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Language comprehension and working memory language comprehension and working memory deficits in patients with schizophrenia

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Abstract

The present study examined the hypothesis that patients with schizophrenia have deficits in language comprehension compared to normal controls, and that these deficits are associated with disturbances in working memory (WM). In addition, we hypothesized that language comprehension deficits would be associated with the severity of specific symptoms in the patients (formal thought disorder and hallucinations). Participants were 27 stable outpatients with schizophrenia and 28 demographically similar controls. Language comprehension was measured by presenting sentences auditorily that varied in length and syntactic complexity, followed by two or three comprehension questions. We measured working memory by administering a reading span task. Results indicated that, as predicted, language comprehension deficits were significantly greater in patients with schizophrenia than controls. Also as predicted, working memory was strongly correlated with language comprehension performance in both patients with schizophrenia and controls. Contrary to our predictions, language comprehension and working memory deficits were not associated with either formal thought disorder or hallucinations.

Keywords: Schizophrenia; Working memory; Language comprehension; Formal thought disorder

1. Introduction

Language production disturbances (i.e., formal thought disorder) have been extensively researched and well documented in the literature on schizophrenia (Andreasen, 1986). However, language comprehension has not received as much systematic attention in the schizophrenia literature. There is some evidence for the existence of language comprehension deficits in schizophrenia (Condray et al., 1992; Condray et al., 1995; Morice and McNicol, 1985). However, the causes of language comprehension deficits and their relationship to specific clinical symptoms of schizophrenia are still unclear. The goal of the current project was to investigate language comprehension deficits in schizophrenia and examine the relationships of these language comprehension deficits to working memory (WM) disturbances and specific clinical symptoms.

A few previous studies have examined comprehension in schizophrenia (Condray et al., 1992; Condray et al., 1995). For example, Condray et al. (1992)

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examined language comprehension in patients with schizophrenia and their brothers with and without schizophrenic-spectrum disorders. The authors found that the brothers with schizophrenia and the brothers with schizophrenic-spectrum disorders had more impaired language comprehension than the unaffected brothers and the controls. Surprisingly, brothers with schizophrenia-spectrum disorders showed greater deficits in language comprehension than brothers with schizophrenia (Condray et al., 1992). More recently, Condray et al. (1995) found that chronic, but unmedicated, patients with schizophrenia displayed deficits in language comprehension compared to controls. Further, when the same patients were treated with haloperidol, they continued to display language comprehension deficits, with no significant differences in comprehension performance between unmedicated and medicated states. Thus, the administration of medication did not appear to improve language comprehension in chronic patients with schizophrenia.

The presence of language comprehension disturbances among patients with schizophrenia raises the question of what mechanisms contribute to such deficits. Research on normal language comprehension suggests that WM function may be a key element in explaining language comprehension ability. WM is defined as the ability to maintain and manipulate information over a short period of time. Just and Carpenter (1992) have argued that the extent to which we use WM in language comprehension depends on the complexity of the stimulus or sentence. For example, King and Just (1991) compared two types of sentences with embedded clauses that they believed differed in their demand on WM resources: (1) center-embedded object-relative sentences (high WM load) and (2) center-embedded subject-relative sentences (lower WM load). An object-relative sentence is one in which the subject is the actor in the main sentence, but the object in the embedded clause, such as "The reporter that the senator attacked admitted the error" (King and Just, 1991). In this example, the reporter is the actor of the main sentence since he admitted the error, but he is the object of the clause since the senator attacked him. A subject-relative sentence is one in which the subject is the actor in both the main sentence and the embedded clause, such as "The accountant that sued the lawyer read the paper" (King and Just, 1991). In this example, the accountant is the actor in both clauses because he sued the lawyer and read the paper.

King and Just (1991) have argued that object-relative sentences demand more WM resources than subject-relative sentences for three reasons. First, the embedded clauses in these sentences produce a disruption in the flow of the main sentence and require more storage resources of WM. Second, understanding the roles of the actors and the objects in both the main sentence and the embedded clause utilizes both processing and maintenance resources, making comprehension more difficult. Third, the assignment of two roles, both actor and object, to both the noun in the main sentence and the noun in the embedded clause also increases WM demand (King and Just, 1991). In contrast, subject-relative sentences do not place as much of a demand on WM resources as the object-relative sentences because even though the clause interrupts the flow of the sentence, the roles of the nouns stay consistent throughout the entire sentence.

In a number of studies (Condray et al., 1996; Daneman and Merikle, 1996; Just and Carpenter, 1992; Just et al., 1996; King and Just, 1991; Miyake et al., 1994), researchers have demonstrated that language comprehension performance is related to an individual's WM capacity. In these studies, WM is often measured using the Reading Span task. In this task, participants read a series of unrelated sentences aloud and are asked to recall the last word of each sentence. An individual's reading span is determined by the number of sentences an individual can read in a row while still correctly recalling the last word of each sentence. Individuals with a high reading span comprehend object-relative sentences better than individuals with a low reading span (King and Just, 1991). In contrast, for subject-relative sentences (lower WM demand) there is no difference in comprehension performance between individuals with a high or low reading span.

Interestingly, a growing body of research suggests that patients with schizophrenia have WM deficits (Gold, 1992; Gold et al., 1997; Park and Holzman, 1992; Perlstein et al., 2001). Given the evidence that patients with schizophrenia have deficits in both language comprehension and WM, it may be possible that such WM deficits contribute to language comprehension deficits. Condray et al. (1996) presented an initial test of this hypothesis. Participants performed the reading span to determine their WM capacity. Language comprehension was measured by asking participants questions about three different types of sentences: (1) simple (no embedded clause); (2) subject relative; and (3) object relative. Condray et al. (1996) found that patients with schizophrenia displayed deficits in both WM capacity (i.e., reading span) and language comprehension compared to the controls, and that WM and language comprehension were strongly correlated. However, language comprehension was worse for all sentences in patients with schizophrenia, with no interaction with sentence type. Nonetheless, examination of the data suggests that patients may have performed particularly poorly on object-relative sentences, which would be consistent with the hypothesis that patient's language comprehension deficits are at least in part related to WM disturbances. The lack of a significant interaction in the Condray et al. (1996) study might have been due to a small sample size ($N=14$ inpatients, 11 outpatients, and 11 controls).

We also know relatively little about how language comprehension deficits are associated with clinical symptoms in schizophrenia. Condray et al. (1995) suggested that patients' comprehension performance was not significantly correlated with clinical symptoms. However, she did find relatively large correlations between ratings of language comprehension and both psychosis ($r=0.41$) and thought disturbance ($r=0.47$), though neither were significant due to the small sample size. One symptom that language comprehension deficits may be particularly related to is thought disorder. There are two reasons to think that this might be true. First, both disturbances are associated with language, though one involves comprehension and one involves production. Second, in prior research, we (Cohen et al., 1999) and others (Docherty et al., 1996) have found that thought disorder among patients with schizophrenia is negatively correlated with performance on WM tasks. Thus, given past research (Condray et al., 1996) suggesting that language comprehension is also related to WM, one might predict that language comprehension, thought disorder and WM are all related to each other. Another symptom of schizophrenia that might also be related to language comprehension and WM deficits is hallucinations. It is possible that hallucinations impair auditory language comprehension because they may act as a distracter to the patient. If a patient hears voices during a language comprehension task or WM task, such voices may distract the patient's thoughts and impair their ability to comprehend language. This type of distraction could be similar to the distraction found in a dual-task paradigm.

The goals of the current study were threefold. The first goal was to determine whether language comprehension deficits among patients with schizophrenia are differentially greater on object-relative sentences (high WM load) as compared to either subject-relative sentences (low WM load) or sentences of equal length without embedded clauses (low WM load). Therefore, we administered the same language comprehension task as used by Condray et al. (1996) to a larger group ($N=27$) of outpatients with schizophrenia. However, Condray et al. (1996) only studied the complexity of sentences. We also included a set of short simple sentences to compare to the simple long sentences to determine if sentence length has an effect on comprehension deficits in addition to syntactic complexity. The second goal was to replicate the findings of a relationship between WM deficits and language comprehension deficits among patients with schizophrenia. To do so, we administered the reading span task as a measure of WM function. The third goal was to examine the relationships among language comprehension, WM, and clinical symptoms. We predicted that both WM and language comprehension deficits would be strongly correlated with measures of formal thought disorder. In addition, we predicted that both WM and language comprehension deficits would be moderately correlated with hallucinations.

2. Methods

2.1. Participants

Participants were 27 DSM-IV diagnosed outpatients with schizophrenia and 28 healthy controls. Patient diagnoses were based on the patient edition of the Structured Clinical Interview for DSM-IV (Spitzer et al., 1990) and the controls were screened using the non-patient edition of the SCID. The diagnostic interview for patients were completed either by a PhD level psychologist (Barch) or an M.A. level psychologist (Melinder). An M.A. level psychologist (Melinder) or a trained research assistant completed the diagnostic interviews for controls. Potential control participants were recruited to be similar to patients on age, gender, and parental education. The demographic and clinical characteristics of both participant groups are shown in Table 1. Patients and controls did not differ significantly on age ($t(53)=1.4$, $p>0.15$), level of parental education ($t(53)=1.7$, $p>0.05$), or gender ($\chi^2(1)=0.21$), $p>0.6$). Controls and patients were excluded for: (1) neurological illness or history of head trauma with loss of consciousness; (2) lifetime history of substance dependence; (3) substance abuse within the last 6 months; and (4) English as a non-native language. In addition, controls were excluded for: (1) lifetime diagnosis of any Axis I disorders; and (2) family history of psychosis.

The Positive and Negative Symptom Scale (PANSS) (Kay, 1991) was used to evaluate clinical state in the patients with schizophrenia. The ratings were measured by either a PhD level psychologist (Barch) or by a M.A. level psychologist (Melinder). Both raters rated a subset of six patients. Interrater reliability was measured using intraclass correlation coefficients, treating the individual rater as the unit of reliability. As described in the Introduction, we hypothesized that formal thought disorder (conceptual disorganization on the PANSS) and hallucinations would be correlated with language comprehension and WM deficits. Interrater reliability was 0.98 for conceptual disorganization and 1.0 for hallucinations.

As described above, we hypothesized that hallucinations might be related to language comprehension deficits and WM deficits because they may distract the patient by acting like secondary tasks. Therefore, after both the language comprehension task and the WM task, we asked each patient whether they had hallucinated during the task, using the following question: “Did you hear any voices during the previous task?” If patients answered yes, we inquired what the hallucinations were about, and then asked the patients to determine on a scale from 0 to 100% how often they had heard the voices during performance of the task.

2.2. Materials and tasks

Each participant completed four tasks, with order counterbalanced across participants: (a) the Vocabulary subtest of the Wechsler Adult Intelligence Scale-III (WAIS-III; Wechsler, 1997); (b) the Reading subtest of the Wide Range Achievement Test-III; (c) the reading comprehension task; and (d) the reading span task.

Table 1
Demographics and clinical characteristics

Variable	Group			
	Normal controls		Patients with schizophrenia	
	M	S.D.	*M*	S.D.
Sex (% male)	60.71%	–	66.67%	–
Age	35.39	9.72	38.81	9.72
Parent’s Education (in years)	13.93	1.92	12.67	3.22
WAIS-III Vocabulary Standard Scores	13.36	3.48	9.74	3.64
WRAT Reading Standard Scores	106.07	14.46	95.07	15.82
Number of Previous Hospitalizations	–	–	6.30	8.56
Age of First Hospitalization	–	–	22.92	6.67
Length of Illness (in years)	–	–	15.81	8.69
% Taking Antipsychotics			89%	
% Typical			20%	
% Atypical			69%	
% Taking Antiparkinsonians			19%	
% Taking antidepressants			33%	
% Taking Mood Stabilizers			11%	
% Taking Benzodiazepines			4%	
PANSS—Conceptual Disorganization	–	–	2.93	1.44
PANSS—Hallucinatory Behavior	–	–	2.37	1.62
PANSS—Total	–	–	59.79	14.51

2.2.1. WAIS-III Vocabulary

The Vocabulary subtest of the WAIS-III was administered as a measure of verbal intelligence. This particular subtest was chosen because it displays the highest correlation of any subtest with verbal IQ scale score ($r = 0.90$; Wechsler, 1997). The Vocabulary subtest was scored by one of the authors (Bagner) and another trained research assistant. Interrater reliability, measured using intraclass correlation coefficients treating the mean of the raters as the unit of reliability, was 0.98. Raw scores on the Vocabulary subtest were converted to age-scaled standard scores based on the guidelines presented in Wechsler (Wechsler, 1997).

2.2.2. WRAT Reading

The Reading subtest of the Wide Range Achievement Test-III (Sattler and Ryan, 1999) was administered as a measure of premorbid verbal achievement (Johnstone et al., 1996; Wiens et al., 1993). One of the authors (Bagner), a graduate student, or a trained research assistant scored the Reading subtest.

2.2.3. Reading comprehension

Participants listened to a total of 64 sentences and answered either two or three questions per sentence. The order of sentence presentation was counterbalanced across participants. There were four grammatically different sentences: 16 simple short sentences; 16 simple long sentences; 16 center-embedded subject-relative sentences; and 16 center-embedded object-relative sentences. The latter three types of sentences were taken from King and Just (1991) and Condray et al. (1996) and were nine words in length. The simple short sentences were devised for this study to determine whether length, in addition to grammatical complexity, affected language comprehension, and each simple sentence was five words in length. Examples of the simple sentences were: *simple short*—"The teacher graded the test"; and *simple long*—"The administrative assistant prepared the report for the executive." Of the two simple sentences, the simple long sentences were hypothesized to produce greater demands on WM maintenance. Examples of the center-embedded sentences were: *subject-relative*—"The chemist that questioned the professor discovered the cure"; and *object-relative*—"The candidate that the governor endorsed lost the campaign." After every simple sentence, participants heard two questions about the sentence, and after the other three types of sentences, participants heard three questions about the sentence. The first question always asked for the actor of the sentence. The second question always asked for the object of the sentence in the simple sentences and the object of the clause in the center-embedded sentences. The third question asked for who or what the actor acted the object on in the simple long sentences and the actor of the clause in the center-embedded sentences. The dependent variables were the total percentage correct of each sentence type as well as the median reaction times.

2.2.4. Reading span

Participants read a series of unrelated sentences aloud and recalled the last word of each sentence. The individual's reading span is determined by how many sentences the individual can read in a row and remember the last word of each sentence. For example, a participant will first read, "I like to eat ice cream" and then "The dog ran up the tree." When the participant sees "???," the participant must respond "cream, tree" or "tree, cream." The trials start with sets of two sentences and increase in length every five trials up to a maximum set size of six sentences. A set was scored as correct when the participant recalled every sentence final word from that set. A participant passed a level if at least three sets are answered correctly. The task was discontinued when the participant answered four out of the five sets incorrectly at a particular level. The dependent variable was the total number of sentence final words correctly remembered by each participant.

2.3. Procedure

Each participant was tested individually. Stimuli for reading comprehension and reading span tasks were presented on an Apple Macintosh computer, using PsyScope software (Cohen et al., 1993). Participant's verbal responses in both the language comprehension and reading span tasks were coded for accuracy by the experimenter. Reaction times (RTs) for the onset of verbal responses during the language comprehension task were automatically recorded by the computer using a microphone and a voice activated relay. A short practice period preceded the actual testing for both tasks to ensure that participants understood the instructions, were comfortable with the apparatus, and were performing a the task appropriately.

2.4. Data analysis

Error rates and median reaction times (RTs) were examined for the language comprehension task. Correlations between error rates and RTs for condition of the comprehension task were examined to ensure that speed–accuracy tradeoffs were not driving any significant effects. For both patients and controls, all correlations were negative, suggesting that better performance was associated with faster RTs. Thus, speed–accuracy tradeoffs were not playing a major role in any reported effects. Correlations between performance in the language comprehension and reading span task were examined separately for each group, using Pearson's Product–Moment correlations.

3. Results

3.1. Language comprehension

Accuracy data for the language comprehension task are shown in Table 2. We analyzed the accuracy data using a two-factor ANOVA, with group (control, patient) as a between-subject factor and sentence type (simple short, simple long, subject-relative, object-relative) as a within-subject factor. This ANOVA indicated a main effect of group ($F(1,53)=16.60$, $p<0.001$), with patients overall less accurate than controls. The ANOVA also indicated a main effect of sentence type ($F(3,159)=128.52$, $p<0.001$). Planned contrasts indicated that for all participants, comprehension for simple short sentences was more accurate than comprehension for either simple long ($F(1,53)=92.13$, $p<0.001$) or subject-relative sentences ($F(1,53)=74.40$, $p<0.001$), which did not differ from each other ($F(1,53)=0.43$, $p=0.51$). Further, as predicted, comprehension for simple long ($F(1,53)=145.59$, $p<0.001$) and subject-relative ($F(1,53)=134.27$, $p<0.001$) sentences was more accurate than comprehension for object-relative sentences. The ANOVA also indicated a group by sentence type interaction ($F(3,159)=128.52$, $p<0.001$). Simple effects tests indicated that patients performed significantly worse than controls with all sentence types ($p<0.05$). Planned contrasts suggested that the group by sentence type interaction reflected the fact that patients demonstrated a greater difference in accuracy between simple short sentences and all other sentence types ($p<0.001$). There was also a marginal trend for patients to show a greater drop in accuracy between simple long and object-relative sentences than controls ($F(1,53)=3.36$, $p<0.07$). However, the difference in accuracy between subject-relative and object-relative sentences did not differ between patients and controls ($F(1,53)=1.65$, $p=0.21$).

Table 2
Comprehension accuracy by sentence type

Sentence type	Normal controls		Patients with schizophrenia		Group difference effect size
	M	S.D.	*M*	S.D.	
Simple short	0.99	0.02	0.97	0.05	0.50
Simple long	0.90	0.10	0.76	0.16	0.93
Subject relative	0.91	0.10	0.76	0.17	0.94
Object relative	0.75	0.17	0.56	0.21	0.90

3.2. Reaction time

Reaction Time (RT) data for the language comprehension task are shown in Table 3. We analyzed the RT data using a two factor ANOVA, with group (control, patient) as a between subject factor and sentence type (simple short, simple long, subject-relative, object-relative) as a within-subject factor. The RT ANOVA indicated a main effect of group ($F(1,53)=5.26$, $p<0.05$), with patients overall slower in response time than controls. The ANOVA also indicated a main effect of sentence type ($F(3,159)=17.42$, $p<0.001$). Planned contrasts indicated that for all participants, RTs for simple short sentences were faster than RTs for center-embedded subject-relative ($F(1,53)=35.28$, $p<0.001$) and object-relative ($F(1,53)=63.10$, $p<0.001$) sentences. However, RTs for simple short sentences were only marginally faster than RTs for simple long sentences ($F(1,53)=1.08$, $p=0.30$). Interestingly, although there were no accuracy differences between simple long and subject-relative sentences, RTs for simple long sentences were faster than RTs for subject-relative sentences ($F(1,53)=5.80$, $p<0.05$). Further, RTs for simple long ($F(1,53)=15.95$,

Table 3
Reaction time by sentence type

Sentence type	Normal controls		Patients with schizophrenia		Group difference effect size
	M	S.D.	*M*	S.D.	
Simple short	360.64	147.60	506.00	517.87	0.35
Simple long	404.52	175.39	567.57	246.81	0.72
Subject relative	484.07	198.88	778.50	737.99	0.54
Object relative	548.91	243.58	941.48	784.58	0.65

$p<0.001$) and subject-relative ($F(1,53)=17.72$, $p<0.001$) sentences were faster than RTs for object-relative sentences. The ANOVA also indicated a group by sentence type interaction ($F(3,159)=2.96$, $p<0.05$). Simple effects tests indicated that patients responded significantly slower with all sentences types ($p<0.05$), except for the simple short sentences ($p=0.20$). There was also a marginal trend for patients to respond slower on object relative versus simple long sentences than controls ($F(3,159)=3.13$, $p=0.08$). Examination of the RT data in Table 3 indicated that there were relatively large S.D.s among the patients with schizophrenia. Inspection of the raw data indicated one patient had extremely long RTs. Thus, we repeated the above RT analyses excluding the data from this outlier, with identical results.

3.3. Reading span

An independent sample *t*-test ($t(53)=2.36, p<0.05$) indicated that, as predicted, patients ($M=19.4$, S.D. = 16.2) had significantly lower reading span scores than controls ($M=28.6$, S.D. = 16.1).

3.4. Correlations between reading span and language comprehension

One of the hypotheses of this study was that there would be a relationship between WM deficits and language comprehension deficits. Thus, we examined the correlations between reading span performance and language comprehension accuracy for each of the sentence types. As can be seen in Table 4, reading span performance was significantly positively associated with language comprehension accuracy for all sentence types, for both controls and patients. Although reading span performance was significantly correlated with performance on all sentence types, we had predicted that WM capacity would be more strongly correlated with comprehension for syntactic constructions that place a greater demand on WM (i.e., object-relative sentences) as compared to syntactic constructions that should place less demands on WM (i.e., simple short, simple long, and subject-relative sentences). To determine whether reading span performance was significantly more strongly correlated with object-relative comprehension for other sentences types, we utilized methods for comparing correlated correlation coefficients suggested by (Meng et al., 1992). For controls, reading span performance was not significantly more correlated with the comprehension of object-relative sentences compared to any of the other sentence types (all *p*s>0.10). For patients, reading span performance was significantly more correlated with the comprehension of object-relative sentences than with comprehension of either simple short ($Z=-2.98$, $p<0.01$) or subject-relative ($Z=-2.13$, $p<0.05$). There was also a trend for reading span performance to be more correlated with the comprehension of object-relative than simple long sentences ($Z=-1.42$, $p<0.08$).

The hypotheses outlined in the Introduction suggest that impaired language comprehension performance in schizophrenia reflects WM deficits. If so, one might expect that reading span performance would be more correlated with language comprehension among patients than among controls. To examine this hypothesis, we used Fisher's *r*-to-*Z* transformation to compare the correlations across groups. These analyses indicated that performance on object-relative sentences was significantly more strongly correlated with

Table 4
Correlations between language comprehension and reading span performance

Sentence type	Group	
	Normal controls	Patients with schizophrenia
Simple short	0.34 *	0.38 *
Simple long	0.58***	0.70***
Subject relative	0.52***	0.62***
Object relative	0.54**	0.82***

* $p<0.05$.
** $p<0.01$.
*** $p<0.005$.

reading span performance among patients as compared to controls ($Z = -1.93$, $p < 0.05$). None of the other correlations differed significantly across groups.

3.5. Verbal IQ, working memory, and language comprehension

We had also obtained measures of verbal IQ (WAIS-III Vocabulary and WRAT-III Reading) in these participants. These measures of verbal IQ were significantly positively correlated with language comprehension performance for all sentence types, among both controls ($0.41 < r < 0.86$) and patients ($0.59 < r < 0.87$). Such strong correlations between language comprehension and verbal IQ raises the concern of whether WM accounts for any variance in language comprehension performance over and above verbal IQ. This is of particular concern given that the reading span, our measure of WM, has a language comprehension component. To address the question, we conducted a series of hierarchical regressions, one for comprehension accuracy with each sentence type. In these regressions, comprehension accuracy was the dependent variable, and the WAIS-III Vocabulary and the WRAT-III Reading scores were entered in the first step. Reading span scores were entered in the second step to determine whether WM accounted for a significant increase in variance among language comprehension scores. For controls, these hierarchical regressions indicated that reading span performance did not account for any significant increase in variance over and above verbal IQ for any of the sentence types (all ps>0.20). For patients with schizophrenia, the hierarchical regressions also indicated that reading span performance did not account for any significant increase in variance, over and above verbal IQ, for either simple short, simple long, or subject relative sentences (all ps> 0.15). However, reading span performance did account for a significant increase in variance ${R_{cha}}^2 = 0.07$, $F(3, 23) = 6.86, p < 0.05$) for object-relative comprehension, over and above the amount of variance accounted for by verbal IQ.

3.6. Correlations between language comprehension and reading span and clinical symptoms

Another hypothesis of this study was that formal thought disorder and hallucinations would be correlated with language comprehension and WM deficits in schizophrenia. Thus, we examined the correlations between PANSS ratings of conceptual disorganization and hallucinations and: (1) reading span performance; (2) overall language comprehension accuracy (average of performance across the four sentence types); and (3) object-relative language comprehension accuracy. Contrary to our predictions, conceptual disorganization ratings were not significantly correlated with reading span performance ($r = 0.12$, p>0.5), overall language comprehension ($r = 0.24$, p>0.2), or object-relative comprehension ($r = 0.08$, p>0.5). Similarly, hallucination ratings were not significantly correlated with reading span performance ($r = 0.16$, p>0.4), overall language comprehension ($r = 0.24$, p>0.2), or object-relative comprehension ($r = 0.32$, p>0.1).

The above correlations were conducted with the PANNS ratings based on the general functioning of patients over the last week. However, as described under methods, we had also collected self-reports of hallucinations during task performance, which might be more strongly related to language comprehension and WM deficits. However, very few patients reported actively hallucinating during either the language comprehension (3/27) or reading span (4/27) tasks. When these participants were removed from the analyses, significant group differences remained for both language comprehension and reading span performance.

4. Discussion

The results of the current study demonstrated that for all participants, language comprehension was best for simple short sentences and worst for object-relative sentences with simple long and subject-relative sentences falling in between. Consistent with prior research, patients with schizophrenia demonstrated impaired language comprehension for all sentence types. However, the hypothesis that patients with schizophrenia would be differentially impaired on object-relative sentences compared to subject-relative and simple long sentences was only partially supported. Nonetheless, consistent with our hypotheses, WM capacity was strongly correlated with language comprehension performance in both patients with schizophrenia and controls. More importantly, WM capacity was more strongly correlated with language comprehension (particular for object-relative sentences) among patients with schizophrenia than among controls. Finally, we did not find the predicted relationship between language comprehension deficits and clinical symptoms. Each of these findings will be discussed in more detail below.

Consistent with the results of Condray et al. (1996), we found that patients with schizophrenia had impaired language comprehension as compared to controls. However, we had predicted that with a larger sample size than that studied by Condray et al. (1996), we would find that patients with schizophrenia would display differentially impaired performance on the object-relative sentences. This hypothesis was only minimally supported. Patients showed trends for a greater drop in accuracy and a greater slowing of RT between simple long and object relative sentences as compared to controls. However, the performance differences between subject-relative and object-relative sentences did not differ significantly between patients and controls. There are two possible reasons why our findings did not support our hypothesis. First, our findings may reflect the need for an even larger sample size. Compared to controls, patients did tend to show a greater performance difference between subject-relative and object-relative sentences, although the magnitude of this effect was relatively small (effect size = 0.34). Thus, it is possible that an even larger sample size would have made this trend a significant difference, although the sample size would need to be very large to detect an effect size of this magnitude at even a power of 70% (i.e., at least 60 participants in each group). Second, our findings may reflect that, in and of themselves, simple long and subject-relative sentences require significant WM resources among patients with schizophrenia. This hypothesis is consistent with the finding that, for both patients and controls, reading span performance was highly correlated with comprehension for simple long and subject-relative sentences as well as object-relative sentences. Since patients are significantly impaired even on simple long and subject-relative sentences, it may be difficult then to observe a further differential decline in ability with object-relative sentences.

Although we did not find a differential effect of syntactic complexity among patients with schizophrenia, we did find that comprehension among patients with schizophrenia was more impaired by increasing sentence length than was the comprehension of controls. In other words, increasing sentence length had a greater impact on language comprehension performance in patients as compared to controls. This particular finding has interesting implications. This study was the first to examine the influence of sentence length on language comprehension performance in patients with schizophrenia. There are at least two possible explanations as to why patients were more impaired on simple long as compared to simple short sentences. The first and less interesting explanation is that this simple reflect a generalized deficit. Even among controls, performance on simple long sentences was worse than performance on simple short sentences, and accuracy was very high for simple short sentences, raising the possibility of ceiling effects for simple short sentences. Thus, patients may have performed differentially worse on simple long sentences simply because they were more difficult. However, if these results simply reflected a generalized deficit, one might have expected to find the largest group differences on object-relative sentences, which were the most difficult for controls. Instead, the effect sizes (both accuracy and RT) for group differences on simple long sentences were as large or larger than the effect sizes for any other sentence type. Thus, a second possibility is that performance on simple long sentences are more impaired among patients than performance on simple short sentences because longer sentences place more of a demand on maintenance and/or manipulation resources in WM. The longer sentences clearly contained more information than the shorter sentences, and thus placed a greater demand on maintenance of information in WM. In addition, longer sentences require more semantic and syntactic processing, and thus may also have placed a greater demand on manipulation resources in WM.

The second goal of this study was to test the hypothesis that language comprehension deficits among patients with schizophrenia would be strongly associated with deficits in WM function. The results of the current study strongly supported this hypothesis. Consistent with past research (Condray et al., 1996; Just and Carpenter, 1992; Just et al., 1996; King and Just, 1991), we found a strong relationship between WM and language comprehension. In both patients and controls reading span performance was significantly positively correlated with performance on all sentence types. More importantly, reading span performance appeared to be more strongly associated with language comprehension performance among patients than controls. For example, the correlation between reading span performance and performance on object-relative sentences was significantly larger among patients that controls. Further, among patients, but not controls, reading span performance accounted for a significant increase in variance in object-relative performance over and above that accounted for by verbal IQ. It is interesting to note that the strongest relationships between reading span and comprehension performance found for patients were in the object-relative condition. For example, in addition to the results described above, reading span performance was significantly more correlated with object-relative performance than performance on any other sentences type among patients. These results are consistent with prior research suggesting that object-relative sentences place the greatest demand on WM resources during language comprehension. However, the fact that there were still significant correlations between span performance and comprehension on the other sentences types also suggest that individual differences in WM capacity influence comprehension of less syntactically complex constructions, although perhaps not to as great a degree. Taken together, the results of the correlational and regression analyses strongly support the hypothesis that language comprehension deficits among patients with schizophrenia are influenced by deficits in WM function.

Our findings of the relationships of clinical symptoms to language comprehension and WM deficits were not consistent with our expectations. First, higher ratings of formal thought disorder were not associated with either language comprehension deficits or WM deficits. These results were somewhat surprising, in that we and others have found a relationship between language production deficits and working memory deficits among individuals with schizophrenia in prior research (Cohen et al., 1999; Docherty et al., 1996). On the surface, this result suggests that disturbances in language production and language comprehension in patients with schizophrenia may not reflect that same underlying mechanisms. However, it should be noted that our measure of thought disorder relied on a single global item from the PANSS. It is possible that additional research using more detailed analyses of thought disorder (i.e., using a rating scale such as the Scale for the Assessment of Thought, Language, and Communication) might reveal evidence for a relationship between formal thought disorder and language comprehension and WM deficits.

Similarly, we did not find a relationship between the presence of hallucinations and deficits in either language comprehension or WM. This was true whether we examined ratings based on the past week of functioning or self-ratings during performance of each task. Although these results are not consistent with our original hypothesis, they do provide interesting data regarding the role of hallucination in cognitive task performance among patients with schizophrenia. As noted in the Introduction, researchers sometimes argue anecdotally that it is possible that hallucinations distract patients with schizophrenia and cause disturbances in their cognitive task performance. However, the current results directly contradict this hypothesis, in that few patients reported experiencing hallucinations during task performance, and task performance was still clearly impaired even among patients not reporting hallucinatory experiences.

In conclusion, the current study replicated previous findings of impaired working memory and language comprehension performance in patients with schizophrenia. Language comprehension deficits increased among patients with schizophrenia as sentence length increased, but patients were not differentially impaired on object relative as compared to subject relative sentences. However, we did find strong relationships between working memory performance and language comprehension performance among both patients with schizophrenia and controls. As predicted, this relationship was strongest for object-relative sentences, the sentence type argued to demand the most working memory resources (King and Just, 1991). Further, we found that working memory performance and object-relative sentence comprehension were more strongly correlated among patients than among controls. Taken together, these results suggest that working memory deficits may contribute to at least some aspects of language comprehension deficits among patients with schizophrenia. Contrary to our predictions, we did not find that either thought disorder or hallucinations were related to either working memory or language comprehension deficits among patients with schizophrenia. However, further research using potentially more sensitive measures of thought disorder is needed to further clarify the relationships among deficits in language comprehension, language production, and working memory in schizophrenia.

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