Working memory capacity predicts language comprehension in schizophrenic patients

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Abstract

The association between language comprehension and working memory capacity was evaluated in 25 male DSM-III-R schizophrenic patients (14 inpatients; 11 outpatients), and in 11 male normal controls (no lifetime DSM-III-R disorder). Patients and controls did not differ significantly on age and education. Language comprehension was examined as a function of two types of processing demand: grammatical complexity (complex versus simple sentences) and presentation rate (accelerated versus conversational). Schizophrenic patients showed significantly reduced language comprehension and decreased working memory capacity for language, compared with controls. Patients showed general difficulty in comprehending accurately, rather than exhibiting problems with specific grammatical structures. Subject groups were highly accurate and did not differ in their ability to perceive the individual words in sentences presented at the accelerated rate (intelligibility). Presentation rate and grammatical complexity affected comprehension accuracy in all groups, however, with increases in rate and complexity producing decreases in understanding. Of most importance, theoretically, is the finding that working memory capacity predicted language comprehension accuracy in both schizophrenic patients and normal controls. Results suggest that language comprehension deficits in schizophrenic patients may involve a general dysfunction that is associated with working memory capacity for language.

Keywords: Working memory capacity; Language comprehension; (Schizophrenia)

1. Introduction

Impaired language comprehension has been reliably observed in individuals diagnosed with schizophrenia and in their non-psychotic relatives (Thomas and Huff, 1971; Purisch et al., 1978; Green et al., 1979; Faber and Reichstein, 1981; Hallet and Green, 1983; Kugler, 1983; Shelly and

Goldstein, 1983; Morice and McNicol, 1985; Condray and Steinhauer, 1992; Condray et al., 1992, Condray et al., in press). The processing demands and cognitive capacities that are responsible for this language dysfunction, however, have not been determined.

Grammatical complexity and presentation rate are strong candidates for the processing demands that produce disturbances in comprehension for schizophrenics. In non-clinical populations, comprehension accuracy is a function of grammatical
complexity, with decreases in understanding observed for complex sentences (for reviews, see: Just and Carpenter, 1992; MacDonald et al., 1992). Comprehension processes are also influenced by presentation rate. In non-schizophrenic individuals, comprehension accuracy declines systematically as presentation rates increase above the conversational rate of 250–300 words per minute, although performance above chance or guessing level has been observed for speech accelerated to twice that conversational rate (Fairbanks et al., 1957; Carver, 1982; Condray, 1987; for a review of the early literature see: Foulke and Sticht, 1969; Overmann, 1971; Wingfield, 1975; Hausfeld, 1981; Wallace, 1983). Schizophrenic patients are characterized by abnormalities in responding to sequential stimuli presented at rapid rates (see Braff and Geyer, 1990). This disturbance may be important for their understanding of spoken language, which requires the processing of individual words presented sequentially within a semantic context (Marslen-Wilson, 1975). The impaired language comprehension associated with schizophrenia may therefore be due to disturbances in the processing of both grammatical complexity and sequential, time-linked stimuli.

Individual differences in comprehension performance have been documented for non-clinical populations (Perfetti and Goldman, 1976; Perfetti and Lesgold, 1978; Daneman and Carpenter, 1980, Daneman and Carpenter, 1983; King and Just, 1991; Just and Carpenter, 1992). The capacity theory of language comprehension proposed by Just and Carpenter (1992) provides an account for these individual differences. In this model, working memory capacity drives the storage and processing of information. Reductions in this memory capacity produce inefficiencies in comprehension. Supportive evidence is provided by studies of college students in which increased reading time and reduced understanding were associated with limited working memory capacity for language. Individuals with reduced working memory capacity were least efficient in the processing of complex sentences (Daneman and Carpenter, 1980, Daneman and Carpenter, 1983; King and Just, 1991; Just and Carpenter, 1992; MacDonald et al., 1992). Language comprehension is therefore restricted by working memory capacity in non-schizophrenic individuals. Although recent evidence suggests that schizophrenic patients may be impaired in spatial working memory (Park and Holzman, 1992), the association between language comprehension and working memory for language has not been examined in this patient group.

In the present study, we investigated whether the capacity theory of language comprehension (Just and Carpenter, 1992) can provide an account for the comprehension disturbances that are associated with schizophrenia. We also examined the effects of two types of processing demand on the auditory language comprehension of schizophrenic patients: grammatical complexity (complex versus simple sentences) and presentation rate (accelerated versus conversational). The presentation rate procedure was adapted from previous work by Wallace (Wallace and Koury, 1981; Wallace, 1983) on the intelligibility and comprehension of accelerated prose. Working memory capacity for language was evaluated using the Sentence Span Test (Leahy, 1987), which is based on the Reading Span task developed by Daneman and Carpenter (1980). These language and memory functions were evaluated in schizophrenic patients and normal controls. The following questions were addressed: (1) Are schizophrenic patients characterized by reduced comprehension accuracy for grammatically complex sentences presented at an accelerated rate, compared with normal controls? (2) Are schizophrenic patients characterized by decreased working memory capacity for language, compared with controls? (3) Is working memory capacity for language associated with language comprehension performance in schizophrenic patients?

2. Methods

2.1. Subject selection criteria

Subjects included 25 males diagnosed with DSM-III-R schizophrenia (American Psychiatric Association, 1989), and 11 male normal controls. At the time of testing, 14 patients were hospitalized
and 11 were outpatients. Controls were diagnosed as no lifetime DSM-III-R Axis I or Axis II disorder. Diagnoses were based on the results of standardized semi-structured clinical interviews. Axis I disorders were evaluated using the Structured Clinical Interview for DSM-III-R (SCID) (Spitzer et al., 1989). Axis II disorders were assessed in the controls using the Personality Disorder Examination (PDE) (Loranger, 1988). In our research program, inter-rater agreement is high for both Axis I interviews (mean point-by-point, 89%; mean diagnostic, 94%) and Axis II interviews ($\kappa = 0.81$ for the diagnoses most pertinent to our research focus, the schizophrenia-spectrum personality disorders). Patients were recruited from inpatient units and the outpatient clinic at Highland Drive VA Medical Center. Normal controls were recruited through media advertisements. Seven of the 36 individuals who participated in the present study also participated in earlier cognitive processing studies conducted in our research program.

Signed informed consent was obtained from all subjects prior to participation in the diagnostic interviews and the language processing protocol. Controls and outpatients were reimbursed for participation.

General selection criteria included: American English as the first language; 8th grade reading level as measured with the Wide Range Achievement Test (WRAT); WAIS-R Full Scale IQ $\geq 75$; no history of neurological disorder (e.g., diagnosed epilepsy, periods of unconsciousness $\geq 30$ min); no major Axis III diagnosis (e.g., diabetes, heart disease). Audiometric screening was conducted for all subjects using 500, 1000, 2000, and 4000 Hz at 40 dB.

2.2. Language comprehension procedures

Two types of processing demand were varied. Syntactic demand was varied by contrasting grammatically simple and complex sentences, while holding item load constant (all sentences contained an equal number of words). Temporal demand was varied by contrasting a conversational rate and an accelerated rate. Sentences and questions were presented in the auditory modality to maintain consistency with our earlier work (Condray and Steinhauer, 1992; Condray et al., 1992; Condray et al., in press).

2.2.1. Grammatical complexity

Three types of grammatical constructions were presented: 16 center-embedded object-relative sentences; 16 center-embedded subject-relative sentences; and 16 simple sentences. All sentences were 9 words in length. The 48 sentences included items used by King and Just (1991, p. 600), and additional items developed for this study. Examples of the complex center-embedded sentences are: object-relative – “The reporter that the senator attacked admitted the error”; and subject-relative – “The accountant that sued the lawyer read the paper.”

Of the two types of center-embedded constructions, object-relative sentences produce greater processing difficulty (Just and Carpenter, 1992). The initial nouns in these sentences serve as agent-actors in the main clause and as objects of the embedded relative clause. These dual syntactic roles require a perspective shift (see Bever, 1970; King and Just, 1991; Just and Carpenter, 1992). In the example above, the reporter is both the agent-actor who admits to an error, and the object of the senator’s attack. In contrast, the initial noun in subject-relative sentences serves as the agent-actor in both the main and relative clauses, which does not require a perspective shift. Simple sentences were in the active voice, and conformed to the word order most commonly observed in the English language (Subject phrase–Verb phrase–Object phrase) (Solso, 1988): “The curator purchased the antique book for the museum.” Simple sentences were control items to test assumptions regarding the processing demand produced by grammatical complexity.

2.2.2. Comprehension questions

Three questions immediately followed each sentence to assess understanding of the facts and logical relationships specified by the syntax. For example, recognizing that the initial noun has dual roles is critical to understanding object-relative sentences. In “The reporter that the senator attacked admitted the error”, it is necessary to understand that the initial noun is both agent-actor in the main clause (“The reporter ... admitted
the error”), and object of the action in the subordinate relative clause (“...that the senator attacked.”). Questions assessing comprehension of this sentence were: (1) Who admitted the error? (2) Who was attacked? (3) Who did the attacking? Scoring was straightforward with a total possible of 144 correct (48 sentences × 3 questions for each sentence).

2.2.3. Presentation rate

Sentences were presented in the auditory modality at two rates: conversational and accelerated. Sentences and questions were recorded by a female native Western Pennsylvania speaker using her typical conversational rate. The accelerated presentation rate was accomplished using a frequency-controlled technique, which produces superior intelligibility when compared with frequency-shifted techniques (Wallace and Koury, 1981). In the present study, the frequency-controlled technique increased the playback speed to twice that of the conversational rate without producing a linear increase in the frequency or pitch of the speech record. A Media Vision sound board was used to produce this accelerated rate. The sound board recorded 16-Bit samples at 44.1 kHz. The software application sampled the speech record digitally and deleted 50% of the samples.

2.2.4. Procedure

The Media Vision sound board in a 486 based computer was used to present the sentence and question stimuli. Subjects listened to the language stimuli through AKG Acoustics K340 stereo headphones. Prior to the test sentences, a separate set of 16 warm-up sentences was presented at the accelerated rate. The task was to repeat each practice sentence verbatim. Warm-up sentences were simple sentence constructions, and were drawn from previous work on the intelligibility of accelerated speech (Wallace and Koury, 1981). The purposes of this practice set were to accommodate subjects to the rapid rate, and to obtain an estimate of intelligibility for this presentation rate (proportion of words repeated correctly). Previous work showed that college students accommodated to frequency-controlled speech after exposure to 16 sentences (Wallace and Koury, 1981). The 48 test sentences and comprehension questions immediately followed the warm-up sentences.

Each subject was presented all 48 sentences. Each of the 3 sentence types was presented under each of the two presentation rates, with 8 sentences in each of the 6 sentence type × presentation rate combinations. Sentences were assigned randomly to the two presentation rate conditions. The 6-sentence type × presentation rate combinations were distributed evenly across the testing session in 8 blocks of 6 sentences each. Each block included one presentation of each sentence type × presentation rate condition. Assignment of sentences to blocks and presentation order of conditions within each block were also randomized. Comprehension questions were presented at the conversational rate, and responses were recorded by a research technician.

2.3. Working memory capacity for language

Working memory capacity for language was evaluated using a modified auditory version of the Sentence Span Test developed by Leahy (1987) for use with clinical and general population individuals. The Sentence Span Test was based on the Reading Span task developed earlier by Daneman and Carpenter (1980) for use with college students. The Sentence Span Test measures memory for the final words in serial sentences that are presented in sets of sentences that gradually increase in size (2 sets of 2 sentences each; 3 sets of 3 sentences each; 3 sets of 4 sentences; 3 sets of 5 sentences; 3 sets of 6 sentences; 3 sets of 7 sentences; and 1 set of 8 sentences). Sentence Span is the largest set size for which all final words are recalled correctly. Subjects were advised that they would hear a series of sentences after which they would be asked to recall the final word of each sentence in each set. They were advised to expect that the number of sentences would increase as the test progressed.

2.4. Response measures

For the language comprehension task, the response measure was the number of correct responses to questions about the logical relation-
ships described in each sentence (total possible = 144). For the intelligibility task, the response measure was the number of words repeated correctly for the warm-up sentences (total possible = 100 words). For the evaluation of working memory capacity, the response measure was the largest set size on the Sentence Span Test (total possible = 8).

3. Results

Data were analyzed using analysis of variance (ANOVA) and simple linear regression. Planned comparisons were conducted using the Bonferroni test and interaction contrasts (Keppel, 1991). Subject groups differed for intelligence, and two analytic strategies were used to address this difference. In the first approach, analyses of covariance (ANCOVAs) were performed for all primary response measures with intelligence entered as the covariate. The second strategy involved re-computing the primary analyses of variance (ANOVA) after excluding individuals with WAIS-R Full-scale IQ <85 and >115 (+1 SD from the mean of 100), and combining the remaining inpatients and outpatients to form a single group, which was then compared with the remaining normal controls. Post hoc correlations were also conducted to explore the associations between patients’ language performance, their clinical characteristics, and dose of antipsychotic and anticholinergic medication. Non-parametric correlation (Spearman’s ρ) was used for these analyses to correct for extreme scores, and the standard significance level of ρ = 0.05 was adjusted using the Bonferroni correction for two families of variables (Grove and Andreasen, 1982): the two language measures and 3 measures of clinical course = 6 comparisons (ρ = 0.008); the two language measures with dose of antipsychotic medication, and working memory capacity with dose of anticholinergic medication = 3 comparisons (ρ = 0.02).

3.1. Subject characteristics

Table 1 summarizes the demographic characteristics, and intelligence and memory functioning of patients and controls. Age and eduction did not differ significantly between the 3 groups. Groups were significantly different for WAIS-R Full scale IQ (F_{2,33} = 11.37, p < 0.001), and the effects of this variable on the primary response measures were evaluated using the two strategies described above.

Table 2 presents summary data regarding patients’ diagnostic subtype and course of illness. Two patients (1 inpatient; 1 outpatient) were additionally diagnosed with a current DSM-III-R Substance Use Disorder (Alcohol). Inpatients and outpatients did not differ significantly for age at first hospitalization (t_{23} < 1, p > 0.50), or for duration of illness (t_{23} < 1, p > 0.50). The greater number of hospitalizations for inpatients, however, reached trend significance (t_{23} = 1.83, p < 0.10).

Twenty-two patients were receiving oral antipsychotic medication at the time of study participation, and the mean daily dose in chlorpromazine equivalents (Appleton and Davis, 1980) is also presented in Table 2. The inpatient and outpatient groups did not differ significantly for oral dose of antipsychotic medication (t_{20} < 1, p > 0.50). Three patients (1 inpatient; 2 outpatients) were receiving injections of haloperidol (haloperidol decanoate, 91.7 ± 38.2 mg/month). Of the 25 patients, 7 outpatients and 6 inpatients (n=13) were also receiving anticholinergic medication (Cogentin, 2.7 ± 1.1 mg/day).

3.2. Intelligibility of accelerated presentation rate

Table 3 shows the mean number of words repeated verbatim in the intelligibility task for each group. Groups did not differ significantly for the number of words repeated correctly for the sentences presented at the accelerated rate (F_{2,33} < 1, p = 0.46). Thus, a high level of intelligibility for the rapid presentation rate was observed for both patients and normals.

3.3. Language comprehension accuracy

Table 3 also shows the mean number of total correct responses in the comprehension task for each group. Mean number of correct responses for each group under each sentence type by presentation rate condition are also shown. Correct responses were analyzed using mixed factor
Table 1
Characteristics of study participants

<table>
<thead>
<tr>
<th></th>
<th>Schizophrenics</th>
<th>Normal controls(n = 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Outpatients(n = 11)</td>
<td>Inpatients(n = 14)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>42.0 (9.2)</td>
<td>41.6 (7.0)</td>
</tr>
<tr>
<td>Education (years)</td>
<td>13.5 (2.4)</td>
<td>12.1 (1.9)</td>
</tr>
<tr>
<td>Intelligence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAIS-R FIQ</td>
<td>96.1 (10.8)</td>
<td>86.9 (8.6)</td>
</tr>
<tr>
<td>Short-term memory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAIS-R Forward Digit</td>
<td>7.5 (1.4)</td>
<td>6.4 (1.6)</td>
</tr>
<tr>
<td>Working memory capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sentence Span Test</td>
<td>2.4 (1.0)</td>
<td>1.8 (1.1)</td>
</tr>
</tbody>
</table>

Values are means. Standard errors are given in parentheses.

Table 2
Clinical characteristics of schizophrenic patients

<table>
<thead>
<tr>
<th></th>
<th>Outpatients (n = 11)</th>
<th>Inpatients (n = 14)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean (SD)</td>
<td>mean (SD)</td>
</tr>
<tr>
<td>Age at first hospitalization (years)</td>
<td>24.9 (5.8)</td>
<td>24.1 (5.4)</td>
</tr>
<tr>
<td>Duration of illness (years)</td>
<td>20.0 (8.4)</td>
<td>18.4 (5.0)</td>
</tr>
<tr>
<td>Number of psychiatric hospitalizations</td>
<td>8.5 (6.9)</td>
<td>13.6 (7.0)</td>
</tr>
<tr>
<td>Oral antipsychotic medication in chlorpromazine equivalents (mg/day)</td>
<td>463.7 (214.4)(n = 9)</td>
<td>539.2 (316.6)(n = 13)</td>
</tr>
<tr>
<td>DSM-III-R diagnosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schizophrenia, undifferentiated</td>
<td>3 (27.3%)</td>
<td>4 (28.6%)</td>
</tr>
<tr>
<td>Schizophrenia, paranoid</td>
<td>2 (18.2%)</td>
<td>3 (21.4%)</td>
</tr>
<tr>
<td>Schizophrenia, disorganized</td>
<td>0 (0%)</td>
<td>1 (7.1%)</td>
</tr>
<tr>
<td>Schizophrenia, residual</td>
<td>5 (45.5%)</td>
<td>4 (28.6%)</td>
</tr>
<tr>
<td>Schizoaffective</td>
<td>1 (9%)</td>
<td>2 (14.3%)</td>
</tr>
</tbody>
</table>

repeated-measures ANOVA. Results determined highly significant main effects of diagnostic group ($F_{2,33} = 10.21$, $p = 0.0004$), grammatical complexity ($F_{2,66} = 12.44$, $p < 0.001$ with Greenhouse–Geisser correction), and presentation rate ($F_{1,33} = 5.34$, $p = 0.03$). Comprehension accuracy in schizophrenic inpatients was significantly reduced under all conditions, compared with normal controls (Bonferroni test, $p < 0.01$). The performance of outpatients was intermediate between that of inpatients and controls, with the difference between the two patient groups reaching trend significance (Bonferroni test, $p = 0.10$). The grammatical complexity × presentation rate interaction was also highly significant ($F_{2,66} = 7.33$, $p = 0.002$ with Greenhouse–Geisser correction). Fig. 1 shows this interaction. Interaction contrasts (Keppel, 1991) determined comprehension accuracy for the object-relative sentences under both presentation rates was significantly reduced, as compared with both the subject-relative sentences ($F_{1,33} = 11.18$, $p < 0.01$) and the simple sentences ($F_{1,33} = 4.61$, $p < 0.05$). Differences in the comprehension accuracy for the subject-relative and simple sentences under the two rates just missed significance ($F_{1,33} = 4.01$, $p = 0.0535$). Increased grammatical complexity thus produced decreased comprehension accuracy for all groups at both presentation rates, with the greatest reduction in accuracy observed for the complex object-relative sentences at the rapid rate.

The potential influence of intelligence on com-
Table 3  
Language performance in schizophrenic patients and normal controls

<table>
<thead>
<tr>
<th></th>
<th>Outpatients (n=11)</th>
<th>Inpatients (n=14)</th>
<th>Controls (n=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intelligibility for accelerated rate (total correct possible = 100)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total correct</td>
<td>98.2 (1.7)</td>
<td>94.9 (13.4)</td>
<td>98.8 (1.3)</td>
</tr>
<tr>
<td><strong>Language comprehension accuracy (total correct possible = 144)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total correct</td>
<td>109.8 (22.5)</td>
<td>92.1 (21.7)</td>
<td>127.5 (11.8)</td>
</tr>
<tr>
<td><strong>Correct responses under each grammatical complexity × presentation rate condition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conversational rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple sentences</td>
<td>19.0 (3.2)</td>
<td>16.2 (3.7)</td>
<td>22.0 (1.5)</td>
</tr>
<tr>
<td>Complex subject-relative sentences</td>
<td>19.5 (4.8)</td>
<td>16.1 (3.7)</td>
<td>21.6 (2.1)</td>
</tr>
<tr>
<td>Complex object-relative sentences</td>
<td>18.0 (5.0)</td>
<td>15.2 (5.0)</td>
<td>21.1 (2.8)</td>
</tr>
<tr>
<td>Accelerated rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple sentences</td>
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<td>19.5 (3.7)</td>
</tr>
</tbody>
</table>

Values are means. Standard deviations are shown in parentheses.

![Rate of Speech](Image)

Fig. 1. Comprehension accuracy as a function of grammatical complexity and presentation rate.

prehension accuracy was evaluated using the analytic strategies described above. First, results were not altered when WAIS-R Full scale IQ was entered as a covariate. The second strategy involved re-computing the analysis of variance after excluding individuals with WAIS-R FIQ <85 and >115 (±1 SD from the mean of 100). The remaining inpatients and outpatients were combined to form a single patient group (n=15: 6 inpatients; 9 outpatients), which was then compared with the remaining normal controls (n=9). WAIS-R FIQ did not differ significantly between these two groups ($F_{1,22} = 2.37, p >0.10$). The main effect of diagnostic group on comprehension accuracy remained statistically significant ($F_{1,22} = 6.62, p =0.02$), and the grammatical complexity × presentation rate interaction was also again highly significant ($F_{2,44} = 6.70, p =0.007$ with Greenhouse–Geisser correction).

3.4. Working memory capacity for language

The average scores of each group on the measure of working memory capacity for language (Sentence Span Test) are presented in Table 1. Groups were significantly different for working memory capacity for language ($F_{2,33} = 13.29, p =0.0001$). The Sentence Span performance of controls was significantly greater than for inpatients (Bonferroni test, $p<0.01$) and outpatients (Bonferroni test, $p<0.01$). Working memory capacity in the two patient groups did not differ significantly. Results were not altered when WAIS-R FIQ was entered as a covariate. In addition, Sentence Span performance remained significantly different between patients and controls ($F_{1,22} = 16.50, p <0.001$) after excluding those individuals with WAIS-R FIQ scores <85 and >115.

In contrast to the findings for working memory capacity, patients and controls did not differ for the longest forward digit span from the WAIS-R Digit Span subtest ($F_{2,33} = 1.43, p >0.10$). Group
means for this test are presented in Table 1. WAIS-R Forward Digit Span provides a measure of short-term memory size or storage capacity (Ryan, 1990). This task is low in linguistic load due to the relative absence of semantic and syntactic contexts. Inspection of the group means for this test shows they are consistent with the prototype of short-term memory storage capacity, which consists of $7 \pm 2$ units of information (Miller, 1956).

In summary, schizophrenic patients and normal controls were significantly different in their working memory capacity for language, but they did not differ in the size of their short-term memory storage.

3.5. Association between working memory capacity and language comprehension in schizophrenic patients

Linear regression analysis of performance on the Sentence Span Test (predictor variable) and the language comprehension task (total correct) showed a highly significant association ($r = 0.68$, $F_{1,34} = 28.67$, $p < 0.001$) for patients and controls combined ($n = 36$). Fig. 2 shows the scatter diagram for this association. A significant linear association was also observed between Sentence Span performance and comprehension accuracy ($r = 0.57$, $F_{1,23} = 11.05$, $p < 0.01$) when only the data of patients were analyzed ($n = 25$). Fig. 3 shows the scatter diagram for this relationship. Our initial data therefore indicate a highly significant linear relationship between language comprehension accuracy and working memory capacity for language in both patients and controls.

Comprehension accuracy and short-term memory size or storage capacity were also associated. Linear regression analysis of WAIS-R Forward Digit Span (predictor) and language comprehension accuracy showed a significant association ($r = 0.35$, $F_{1,34} = 4.90$, $p < 0.05$) for patients and controls combined ($n = 36$). A significant linear association was also observed between Forward Digit Span and comprehension ($r = 0.47$, $F_{1,23} = 6.68$, $p < 0.025$) when only the data of patients were evaluated ($n = 25$).

The possibility that the accelerated presentation rate may place a greater demand on working memory was explored. The relationships between Sentence Span performance and comprehension accuracy for each of the 6 sentence type $\times$ presentation rate conditions were evaluated using the combined data for patients and controls ($n = 36$). These associations were all statistically significant (adjusted $p = 0.008$), and ranged from $\rho = 0.43$ to 0.60. Moreover, the strength of the associations between Sentence Span performance and accuracy for the various sentence types was similar under both presentation rates: (1) object-relative sentences at the conversational ($\rho_{34} = 0.47$) and accelerated ($\rho_{34} = 0.43$) rates; (2)
subject-relative sentences at the conversational ($\rho_{34} = 0.56$) and accelerated ($\rho_{34} = 0.60$) rates; (3) simple sentences at the conversational ($\rho_{34} = 0.59$) and accelerated ($\rho_{34} = 0.54$) rates.

In summary, a highly significant linear relationship was observed between language comprehension accuracy and working memory capacity for language in both patients and controls. A weaker, but statistically significant association was obtained between comprehension accuracy and short-term memory size.

3.6. Association between language functions and clinical profile

Language comprehension (total correct) was not significantly associated with age at first hospitalization ($\rho_{23} = 0.04$, $p > 0.50$), or duration of illness ($\rho_{23} = 0.24$, $p > 0.10$). The correlation between comprehension accuracy and number of hospitalizations just missed trend significance ($\rho_{23} = 0.42$, $p < 0.05$). Working memory capacity was not significantly associated with the measures of clinical course: age at first hospitalization ($\rho_{23} = 0.21$, $p > 0.10$); duration of illness ($\rho_{23} = 0.07$, $p > 0.50$); number of hospitalizations ($\rho_{23} = 0.06$, $p > 0.50$).

The effects of current Substance Use Disorder on the performance of the language and memory tasks were evaluated by excluding the two patients who were diagnosed with current Alcohol disorders (1 inpatient; 1 outpatient), and re-computing the analyses of variance. Results were not altered when those two individuals were excluded from the analyses.

3.7. Associations between language functions and pharmacologic treatment

The correlation between oral antipsychotic medication and comprehension accuracy (total correct) just missed trend significance ($\rho_{20} = -0.43$, $p > 0.10$). Working memory capacity was not significantly associated with either dose of antipsychotic medication ($\rho_{20} = -0.26$, $p > 0.10$), or with dose of anticholinergic medication ($\rho_{11} = 0.13$, $p > 0.50$).

3.8. Effect size and power

Effect size and power ($\alpha = 0.05$, two-tailed) were determined for the primary response measures in the present study. Based on our sample size ($n = 36$), the observed effect sizes for the group comparisons were large (Cohen, 1988). For the comparison of the 3 diagnostic groups on the language comprehension task (total correct), a large effect size ($F = 0.76$) was obtained with a power of 0.98. For the comparison of the 3 diagnostic groups on the test of working memory capacity for language (Sentence Span Test), a large effect size ($F = 0.86$) was also observed with a power of 0.996. For the association between working memory capacity for language (predictor) and comprehension accuracy in patients and controls combined ($n = 36$), a large effect size (0.84) was obtained with a power of 1.00. For the association between working memory capacity (predictor) and comprehension accuracy in patients only ($n = 25$), a large effect size (0.48) was also observed with a power of 0.92. These effect size and power analyses suggest that the results based on the primary response measures are reliable.

4. Discussion

Schizophrenic inpatients showed significantly reduced language comprehension accuracy, compared with normal controls. The comprehension performance of schizophrenic outpatients was intermediate between that of inpatients and outpatients. Working memory capacity for language was significantly reduced in both inpatients and outpatients, compared with controls. The processing demands exerted by grammatical complexity and the accelerated rate produced reductions in comprehension accuracy for all groups. An important control variable in this study was the measure of intelligibility for the accelerated rate. Because groups were highly accurate and did not differ in their intelligibility at the accelerated rate, their reduced comprehension under this condition cannot be accounted for by a failure to perceive the individual words. Patients showed general difficulty in comprehending accurately, rather than
exhibiting problems with specific grammatical structures or with the accelerated presentation rate. Of most importance, theoretically, is our finding that working memory capacity for language predicted language comprehension accuracy in both schizophrenic patients and normal controls.

A caveat is necessary regarding the preliminary nature of our initial findings. Although the effect sizes and power suggest that these results are reliable, replication with a larger sample is required. In particular, the finding of significant effects of diagnostic group and language task, but an absence of a group x language task interaction warrants further investigation. There are at least two possible reasons for this pattern of results. The first concerns the modest sample size. The group x language task interaction may have been suppressed due to a combination of the small control group, and the highly variable performance that is typical of schizophrenic patients. A second possibility is that schizophrenic patients may indeed be characterized by a general dysfunction in sentence comprehension, rather than a deficit in understanding specific grammatical structures. This pattern of results is generally consistent with earlier findings based on college students (MacDonald et al., 1992) and children (Perfetti and Goldman, 1976; Perfetti and Lesgold, 1978), who were classified on the basis of working memory capacity and reading skill, respectively. In those studies, group differences were observed for comprehension and recall accuracy, but all groups showed decreases in accuracy when the processing demand was increased by varying grammatical structure (i.e., no significant group x grammatical structure interaction) (cf. King and Just, 1991). Thus, previous findings with different subject populations parallel our finding with schizophrenic patients and controls. The early discussion by Perfetti and Lesgold (1978) of this pattern included a suggestion, initially made by Jarvella (1971), that syntactic boundaries supply cues to discontinue short-term memory storage, and that this process may occur uniformly across individuals regardless of their working memory capacity.

An additional qualification concerns the possibility that gender may significantly influence performance on the language and memory tests in this study. This issue is not straightforward and will require empirical evaluation. The earlier evidence that showed gender differences for the verbal abilities of general population subjects (Maccoby and Jacklin, 1974) has been challenged recently. Based on a meta-analysis of 165 studies, Hyde and Linn (1988) concluded that the reported gender differences in verbal ability represent a mean effect size that is too small to be considered significant. Recent comparisons between male and female schizophrenic patients, however, suggest that both gender and course of illness may significantly influence verbal memory performance in this patient population (Haas et al., 1991). Statements regarding the findings of our present study should therefore be restricted to male schizophrenic patients with a clinical course that includes recurrent hospitalizations.

The relationship observed between patients’ language comprehension performance and their clinical status suggests that clinical severity may influence comprehension processes. In contrast, working memory capacity for language was not associated with patients’ hospitalization status. The comprehension of outpatients was more accurate than that of inpatients, but these two patient groups did not differ for working memory capacity. The marginal correlation obtained between comprehension accuracy and number of psychiatric hospitalizations is also somewhat supportive of a potential effect of clinical status on comprehension functioning. This possibility should be examined further.

Our data suggest that the Just and Carpenter (1992) capacity theory of language comprehension can provide an account for the dysfunction in language comprehension that is associated with schizophrenia. In the present study, working memory capacity predicted language comprehension performance in both schizophrenic patients and normal controls. Careful attention, however, must be directed to interpretive issues that bear on the complex nature of memory function. Our delineation of working memory as ‘working memory capacity for language’ reflects the growing recognition that it is important to ‘fractionate’ memory systems conceptually and empirically (see
Desimone, 1992, p. 245). Moreover, recent studies of working memory involve various performance tasks (e.g., spatial oculomotor, linguistic) and different levels of analysis (e.g., behavioral, neurochemical, and anatomical). It is therefore important to specify the working memory function being examined. Our restriction of this memory function to a language-based capacity follows that of Just and Carpenter (1992), and is compatible with the argument of Nadel (1992) that memory systems can be meaningfully distinguished by the kind of information processed (e.g., 'content-driven'). In the present study, 'working memory for language' is regarded as the capacity to maintain representations of the words in a sentence while the logical relationships specified by the semantic and syntactic information are being determined.

Most contemporary definitions of working memory describe a general function that enables brief maintenance of information so that it may be used in the performance of some task (Baddeley, 1986; Baddeley, 1992; Funahashi et al., 1989; Sawaguchi and Goldman-Rakic, 1991; Just and Carpenter, 1992; Luciana et al., 1992; Moscovitch, 1992, Nadel, 1992). Both storage and active processing components are presumed to be involved (see Perfetti and Lesgold, 1978; Daneman and Carpenter, 1980; Baddeley, 1986; Baddeley, 1992; Just and Carpenter, 1992). Thus, a functional system is commonly postulated, which includes a structural component devoted to momentary storage, and processing components allocated to using the contents of that storage to perform work. In our present study, schizophrenic patients and normal controls did not differ with respect to short-term memory size, as measured by the WAIS-R Forward Digit Span. In contrast, patients showed significantly reduced working memory capacity, as measured by the Sentence Span Test, compared with controls. Moreover, significant associations were observed between language comprehension, and both short-term memory size and working memory capacity. This pattern of results suggests that working memory capacity may be an important locus of disturbance in the comprehension processes of schizophrenic patients.

The objective of this study was to determine the influence of selected processing demands and cognitive capacities on the language comprehension performance of schizophrenic patients. The methodology developed to accomplish this objective represents an integration of investigative strategies used in cognitive psychology, psycholinguistics, and neuropsychology. Results indicated that schizophrenic patients experienced general difficulty in comprehending accurately, rather than exhibiting problems with specific grammatical structures, or with the accelerated presentation rate. Our finding that working memory capacity predicted language comprehension accuracy in both schizophrenic patients and normal controls is of theoretical importance. This pattern of results suggests that schizophrenic patients may be characterized by a general dysfunction in language comprehension that is associated with working memory capacity for language.

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