Cognitive sequence processing and syntactic comprehension in schizophrenia

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It has been repeatedly demonstrated that schizophrenic patients are impaired in the comprehension of sentences with complex syntax. We investigated the hypothesis that this syntactic comprehension impairment in schizophrenia is not a purely linguistic dysfunction, but rather the reflection of a cognitive sequence processing impairment that is revealed as task complexity increases. We tested 10 schizophrenic patients using a standard measure of syntactic comprehension, and a non-linguistic sequence processing task, both of which required simple and complex transformation processing. Patients' performance impairment on the two tasks was highly correlated ($r^2 = 0.84$), and there was a significant effect for complexity, independent of the task. These results are quite similar to those of aphasic patients with left hemisphere lesions. This suggests that syntactic comprehension deficits in schizophrenia reveal the dysfunction of cognitive sequence processing mechanisms that can be expressed both in linguistic and non-linguistic sequence tasks. *NeuroReport* 11:2145–2149 © 2000 Lippincott Williams & Wilkins.

Key words: Abstract structure; language; schizophrenia; syntax

INTRODUCTION

Schizophrenic subjects display cognitive performance that is largely intact for implicit or automatic tasks, including word-stem completion, repetitive priming and procedural learning [1–6]. Their performance is more impaired, however, on explicit or effortful tasks [7,8]. This behavioral dissociation has been linked to the hypoactivation of anterior cortex both at rest [9,10] and during effortful cognitive tasks [11–14]. The emerging picture is that explicit cognitive processing that relies on intact functioning of the frontal cortex will be impaired in schizophrenia, while implicit processing will be more spared.

It is interesting, from this perspective, to consider the impaired processing of language in schizophrenia. Several studies have now confirmed the observation of impaired processing of complex syntax, both in terms of production and comprehension, in schizophrenic subjects [15–18]. Thus, schizophrenic subjects do well in understanding sentences with simple syntax such as 'John gave the ball to Mary', but have trouble with more complex sentences involving syntactic movement such 'The ball was given to Mary by John'. This profile appears similar to that observed in aphasic subjects with left hemisphere lesions in the peri-sylvian cortex. These agrammatic subjects have relatively intact performance for understanding simple syntax, and fail with more complex syntax [19,20]. It will thus be of great interest to make a detailed comparison of performance between these two groups.

Regarding the underlying cause(s) of this syntactic dysfunction in schizophrenia, we can consider two possible explanations. The linguistic resources explanation is that the impairment in syntax processing results from damage to language-specific resources in schizophrenia. The shared resources explanation claims that the linguistic deficit results from damage to cognitive-sequencing process that are used in language and other cognitive functions involving the structural manipulation of sensorimotor sequences. The shared resources explanation would thus predict that schizophrenic patients with syntactic comprehension deficits would display comparable impairments in a non-linguistic sequencing task that tap into these shared resources.

From this perspective, we have recently demonstrated in a group of schizophrenic patients, an impaired capability to learn the abstract structure of sensorimotor sequences, while their capability to learn the surface structure remained intact [21]. We define surface structure of a sequence as the serial order of sequence elements, and the abstract structure in terms of relations between repeating elements [22]. Thus the sequences ABCBAC and DEFEDF have different surface structures but identical abstract structure (123213), and are by our definition isomorphic. For any sequence based on the abstract structure 123213, we can see that the elements 213 are entirely predictable by the preceding elements 123, which are in contrast unpredictable. Given the fragment GHI of a new isomorphic sequence, based on the abstract structure we can predict the next three elements HGI. In other words, knowledge of abstract structure transfers to isomorphic sequences. While control subjects can learn both the surface structure and the abstract structure of a given sequence, schizophrenic subjects learned only the surface structure. We have speculated [22,23] that abstract structure processing is functionally related to the processing of syntactic rules, in that both require transformations that apply to isomorphic sequences (sentences). This would suggest that for schizophrenic patients the observed impairments in abstract structure processing [21] and in syntactic processing [15–18] could be functionally related.

The goal of the current study is thus to examine the syntactic comprehension performance in a group of schizophrenic patients and compare this to their performance in a non-linguistic sequence processing task, based on the use of abstract structure as defined above. Within both tasks there will be variation in the structural complexity. We predict that performance impairments in both tasks will be predicted by the degree of complexity, as we have observed in aphasic subjects displaying agrammatic comprehension [23].

MATERIALS AND METHODS

Subjects: The subjects were 10 schizophrenic patients (seven males, three females). Their mean age was 35.5 (s.d 6.8). They were diagnosed based on the DSM-IV criteria, and were clinically stable at the time of testing. Five patients met the criteria for paranoid schizophrenia, three for undifferentiated schizophrenia, and two for residual schizophrenia. Exclusion criteria were mental retardation, neurological illness or trauma, or alcohol or drug abuse.

The mean average disease duration was 11.8 ± 6.1 years. All patients were receiving antipsychotic medication (principally risperidone or olanzapine). Clinical symptoms were rated by using the Scale for Assessment of Positive Symptoms [24] and the Scale for Assessment of Negative Symptoms [25]. The mean values (s.d.) for the positive and negative symptoms (SAPS and SANS total scores) were 17.0 (16.5) and 42.3 (25.3), respectively. All patients spoke French as their first language, or have acquired it as their principal language before puberty. All were unaware of the nature of the study.

Syntactic comprehension assessment: The comprehension of syntactic structure was evaluated using a task developed by Caplan *et al.* [19] in which sentences are read aloud to the subjects who are then required to demonstrate the meaning of each sentence by identifying the agent, object and recipient from amongst a set of six photographs. For example, given the dative passive sentence 'The elephant was given to the monkey by the rabbit', subjects should respond (by pointing to the appropriate photographs) that the rabbit is the agent, the elephant is the object and the monkey is the recipient, in that order. Five examples of nine different sentence types are tested, for a total of 45 sentences. Of the nine sentence types, five are canonical (syntactically simple) involving no syntactic movement, and four are non-canonical (syntactically complex) involving syntactic movement. Using this material, Caplan *et al.* [19] observed that in aphasic subjects (excluding severe Wernicke's and global aphasics) canonical sentences of the type cleft subject (e.g. It was the elephant that hit the monkey) and active types (e.g. The elephant hit the monkey) were processed with the fewest errors, while non-canonical dative passive (see above) and subject–object relative types (The elephant that the monkey hit hugged the rabbit) sentences were processed with the most errors. Healthy subjects perform at ceiling ($\geqslant 95\%$ correct) on this task. We can thus consider this difficulty with non-canonical word order to be among the defining characteristics of agrammatic comprehension [19,20].

Abstract sequence processing assessment: We examine abstract structure processing with a protocol [22,23] similar to those used in studies of artificial grammar learning [26], that tests the ability to learn an abstract structure in order to judge whether new letter-sequences follow that structure (i.e. does BKTKBT follow the abstract structure 123213. Answer: yes).

During an initial familiarization and training period of 10–15 min, the subjects studied a list of 10 letter-sequences (e.g. HBSBHS, YPBPYB) generated from the non-canonical abstract structure 123213. We verified that the patients all displayed intact letter recognition and naming capabilities. The subjects were instructed to study the list in order to decide how to complete the sequence BKT_ _ _. After this training period, subjects demonstrated their understanding of the abstract structure and the task by completing the above sequence with KBT (to form the sequence BKTKBT, following the abstract structure 123213).

In a subsequent testing period of 5 min the patients were presented with 20 new sequences, and were informed that each of the 20 sequences had to be judged as corresponding, or not, to the abstract structure they learned in the study phase. In a separate testing phase, the same procedure was performed with the simple abstract structure 123123 for nine of the ten patients, as one became unavailable for subsequent testing. We verified that performance in these abstract structure tasks remains stable between testing sessions such that there was not an order effect for the simple and complex conditions. As with the syntactic comprehension task, healthy age matched subjects perform at ceiling on this task ($\geqslant 95\%$ correct).

Data analysis: To determine whether there is global relationship between performance on the syntactic and abstract structure tasks, we first compare scores on the syntactic comprehension task with those for the abstract sequence processing task in a linear regression. In order to examine the more detailed relations between performance for simple and complex structures in the two tasks, we then perform a repeated measures ANOVA where the within-subject variables are complexity (simple, complex) and task (linguistic, sequencing). The dependant variable is the percentage of correct comprehension or judgement for each of the four possible cases. Percentage correct scores for the nine sentence types in the syntactic comprehension task are thus collapsed into two categories (simple and complex) according to whether they are canonical (no syntactic movement) or non-canonical. If complex structure processing is impaired independant of the task domain, then we should observe an effect for complexity, without a complexity $\times$ task interaction.

In order to compare the schizophrenic comprehension and sequence processing deficits to those in agrammatical aphasic patients, we will finally perform a repeated measures ANOVA as described above, with the addition of a group analysis for the schizophrenic subjects, and agrammatic aphasic patients that we have previously studied [23].

RESULTS

As displayed in Fig. 1, scores for processing complex structures in syntactic comprehension and sequence classification were significant correlated ($r^2 = 0.91$, $F(1,8) = 81$, $p < 0.00002$). In contrast, scores for simple structures were not correlated ($r^2 = 0.13$, $F(1,7) = 1$, $p = 0.3$). Finally, the overall performance (simple and complex combined) scores for syntactic comprehension and sequence classification were significantly correlated ($r^2 = 0.84$, $F(1,7) = 37.5$, $p = 0.0005$).

Looking at these results in more detail, we observe from Fig. 2 that for sentences and for sequences, performance for simple structures is superior to that for complex structures. This observation is confirmed by a repeated measures ANOVA in which the within-subjects factors are task (syntax, sequence) and complexity (simple, complex). The main effect for task was significant ($F(1,8) = 9.8$, $p < 0.05$) with superior performance for the sequence task. We recall that chance in the sequencing task is 50%, while it is < 25% for the syntax task, since a correct response requires at least 2 or 3 correct choices. The main effect for complexity was also significant ($F(1,8) = 9.9$, $p < 0.05$), with superior performance for canonical *vs* non-canonical forms. Most importantly, there was no task × complexity interaction ($F(1,8) = 0.0002$, $p = 0.99$), indicating that the superior performance for simple (canonical) forms does not vary between the two tasks. Planned comparisons revealed that for both tasks, performance on the simple (canonical) forms was significantly superior to that for complex (non-canonical) forms ($p < 0.05$).

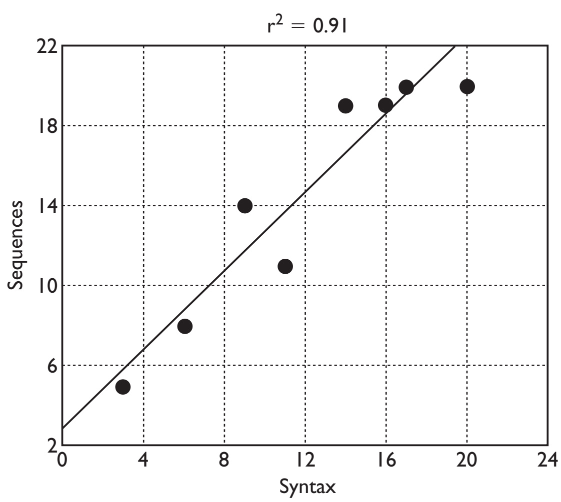

Fig. 1. Schizophrenic processing of syntactic and abstract structure. Correlation between syntactic comprehension performance for complex (non-canonical) sentences, and abstract structure judgement performance for complex sequences. The correlation is highly significant, with $r^2 = 0.91$.

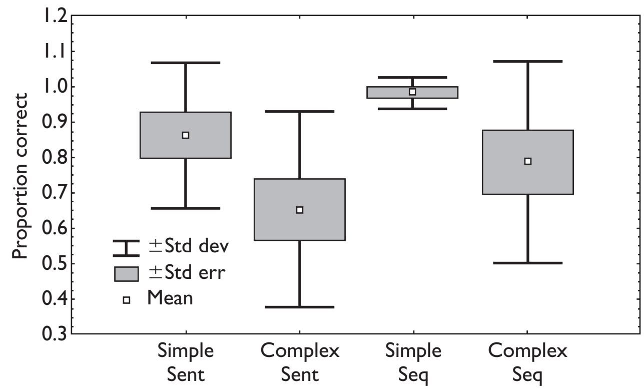

Fig. 2. Schizophrenic performance (proportion correct) for simple *vs* complex conditions with sentences and non-linguistic sequences. Both for sentences and non-linguistic sequences, performance is superior for the simple condition and impaired for the complex condition.

In the comparison between schizophrenic and agrammatic performance, the scores of our schizophrenic patients are significantly linearly related with those of Caplan *et al.* [19] ($y = 2.8018 + 0.45068 \times x$, $r = 0.82$, where x and y are performance aphasic and schizophrenic subjects, respectively). The same relation holds between the schizophrenic patients and a group ($n = 7$) of aphasic patients [23] we have recently studied ($y = 2.4984 + 0.50061 \times x$, $r = 0.86$, where x and y are aphasic and schizophrenic subjects, respectively).

Looking at this relationship between the aphasic and schizophrenic groups in more detail, in Fig. 3 we compare simple *vs* complex performance in syntax and abstract structure tasks for the two groups. For both the schizophrenic and agrammatical aphasic groups, performance is superior for simple *vs* complex structure, both for the syntactic and sequence processing tasks. While this impair-

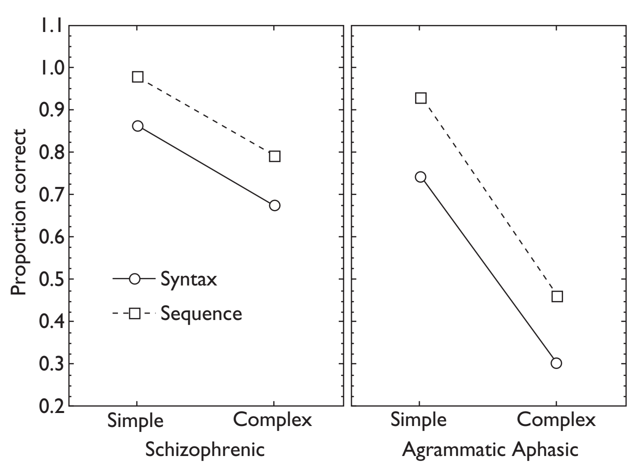

Fig. 3. Comparison of schizophrenic and agrammatical Broca's aphasic performance. For both groups there is a parallel impairment in performance for the linguistic syntax, and non linguistic sequence tasks, as a function of complexity.

ment is more pronounced in the aphasics, the observation that the impairment in the two tasks is parallel does not vary between the two groups. These observations are confirmed by the group (aphasic, schizophrenic) × task (syntax, sequence) × complexity (simple, complex) ANOVA.

The main effect for group was significant ($F(1,13) = 5.2$, $p < 0.05$), corresponding to the observation that the schizophrenic group performance is superior to that of the aphasic group. The task effect is also significant ($F(1,13) = 30$, $p < 0.001$), corresponding to the observation that the syntactic performance is inferior to that for the sequencing task. Again, we recall that chance in the sequencing task is 50%, while it is < 25% for the syntax task, since a correct response requires at least 2 or 3 correct choices. Finally, as predicted the complexity effect was significant ($F(1,13) = 39.5$, $p < 0.001$). The only significant interaction was the group × complexity ($F(1,13) = 5.9$, $p < 0.05$), as the aphasics were more impaired in the complex conditions. The lack of group × task interaction ($p = 0.42$), and the lack of group × task × complexity interaction ($p = 0.99$) confirms the observation of a parallel impairment for both syntax and cognitive sequencing as a function of complexity in the schizophrenic and aphasic subjects.

DISCUSSION

Our results demonstrate that schizophrenic subjects display parallel impairments in tasks that measure syntactic comprehension and non-linguistic cognitive sequencing capabilities. We also demonstrate that the syntactic comprehension profile in the schizophrenic subjects is correlated with that of agrammatic aphasic subjects, with both groups displaying a selective impairment for non-canonical sentences with complex syntax. This suggests that the language comprehension deficits observed in schizophrenics bears some functional relation to that observed in aphasia resulting from left peri-sylvian cortical lesions.

This leads to two possible explanations for syntactic comprehension deficits in schizophrenic patients. (1) There is a neurophysiological impairment in the left cortical areas that are thought to participate in syntactic analysis. Alternatively one could propose that (2) there is a more general cortical dysfunction that affects non-specific processing resources, leading to degraded cognitive function including impaired syntactic processing. In an effort to distinguish between these possibilities we can refer to recent studies of cerebral blood flow in schizophrenic patients, indicating a reduced frontal blood flow at rest [9,10] and during cognitive task performance [11–14]. Interestingly, it has been demonstrated that during the execution of motor sequencing tasks with the right hand, acute schizophrenic patients display a hypoactivation of the left anterior cortex and caudate nucleus [13]. This suggests that a selective dysfunction in the left anterior cortex of these patients could contribute to syntactic dysfunction. To test this hypothesis one should observe cerebral blood flow in these patients during the performance of syntactic comprehension tasks.

In favor of the second non-specific dysfunction alternative, we note that agrammatic comprehension profiles can be induced in normal subjects who have their processing capacity diminished by engaging in a secondary task [27]. This suggests that the apparently selective impairment of complex syntax in the schizophrenic and aphasic patients is not the reflection of a specific lesion, but rather the reflection of the high requirements that complex syntax places on processing resources that would be reduced both by vascular lesions and schizophrenia. The final answer is likely between these two extremes. As proposed by Caplan *et al*. [20], we can consider syntactic processing involves an extensive distributed neural system, whose most important region is the left perisylvian cortex.

CONCLUSION

We set out to test the hypothesis that impaired syntactic comprehension in schizophrenia is not a purely linguistic dysfunction, but rather the reflection of a cognitive sequence processing impairment that is revealed as task complexity increases. We demonstrated that, indeed, syntactic comprehension deficits are highly correlated with deficits in a cognitive sequence processing task that requires the manipulation of syntax-like rules. We also demonstrated that the syntactic comprehension impairment in schizophrenia, though less severe, demonstrates the same complexity effects both for syntax and non-linguistic cognitive sequences, as observed in aphasic patients with left-hemisphere lesions. These observations support the proposition that processing syntax and non-linguistic abstract structure both rely on an extensive neural system, whose most important region is the left perisylvian cortex. The normal function of this network can be impaired by selective lesions, and by less selective dysfunctions as those associated with schizophrenia.

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