events in question are intentional or not. Variance captured by them overlaps with that captured by conventional standardized ToM scores and confirms previous findings of a partial confluence of the neurocognitive mechanisms involved in embedded clauses and ToM, respectively.

Limitations of our study are the unavailability of antipsychotic medication for all participants and the heterogeneity of the patients. For a more comprehensive understanding of the language profile in schizophrenia in Chinese, future studies may explore grammatical complexity beyond the factors we explored here and encompass linguistic variables instantiated from the entire syntactic hierarchy (including NPs) and adapted to Chinese grammar. Importantly, also, it should be explored whether automated analyses using natural language processing (NLP) can replicate the present findings; moreover, as syntactic structure-building in human language is never independent of semantic structure-building, and NLP is particularly suited for semantic metrics, analysis pipelines need to be built that unify these two crucial domains of linguistic organization.

## CRediT authorship contribution statement

**Han Zhang:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Project administration, Visualization. **Alberto Parola:** Resources, Writing – review & editing. **Yuan Zhou:** Resources, Data curation. **Huiling Wang:** Resources, Data curation. **Vibeke Bliksted:** Resources, Data curation. **Riccardo Fusaroli:** Resources, Writing – review & editing. **Wolfram Hinzen:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition.

## Declaration of Competing Interest

Riccardo Fusaroli has been a paid consultant on related but not overlapping topics for Roche. All other authors report no relevant conflicts.

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.psychres.2023.115253.

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