The Language System in Schizophrenia: Effects of Capacity and Linguistic Structure

by Ruth Condray, Stuart R. Steinhauser, Daniel P. van Kammen, and Annette Kasparek

Abstract

Dysfunction in receptive language processes has been reliably observed in individuals diagnosed with schizophrenia and their first degree family members. The present study addressed the unresolved issue of whether receptive syntax is intact in schizophrenia. The principal question concerned whether comprehension dysfunction in schizophrenia involves a disturbance in the processing of syntactic structure, a susceptibility to demands placed on temporal auditory processing, or some combination of these two general factors. Comprehension accuracy was compared between 32 males diagnosed with schizophrenia and 22 males with no lifetime diagnosis of psychiatric disorder. Accuracy was examined for responses to Who questions (“Who did X?” and “Who was done X?”) about information in the sentential clauses (main vs. relative) of two types of relative sentences (subject-relatives vs. object-relatives) that were presented aurally at conversational and accelerated rates. The relationship between cognitive functions and comprehension accuracy was also tested. Results showed highly significant effects of diagnosis, syntactic structure, and temporal demand. Patients were characterized by reduced overall comprehension accuracy compared to controls. More important, patients and controls differed in their patterns of accuracy across the different types of syntactic structure. Finally, cognitive functions predicted but did not completely account for comprehension accuracy. Findings suggest the hypothesis that receptive syntax is disrupted in schizophrenia, and this dysfunction may not be entirely explained by compromised general cognitive ability. Keywords: Schizophrenia, receptive syntax, relativization, word order. Schizophrenia Bulletin, 28(3):475–490, 2002.

The language system has been assigned a central role in the etiology (Crow 1997) and clinical manifestation (Bleuler 1911; Kraepelin 1919; American Psychiatric Association 2000) of schizophrenia. Dysfunction in both receptive language and speech production has been described for schizophrenia patients and their biological relatives. Although speech production abnormalities are more obvious as clinical signs and have been more commonly targeted for empirical study (for recent reviews, see Docherty et al. 1999; Docherty et al. 2000), dysfunction in receptive language has also been consistently observed for patients and their first degree family members, including disturbances in the perception of words presented aurally at various levels of intensity (Bull and Venables 1974) and background noise (DeLisi et al. 1997; Shedlack et al. 1997); and reduced comprehension accuracy for information in sentences (Thomas and Huff 1971; Faber and Reichstein 1981; Morice and McNicol 1985; Condray et al. 1992, 1995, 1996; Landre et al. 1992; Goldberg et al. 1998). The collective findings to date are therefore consistent with the hypothesis that integrity of the language system may reflect biological risk for the disorder. However, detailed analyses of complex behavioral phenotypes are required to provide a solid empirical basis for selecting variables for genetic studies of schizophrenia (for discussion about the importance of this issue for behavior genetics in general, see Pennington and Smith 1997). If receptive language disturbance is to serve as an informative phenotype in behavior genetics studies of schizophrenia, detailed analyses of its underlying functional components are essential.

An important unresolved question is whether receptive syntax is intact in schizophrenia. Attempts to address this issue have involved a variety of strategies, including comparisons of schizophrenia patients and control groups on aphasia and neuropsychology test batteries, examinations of patients’ sensitivity to syntactic structure, and

Send reprint requests to Dr. R. Condray, Western Psychiatric Institute and Clinic, Department of Psychiatry, University of Pittsburgh School of Medicine, 3811 O’Hara Street, Pittsburgh, PA 15213; e-mail: condrayr@mxs.upmc.edu.
evaluations of their accuracy in responding to complex syntactic constructions. The findings from these empirical efforts are not conclusive, although clear trends are present. Schizophrenia patients appear sensitive to syntactic boundaries in sentences (embedded click paradigm developed by Fodor and Bever 1965; Rochester et al. 1973; Carpenter 1976; Grove and Andreasen 1985). In contrast, reduced accuracy has been documented for patients across a range of tasks involving complex syntactic constructions: carrying out instructions described in syntactically complex sentences (revised Token Test: Morice and McNicol 1985), ordering direct and indirect objects within sentences (Rausch et al. 1980), and understanding logical relationships specified in relative-clause sentences (Condray et al. 1992, 1996). One linguistic feature common to these latter studies is a transformational operation, movement of phrase constituents (Chomsky 1986; for a discussion regarding the relevance of movement to receptive syntax in Broca’s aphasia, see Grodzinsky 2000). The appearance in schizophrenia patients of intact sensitivity to syntactic boundaries but disrupted syntactic movement requires empirical refinement.

An additional unresolved question concerns the role of extralinguistic capacities in schizophrenia patients’ syntactic processing (for discussions relevant to language disorders in schizophrenia in general, see Schwartz 1982; Morice 1986; Frith and Allen 1988; Maher 1991). In particular, results from several lines of investigation are suggestive of the importance of memory capacity in patients’ receptive language function. Knight and Sma-Knight (1979) reported an association between severity of schizophrenia illness and the ability to organize and integrate in memory the ideas described in serial sentences. Grove and Andreasen (1985) observed that the performance of patients and controls differed significantly for a short-term memory task, but that those same individuals did not differ for sensitivity to syntax boundaries in sentences or memory for gist in serial sentences. The results of Grove and Andreasen are consistent with the patterns reported earlier by Carpenter (1976) and Rochester et al. (1973). Moreover, memory span for sentence-length materials has been found to correlate with overall comprehension accuracy in patients and controls (Condray et al. 1996). It has not been established whether patients’ memory capacity is associated with their processing of linguistic structures requiring transformational operations.

Theoretical Framework for the Present Study

The present study was designed to address the issue of whether receptive syntax is intact in schizophrenia. The methodology involved examination of the influence of syntactic structure and psychological function on comprehension accuracy in individuals with schizophrenia and normal controls. The research was guided by a general capacity hypothesis that is broadly consistent with the capacity theory of Just and Carpenter and their colleagues (Just and Carpenter 1992; Miyake et al. 1994; Haarmann et al. 1997) as well as earlier formulations in which the interaction of syntactic parsing and semantic integration was emphasized (Perfetti and Lesgold 1977; Bock 1982; Kintsch 1988). The primary assumption was that dysfunction of receptive syntax in schizophrenia is due, in part, to capacity or activation disturbances that compromise the storage and computation functions required to create representations of logical relationships that are specified by the syntax of linguistic constructions. In the following discussion, a limited review is provided for the two classes of variables of interest.

Linguistic Structure. The structure of language influences understanding. Comprehension processes in nonclinical populations are affected by syntactic complexity, with systematic declines in comprehension accuracy accompanying increases in complexity (for reviews, see Just and Carpenter 1992; MacDonald et al. 1992). Insight into receptive syntax in schizophrenia can therefore be gained through examinations of the effects of syntactic structure on understanding accuracy in this patient population, an approach that has led to increased understanding about receptive syntax in Broca’s aphasia (for review and commentary, see Grodzinsky 2000). Structural factors believed to influence comprehension include word order, transitivity, and relativization.

Word order. Word order specifies the logical relationships that hold for a linguistic expression. Although determining the dominant or basic typology for a given language is not a straightforward issue (see Comrie 1981), English is typically considered a fixed-order language (Quirk et al. 1985), with the SVO (subject verb object) order representing the most consistent scheme (Siewierska 1999). Most of the worlds’ languages (95%) employ an SO ordering (subjects preceding objects) (for a review, see Siewierska 1999), and it has been suggested that processing demand may influence the principle(s) that govern this ordering in some nonrandom manner (Bock 1982). One implication of this assumption is that an OS ordering (objects preceding subjects) increases the demand on processing resources.

Transitivity. Transitive clauses communicate ideas about “who did what to whom.” Traditional definitions of transitivity include the presence of a direct object and a verb denoting that an action has been transferred from a subject to an object. More recently, the interface of seman-
tic and syntactic knowledge has been emphasized, with a distinction made between semantic and syntactic aspects and an emphasis placed on transitivity as a matter of degree (for a discussion, see Hopper and Thompson 1980). According to this perspective, the semantic aspects of transitive clauses include the following: two participants, at a minimum, who fulfill the semantic roles of subject and object; a subject who carries out a completed action in a volitional and controlling manner; and an object who is changed by that action. The degree to which the completed action creates a change in the object produces the continuum of transitivity.

Relativization. Most languages include relative clauses (Fabb 1999; for an exception, see Comrie 1981), and these constructions have been used in theoretical considerations of transformational operations (e.g., movement: Chomsky 1986). Relative clauses commonly modify nouns and are typically introduced with wh-pronouns (e.g., who, whom, which) and that (for discussions regarding the status of that as a relative pronoun, see Sag 1997; Van Der Auwera 1985; and for etymology, see Fabb 1999). In one method of relative clause formation, the noun-head to be modified can differ with respect to grammatical function (subject vs. object) and location (before, after, or within the clause) (Keenan and Comrie 1977). Relative clauses that are formed in this manner involve a modification of either the clause subject (subject-relative: The detective that shot the murderer . . .) or clause object (object-relative: The burglar that the fireman rescued . . .).

Psychological Functions. An assumption common to the various theories of language comprehension is that meaning is formed through multiple layers of linguistic structures that are mutually constraining. According to this general framework, comprehension accuracy depends on some combination of the processing efficacy that occurs at the micro and macro levels: minimally, in the decoding of perceptual input (prerecognition lexical access models: McClelland and Elman 1986; Marslen-Wilson 1987; Marslen-Wilson et al. 1996; Wallace et al. 1998) and in the integration of lexical items to create a grammatical representation (postrecognition computational models: Kintsch 1988; Just and Carpenter 1992; Haarmann et al. 1997). In the comprehension of speech, this process must also be accomplished for lexical items that occur in a temporal sequence (Marslen-Wilson and Tyler 1980; Marslen-Wilson et al. 1996).

Two psychological functions have consistently emerged as important to comprehension processes in non-clinical populations: temporal auditory processing and memory capacity.

Temporal auditory processing. There does appear to be an upper limit on the amount of linguistic informa-

tion that human beings can comprehend accurately per unit of time. Comprehension accuracy declines systematically as presentation rates increase above the conversational rate of 250 to 300 words per minute (Fairbanks et al. 1957; Carver 1982; for a review of the early literature, see Foulke and Sticht 1969; Wingfield 1975; Hausfeld 1981). Training with accelerated speech does not appear to eliminate these comprehension decrements entirely (Wallace 1983). Deficits in temporal auditory processing may be integral to certain developmental learning disorders, such as dyslexia (for discussions, see Linlin 1993; Tallal et al. 1993). Moreover, schizophrenia is associated with disturbances in the processing of sequential, rapidly presented auditory stimuli (suppression of sensory gating: Freedman et al. 1987; Braff and Geyer 1990). Though the rates that are relevant for natural language and the sensory gating phenomenon obviously differ, it is possible that some type of temporal sequencing disturbance may also influence receptive language in schizophrenia.

Memory capacity. Individuals differ in the efficacy of their comprehension processes (Perfetti and Lesgold 1977; Daneman and Carpenter 1980; King and Just 1991; Just and Carpenter 1992). A perspective that has proven useful in accounting for this fact is the capacity theory, as developed and refined by P.A. Carpenter and M.A. Just and their colleagues. In a recent formulation, capacity represents a composite of activation that is finite in extent, and mediates the storage and computations necessary for understanding linguistic constructions (see Miyake et al. 1994; Haarmann et al. 1997). A distinction was also made between the capacity construct and traditional working memory and short-term storage concepts (e.g., Baddeley 1986), with capacity viewed more generally as a resource that enables storage and computations of sentence representations at multiple levels (lexical, syntactic, semantic, thematic, referential). The general assumption underlying the present study design is broadly consistent with this view. Supportive evidence includes findings that the capacity construct, as defined by reading span, predicted comprehension performance for college students (Daneman and Carpenter 1983; Just and Carpenter 1992; MacDonald et al. 1992) and patients with schizophrenia (Condray et al. 1996). Moreover, central nervous system function appears modulated by syntactic complexity, with manipulations of syntactic structure producing systematic changes in the amplitude of event-related potentials (King and Kutas 1995) and the pattern of neural activation in functional magnetic resonance imaging (fMRI) (Just et al. 1996).

Present Study. In an initial report (Condray et al. 1996), comprehension accuracy was compared between schizophrenia patients and normal controls as a function of syn-
tactic complexity and presentation rate. The focus of that initial report was on the global sentential level: simple versus subject-relative versus object-relative sentences. The present report represents a refinement and extension of that earlier work and includes additional participants. In the present report, patients’ receptive syntax was examined through analyses of their understanding about “Who did what to whom” in clauses with variable word orders, which presumably influence transformational operations. The association was also tested between psychological functions, including memory capacity, and comprehension accuracy about information in sentential clauses requiring transformational operations.

Methods

Participants. Study participants included 32 males diagnosed with DSM-III-R schizophrenia (APA 1987), and 22 males diagnosed as no lifetime DSM-III-R Axis I or Axis II disorder (APA 1987). All study participants were evaluated with the Structured Clinical Interview for DSM-III-R (Spitzer et al. 1989). Normal control subjects were additionally evaluated with the Personality Disorder Examination (Loranger 1988). Psychiatric diagnoses were assigned during case conferences. General exclusion criteria were the following: first language other than American English, history of major medical or neurological disorders, Wechsler Adult Intelligence Scale–Revised (WAIS–R, Wechsler 1981) Verbal IQ < 85, and reading level < eighth grade as measured by the Wide Range Achievement Test (WRAT). Schizophrenia patients were excluded if they met criteria for current substance use disorder. Audiometric screening was conducted (both ears) using 500, 1,000, 2,000, and 4,000 Hz at 40 dBA SL. All individuals passed the screening except for one individual who was able to detect further screening tones of 800 and 1,500 Hz at 65 dBA SL.

Following explanation of procedures and prior to testing, all subjects provided written, informed consent to participate. Control subjects and outpatients were reimbursed for study participation.

Evaluation of Sentence Processing. Sentence processing was evaluated using tests of sentence span memory, intelligibility of accelerated presentation rate, and sentence comprehension.

Sentence span memory. Memory span for sentence-length materials was evaluated with a modified aural 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 each; 3 sets of 5 sentences each; 3 sets of 6 sentences each; 3 sets of 7 sentences each; 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 also advised to expect that the number of sentences would increase as the test progressed.

Intelligibility of accelerated presentation rate. An estimate of intelligibility for the accelerated presentation rate was obtained from the responses recorded to a separate set of 16 warm-up sentences presented at the accelerated rate (proportion of words repeated correctly). As described below (in Procedure section), the task was to repeat each warm-up sentence verbatim. Warm-up sentences were simple sentence constructions used in previous work on the intelligibility of accelerated speech (Wallace and Kourey 1981).

Sentence comprehension task. Two types of sentence processing demand were varied: syntactic and temporal. Syntactic demand was varied by contrasting sentence constructions that differed in grammatical structure, while holding the item load constant (i.e., all sentences contained an equal number of words). Temporal demand was varied using a conversational and an accelerated rate. Sentences and questions were presented aurally.

Syntactic structure. The focus of the present report concerns accuracy of understanding about the roles of actor versus object as they were specified by the syntax of the main and embedded relative clauses in subject-relative and object-relative sentences (i.e., “Who did what to whom?”). Three types of sentence constructions were presented to all study participants: 16 object-relative sentences, 16 subject-relative sentences, and 16 simple declarative sentences. All sentences were 9 words in length. All relative sentences contained two past tense verbs, the majority (n = 53/64 = 83%) of which were classified as transitive in their first or dominant meaning (Webster’s 1979). Word order differs between the two types of relative sentences: the basic word order in English (SVO) is preserved in subject-relative sentences, while the uncommon word order involving objects preceding subjects (object subject verb [OSV]) occurs in object-relative sentences. The 48 sentences included items used by King and Just (1991, p. 600) and items that were developed for the present study. Examples of the relative sentences are

Object-relative: The reporter that the senator attacked admitted the error.
Subject-relative: The accountant that sued the lawyer read the paper.

Simple declarative sentences were SVO constructions that served as control items in earlier comparisons of global sentence processing (Conradt et al. 1996); for example,

Simple declarative: The curator purchased the antique book for the museum.

Sentence comprehension questions. Relative sentences: Three Who questions immediately followed each relative sentence to assess understanding of the facts and logical relationships that were specified by the syntax. For example, recognizing that the initial noun plays dual roles (actor and object) is necessary for an accurate understanding of object-relative sentences. Thus, in the sentence "The reporter that the senator attacked admitted the error," it is necessary to understand that the reporter serves as the actor in the main clause ("The reporter . . . admitted the error"), and as the object of the action in the relative clause (". . . (that) the senator attacked"). The Who questions used to assess understanding of these relations were (1) "Who admitted the error?"—that is, Who did X? in the main clause; (2) "Who was attacked?"—or, Who was done X? in the relative clause; and (3) "Who did the attacking?"—or, Who did X? in the relative clause. Scoring was straightforward, with a total possible of 96 correct: 32 sentences (16 object-relative and 16 subject-relative) × 3 questions per sentence. Simple declarative sentences: Three Wh-questions (Who? What? Where? and/or Whose?) followed each simple declarative sentence to assess understanding of the facts and relationships described in the sentence. Scoring was straightforward, with a total possible of 48 correct: 16 sentences × 3 questions per sentence.

Presentation rate. Sentences were presented aurally at two rates: conversational and accelerated. All sentences and questions were recorded by a female speaker (native of western Pennsylvania) using her typical conversational rate. The accelerated presentation rate was accomplished using a frequency-controlled technique. Frequency-controlled techniques of accelerating speech records have been demonstrated to produce 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 approximately 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 randomly sampled the original speech record digitally and deleted half of the samples (50% compression).

Procedure. A PC-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 warm-up sentence verbatim. The purposes of this warm-up set were to accommodate subjects to the rapid rate, and to obtain an estimate of intelligibility for this presentation rate. Previous work showed that college students accommodated to frequency-controlled speech after similar exposure (Wallace and Koury 1981). The 48 test sentences and comprehension questions immediately followed the warm-up sentences.

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

Data Analyses

Primary Measures. The measures of primary interest included response accuracy in the Sentence Span Test, the Intelligibility task, and the Sentence Comprehension task—Relative Sentences. Response accuracy (number correct) was converted to the proportion correct and then transformed by the arcsine transformation prior to conducting the statistical tests (Fleiss 1986). Data values that are presented in tables and graphs are proportions (exception: Sentence Span data are presented as Span Set Size to facilitate interpretation). However, all statistical analyses are based on the arcsine transformation of the proportion of correct responses. This strategy was used to adjust for distributions associated with high accuracy rates that were produced by some of the tasks and experimental conditions, and to provide more conservative tests of the data. The experimental design for the Sentence Comprehension task was a mixed factorial that included both between- and within-subjects factors. Results were tested using analyses of variance (BMDP2V ANOVAs), with diagnosis (two levels) as the between-subjects factor, and sentence complexity (two levels), presentation rate (two levels), and within-sentence clause (three levels) as the within-subjects factors. The Greenhouse-Geisser correction was applied to analyses of the within-sentence clause variable, and the epsilon factors for these adjustments are
reported. The standard significance level of $\alpha = 0.05$ was used for the omnibus ANOVAs. Theoretically motivated analytical comparisons followed findings of significant results in the omnibus ANOVAs (see Keppel 1991). These analytical comparisons were evaluated at the more stringent significance level of $\alpha = 0.01$ to reduce the risk of Type I errors that may accompany such comparisons (Keppel 1991). Trend significance for analytical comparisons was set at $\alpha = 0.05$.

**Tests of Association.** The association between language comprehension and other psychological functions was examined using linear regression analysis with simultaneous entry of variables (SPSS 10.0). Unstandardized betas are reported to facilitate comparisons across samples (Pedhazur 1982). The association between language comprehension and general intellectual ability (WAIS-R) was examined using standard tests of correlation (Pearson $r$).

**Standard Residualized Scores.** To remove extraneous variance measured by the conditions of theoretical interest (relative clauses), standard residualized scores were computed in the manner recommended by Chapman and Chapman (1989, p. 363) and entered as the measure of individual differences in an additional ANOVA: (1) for each individual, the predicted scores on the relative clause conditions (embedded—object and embedded—actor) were computed based on their observed main clause score, using the regression equations for controls; (2) each residualized score was then standardized using the standard errors of controls’ observed relative clause scores; (3) each individual’s standard residualized scores (embedded—object and embedded—actor) were then entered into an ANOVA, with diagnosis (two levels) as the between-subjects factor and relative clause condition (two levels) as the within-subjects factor.

**Results**

**Characteristics of Sample.** Table 1 presents the characteristics of the sample. Patients and controls did not differ for age, education, or single-word reading ability (WRAT). General verbal ability was assessed using the subtests from the WAIS-R Verbal IQ. Compared to controls, patients were characterized by an uneven pattern of performance on these measures of verbal ability, with significant group differences observed only for the Arithmetic and Comprehension subtests. (Data were missing for one control on the Vocabulary subtest and one patient on the Similarities subtest, which is reflected in the degrees of freedom.) Handedness (Kutas and Van Petten 1994) was assessed using items from the Edinburgh Handedness Inventory (Oldfield 1971), and patients and controls showed a similar proportion of individuals with a right-hand preference.

**Clinical Characteristics of Patients.** This sample of 32 schizophrenia patients included 17 inpatients and 15 outpatients who were receiving treatment in the Veterans Affairs Pittsburgh Healthcare System at the time of test-

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**Table 1. Characteristics of the sample**

<table>
<thead>
<tr>
<th></th>
<th>Schizophrenia patients $(n = 32)$</th>
<th>Normal controls $(n = 22)$</th>
<th>$t$ test</th>
<th>$df$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD)</td>
<td>42.4 (7.9)</td>
<td>38.9 (8.4)</td>
<td>1.55</td>
<td>52</td>
<td>0.13</td>
</tr>
<tr>
<td>Education (yrs), mean (SD)</td>
<td>12.8 (1.9)</td>
<td>13.6 (1.2)</td>
<td>1.85</td>
<td>52</td>
<td>0.07</td>
</tr>
<tr>
<td>Single-word reading ability (WRAT), mean (SD)</td>
<td>76.7 (7.4)</td>
<td>73.0 (9.2)</td>
<td>1.65</td>
<td>52</td>
<td>0.11</td>
</tr>
<tr>
<td>Verbal ability (WAIS-R), mean (SD)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Information</td>
<td>10.6 (2.1)</td>
<td>11.0 (1.9)</td>
<td>$&lt; 1$</td>
<td>52</td>
<td>0.42</td>
</tr>
<tr>
<td>Digit span</td>
<td>9.6 (2.4)</td>
<td>10.7 (3.0)</td>
<td>1.49</td>
<td>52</td>
<td>0.14</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>9.9 (1.9)</td>
<td>10.8 (1.9)</td>
<td>1.82</td>
<td>51</td>
<td>0.11</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>8.3 (2.4)</td>
<td>10.7 (3.0)</td>
<td>3.16</td>
<td>52</td>
<td>0.003</td>
</tr>
<tr>
<td>Comprehension</td>
<td>8.2 (2.1)</td>
<td>10.6 (2.3)</td>
<td>3.97</td>
<td>52</td>
<td>0.0002</td>
</tr>
<tr>
<td>Similarities</td>
<td>9.2 (2.8)</td>
<td>10.2 (2.4)</td>
<td>1.30</td>
<td>51</td>
<td>0.20</td>
</tr>
<tr>
<td>Handedness, f(%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>28 (90.6)</td>
<td>20 (90.9)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>2 (6.3)</td>
<td>1 (4.5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both</td>
<td>1 (3.1)</td>
<td>1 (4.5)</td>
<td></td>
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</tbody>
</table>

*Note.—SD = standard deviation; WAIS-R = Wechsler Adult Intelligence Scale—Revised; WRAT = Wide Range Achievement Test.*

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ing. These patients were assigned the following DSM–III–R schizophrenia disorder subtypes: undifferentiated (n = 12), paranoid (n = 6), and residual (n = 11). Three patients were assigned the diagnosis of schizoaffective disorder. Their clinical course of illness was characterized by a mean age of 24.6 years (standard deviation [SD] = 4.7; range: 15–34) at the time of first psychiatric hospitalization, an average illness duration of 18.2 years (SD = 6.7; range: 2–34), and a mean of 9.8 (SD = 6.9; range: 3–28) psychiatric hospitalizations.

Medication status of patients. Of the 32 patients, 18 were receiving haloperidol and 14 were receiving other antipsychotic medications (chlorpromazine, fluphenazine, loxapine, perphenazine, risperidone, thioridazine, thiothixene). Of these 32 patients, 29 were receiving oral antipsychotic medication at the time of study participation, and their mean daily dose in chlorpromazine equivalents (Appleton 1988) was 504.02 mg/day (n = 29; median = 400; SD = 298.57; range: 50–1127.8); 1 patient was receiving oral risperidone (8 mg/day); and 2 patients received injections of haloperidol decanoate (100 mg/month and 125 mg/month, respectively) during the month prior to study participation. Of the 32 patients, 20 were additionally receiving adjunct anticholinergic medication (benztropine, mg/day: n = 20; mean = 2.75; median = 2; SD = 1.29; range: 1–6). (Seven of these 20 patients receiving anticholinergic medication were participating in a double-blind haloperidol maintenance and placebo replacement protocol, in which adjunct anticholinergic medication was discontinued 2 weeks prior to testing [see van Kammen et al. 1996]). Finally, of the 32 patients, 13 were receiving only antipsychotic and adjunct anticholinergic medications; the pharmacology treatment regimens of the remaining 19 patients involved a variety of additional medications, including albuterol (n = 2); amitriptyline (n = 1); clonazepam (n = 2); desipramine (n = 2); diphenhydramine (n = 2); fluoxetine (n = 2); imipramine (n = 1); lithium carbonate (n = 6); lorazepam (n = 2); nizatidine (n = 1); sertraline (n = 6); theophylline (n = 1); trazodone (n = 1); trihexyphenidyl (n = 1).

Sentence Processing. The measures of primary interest included response accuracy in the Sentence Span Test (largest set size possible = 8), the Intelligibility task (total possible = 100 words), and the Sentence Comprehension task—Relative Sentences (total correct possible = 96). Response accuracy (number correct) for these primary measures was converted to the proportion correct and then transformed by the arcsine transformation prior to conducting the statistical tests (Fleiss 1986). Data values that are presented in tables and graphs are proportions (exception: Sentence Span data are presented as Span Set Size to facilitate interpretation); however, all statistical analyses are based on the arcsine transformation of the proportion of correct responses.

Sentence span memory. Performance on the Sentence Span Test (set size) differed (F1,52 = 11.45, p = 0.001) between patients (mean/SD = 2.70/0.94) and controls (mean/SD = 3.5/0.80).

Intelligibility of accelerated presentation rate. Both diagnostic groups exhibited a high rate of intelligibility for the individual words in sentences that were presented at the accelerated rate used in the sentence comprehension task: mean proportion of words repeated verbatim in the intelligibility task for patients (mean/SD = 0.97/0.09) and controls (mean/SD = 0.99/0.01) did not differ (F1,52 = 1.68, p = 0.20).

Sentence Comprehension Performance

Simple sentences. The mean proportion of correct responses to questions about the simple declarative sentences for each diagnostic group under each presentation rate condition were as follows: conversational rate (mean/SD), patients = 0.77/0.12, controls = 0.91/0.07; accelerated rate (mean/SD), patients = 0.75/0.14, controls = 0.87/0.06. Diagnosis and presentation rate influenced overall understanding accuracy for simple sentences, and patients and controls exhibited different patterns of accuracy as a function of presentation rate. These results were obtained as follows: Groups differed in their overall proportion of correct responses to questions about simple sentences (F1,52 = 21.88, p < 0.001), with patients showing reduced accuracy compared to controls (76% vs. 89%, respectively). Presentation rate also influenced comprehension accuracy (F1,52 = 7.75, p < 0.01), with the conversational rate producing greater accuracy compared to the accelerated rate (84% vs. 81%, respectively). The diagnosis × rate interaction effect (F1,52 = 4.71, p < 0.05) indicated that the two groups were characterized by different patterns of accuracy for simple sentences under the two presentation rates. Analyses of the simple effects of presentation rate on accuracy in each diagnostic group showed that rate influenced accuracy in controls (F1,21 = 10.87, p < 0.01) but not in patients (p = 0.64).

Relative sentences. Table 2 presents the mean proportion of correct responses to Who questions for each diagnostic group under each relative sentence and within-sentence clause condition at each presentation rate.

Effects of linguistic structure and presentation rate on comprehension accuracy. Each of the factors of theoretical interest exerted significant main effects on comprehension accuracy. First, sentence complexity influenced comprehension (F1,52 = 43.92, p < 0.001), with greater response accuracy occurring for subject-relative sentences (84%) compared to object-relative sentences (73%).

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Second, type of within-sentence clause information also affected comprehension ($F_{2,104} = 73.60, p < 0.001$, Greenhouse-Geisser $\varepsilon = 0.71$). The highest rate of accuracy occurred in response to questions concerning main clause—actor information (89%), while a reduced and comparable accuracy rate was associated with questions about the two types of embedded relative clauses: embedded—object (73%) and embedded—actor (73%). Pairwise comparisons confirmed the statistical reliability of these differences: main clause—actor versus embedded clause—object ($F_{1,53} = 84.82, p < 0.001$); main clause—actor versus embedded clause—actor ($F_{1,53} = 87.45, p < 0.001$); embedded clause—object versus embedded clause—actor ($p = 0.66$). Third, presentation rate additionally influenced comprehension ($F_{1,52} = 19.06, p = 0.0001$), with the normal or conversational rate producing a higher rate of accuracy compared to the accelerated rate (81% and 76%, respectively).

To provide a more detailed understanding of the interaction effect involving sentence complexity, presentation rate, and within-sentence clause ($F_{2,104} = 10.93, p = 0.0001$, Greenhouse-Geisser $\varepsilon = 0.96$), a set of theoretically motivated simple interactions was conducted in which the joint effects of sentence complexity and presentation rate were examined under each level of within-sentence clause. Results indicate that the combined effects of sentence complexity and presentation rate were influential as a function of the type of clause information queried. Specifically, sentence complexity and presentation rate exerted joint effects on understanding accuracy about “Who did X?” but not on accuracy about “Who was done X?” These results were obtained as follows: The sentence complexity $\times$ presentation rate interaction was significant for accuracy about main clause—actor information ($F_{1,53} = 52.72, p < 0.001$) and embedded clause—actor information ($F_{1,53} = 10.33, p = 0.0022$) but not for accuracy about embedded clause—object information ($p = 0.13$).

Effects of linguistic structure and presentation rate on comprehension accuracy in schizophrenia. Patients and controls differed in their overall proportion of correct responses ($F_{1,52} = 14.45, p = 0.0004$), with patients exhibiting reduced comprehension accuracy compared to controls (71% vs. 85%, respectively). More important, the diagnosis $\times$ within-sentence clause interaction effect ($F_{2,104} = 7.27, p = 0.004$, Greenhouse-Geisser $\varepsilon = 0.71$) indicates that patients and controls were characterized by different patterns of accuracy across the various types of within-sentence clause structures. This two-way interaction is presented in figure 1. None of the other interactions involving the diagnostic group factor reached statistical significance.

Two sets of simple effects were tested to locate the source of the significant diagnosis $\times$ within-sentence clause interaction reported above. These analyses identified a group difference in the comparative levels of accuracy for information contained in main versus relative clauses. In both groups, the highest response accuracy was observed for information described in main clauses, com-
Figure 1. Mean percent correct responses to Who questions about the information described in the sentential clauses of relative sentences in schizophrenia patients (n = 32) and normal controls (n = 22) (± standard error of the mean)

Compared to information contained in embedded relative clauses, while similar rates of accuracy occurred for the two types of relative clauses. However, patients showed an average decrement of 20.5 percent in their accuracy about embedded clause information, compared to their accuracy about main clause information. In contrast, controls showed an average decrement of only 10 percent in their accuracy about embedded clause information, compared to their accuracy about main clause information. These results were obtained as follows: First, analyses of the simple effects of within-sentence clause on response accuracy in each diagnostic group showed a main effect of clause type in both patient and control groups: patients (F2,62 = 87.27, p < 0.001, Greenhouse-Geisser ε = 0.69); controls (F2,42 = 13.87, p = 0.0004, Greenhouse-Geisser ε = 0.64). Moreover, pairwise comparisons of the various clause types showed a similar pattern in each diagnostic group: main clause—actor versus embedded clause—object (patients: F1,31 = 99.26, p < 0.001; controls: F1,21 = 14.98, p = 0.0009); main clause—actor versus embedded clause—actor (patients: F1,31 = 98.59, p < 0.001; controls: F1,21 = 16.01, p = 0.0006); and embedded clause—object versus embedded clause—actor (patients: p = 0.03; controls: p = 0.09). Second, analyses of the simple effects of diagnosis on the response accuracy associated with each clause type showed that accuracy for embedded clause information differed between the two groups: embedded clause—object in patients versus controls: F1,52 = 10.09, p = 0.0025; embedded clause—actor in patients versus controls: F1,52 = 21.86, p < 0.001. In contrast, the effect of diagnosis on the accuracy rate for main clause—actor information reached only trend significance (p = 0.04).

**Standard residualized scores.** To remove extraneous variance measured by the within-sentence clause conditions of theoretical interest (relative clauses), standard residualized scores (Chapman and Chapman 1989) were used as the measures of individual differences (see Data Analyses section): patients: Membedded-object = −0.58, SD = 0.64; Membedded-actor = −0.89, SD = 0.92; controls: Membedded-object = 0.0000, SD = 0.98; Membedded-actor = 0.0008, SD = 0.98. ANOVA results were consistent with findings based on the conventional analyses: patients and controls differed in overall accuracy (F1,52 = 10.02, p = 0.003); type of relative clause information (embedded—actor vs. embedded—object) influenced performance accuracy (F1,52 = 5.49, p = 0.023); and the diagnosis × within-sentence clause interaction effect (F1,52 = 5.56, p = 0.022), which indicated that patients and controls were characterized by different patterns of accuracy for the two types of relative clause information.
Association Between Language Comprehension Accuracy and Capacity. The association between comprehension accuracy and the psychological functions of theoretical interest was tested using linear regression analysis. The two diagnostic groups were combined for these analyses (n = 54). This relationship was examined separately for three dependent variables that involved comprehension accuracy for each type of sentential clause (main and embedded) and word order (SVO and OSV). Main clauses from the two types of relative sentences (subject- and object-relatives) represented an SVO word order, and they were combined for the analyses. Embedded clauses were examined separately based on the type of relative-clause word order: the SVO order of subject-relative sentences, and the OSV order of object-relative sentences. Thus, comprehension accuracy was defined as the number of correct responses to Who questions about the information contained in main clauses of both subject-relative and object-relative sentences (total possible correct = 32); embedded relative clauses of subject-relative sentences (total possible correct = 32); and embedded relative clauses of object-relative sentences (total possible correct = 32). Two models were tested that involved different sets of psychological functions as the independent variables, which were selected and organized based on (1) the theoretical rationale outlined in the Psychological Functions section; and (2) collinearity issues (absence of correlations between independent variables in the present sample). Model 1: The independent variables for Model 1 were age (control variable), digit span (WAIS–R subtest score), and memory span for sentences (Sentence Span Test score). Results in table 3 indicate an association between comprehension accuracy and these psychological functions in this sample. Model 1 accounted for 20 percent of the variance associated with response accuracy for information in the embedded clauses of subject-relative sentences (SVO word order), and 23 percent of the variance associated with response accuracy for information in the embedded clauses of object-relative sentences (OSV word order). The variables in Model 1 were not successful in predicting accuracy about main clause—information. Model 2: Because of collinearity issues, the control variable, age, was replaced by education in Model 2. The independent variables for Model 2 were education, vocabulary (WAIS–R subtest score), and intelligibility. (Note that analyses for Model 2 are based on 53 subjects because of missing data for 1 normal control for the vocabulary measure.) Results in table 4 show an association between comprehension accuracy and this set of psychological functions in this sample. Model 2 accounted for 32 percent of the variance associated with response accuracy for information contained in the main clauses of relative sentences (SVO word order); 32 percent of the variance associated with response accuracy for information contained in the embedded clauses of subject-relative sentences (SVO word order); and 39 percent of the variance associated with response accuracy for information contained in the embedded clauses of object-relative sentences (OSV word order).

The association between language comprehension and general intellectual ability (WAIS–R IQ) was examined using standard tests of correlation (Pearson r) conducted separately for the two diagnostic groups. Results in table 5 show that general intellectual functioning was not

<table>
<thead>
<tr>
<th>Table 3. Association between psychological functions and comprehension accuracy for information in sentential clauses (n = 54)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R²</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Main clauses: SVO</strong></td>
</tr>
<tr>
<td><strong>Predictor variables</strong></td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Digit span</td>
</tr>
<tr>
<td>Sentence span memory</td>
</tr>
<tr>
<td><strong>Embedded relative clauses: SVO</strong></td>
</tr>
<tr>
<td><strong>Predictor variables</strong></td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Digit span</td>
</tr>
<tr>
<td>Sentence span memory</td>
</tr>
<tr>
<td><strong>Embedded relative clauses: OSV</strong></td>
</tr>
<tr>
<td><strong>Predictor variables</strong></td>
</tr>
<tr>
<td>Age</td>
</tr>
</tbody>
</table>

**Note:** adj. = adjusted; OSV = object subject verb; SE = standard error; SVO = subject verb object.
Table 4. Association between psychological functions and comprehension accuracy for information in sentential clauses (n = 53)

<table>
<thead>
<tr>
<th>Main clauses: SVO</th>
<th>R²</th>
<th>Adj. R²</th>
<th>F ratio</th>
<th>df</th>
<th>p</th>
<th>beta</th>
<th>SE beta</th>
<th>t test</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictor variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education (yrs)</td>
<td>0.36</td>
<td>0.32</td>
<td>9.09</td>
<td>3, 49</td>
<td>0.001</td>
<td>0.0383</td>
<td>0.015</td>
<td>2.52</td>
<td>0.02</td>
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<td>Vocabulary</td>
<td>0.0228</td>
<td>0.014</td>
<td>1.69</td>
<td>0.1</td>
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</tr>
<tr>
<td>Intelligibility</td>
<td>0.594</td>
<td>0.158</td>
<td>3.76</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Embedded relative clauses: SVO</th>
<th>R²</th>
<th>Adj. R²</th>
<th>F ratio</th>
<th>df</th>
<th>p</th>
<th>beta</th>
<th>SE beta</th>
<th>t test</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictor variables</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education (yrs)</td>
<td>0.36</td>
<td>0.32</td>
<td>9.26</td>
<td>3, 49</td>
<td>0.001</td>
<td>0.0518</td>
<td>0.021</td>
<td>2.49</td>
<td>0.02</td>
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<td>Vocabulary</td>
<td>0.0563</td>
<td>0.018</td>
<td>3.04</td>
<td>0.004</td>
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<tr>
<td>Intelligibility</td>
<td>0.583</td>
<td>0.216</td>
<td>2.6</td>
<td>0.012</td>
<td></td>
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<table>
<thead>
<tr>
<th>Embedded relative clauses: OSV</th>
<th>R²</th>
<th>Adj. R²</th>
<th>F ratio</th>
<th>df</th>
<th>p</th>
<th>beta</th>
<th>SE beta</th>
<th>t test</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictor variables</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Education (yrs)</td>
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<td>0.0443</td>
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<td>2.17</td>
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<td>Vocabulary</td>
<td>0.0592</td>
<td>0.018</td>
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<td>Intelligibility</td>
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<td>0.212</td>
<td>3.74</td>
<td>0.001</td>
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</table>

Note.—adj. = adjusted; OSV = object subject verb; SE = standard error; SVO = subject verb object.

Table 5. Correlations between WAIS–R scores and language comprehension accuracy

<table>
<thead>
<tr>
<th></th>
<th>Verbal IQ</th>
<th>Performance IQ</th>
<th>Full-scale IQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schizophrenia patients (n = 32)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative sentences</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main clauses</td>
<td>0.24</td>
<td>-0.26</td>
<td>0.04</td>
</tr>
<tr>
<td>Embedded—object</td>
<td>0.29</td>
<td>-0.05</td>
<td>0.17</td>
</tr>
<tr>
<td>Embedded—actor</td>
<td>0.27</td>
<td>0.002</td>
<td>0.16</td>
</tr>
<tr>
<td>Total correct</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple and relative sentences</td>
<td>0.28</td>
<td>-0.09</td>
<td>0.15</td>
</tr>
<tr>
<td>Normal controls (n = 22)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative sentences</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main clauses</td>
<td>0.30</td>
<td>0.14</td>
<td>0.26</td>
</tr>
<tr>
<td>Embedded—object</td>
<td>0.52*</td>
<td>0.56**</td>
<td>0.59**</td>
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<tr>
<td>Embedded—actor</td>
<td>0.57**</td>
<td>0.38</td>
<td>0.53*</td>
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<tr>
<td>Total correct</td>
<td></td>
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<tr>
<td>Simple and relative sentences</td>
<td>0.60**</td>
<td>0.47*</td>
<td>0.59**</td>
</tr>
</tbody>
</table>

Note.—WAIS–R = Wechsler Adult Intelligence Scale–Revised.
* p < 0.05, 2-tailed; ** p < 0.01, 2-tailed

significantly associated with language comprehension accuracy for schizophrenia patients. In contrast, general intellectual functioning was strongly and significantly correlated with language comprehension accuracy for normal controls.

Discussion

The present study addresses an unresolved question in the literature: whether receptive syntax is intact in schizophrenia. Results showed that patients and controls differed in their overall comprehension accuracy about relative sentences, with patients exhibiting a mean reduction of 14 percent in their overall accuracy, compared to controls. More important, patients and controls differed in their pattern of accuracy, and this pattern was a function of syntactic structure. Patients showed an average decrement of 20 percent in their accuracy about “Who did X?” and “Who was done X?” in relative clauses, compared to their accuracy about actors in main clauses. In contrast, controls exhibited an average decrement of only 10 percent between relative and main clause information. Patients
and controls did not show different patterns of accuracy for information in relative sentences as a function of presentation rate, although this finding may be due to ceiling effects for the rate factor. For example, it is possible that even further increases in temporal demand (e.g., deletion of > 50% of the speech sample) would result in a different pattern of effects of presentation rate on understanding accuracy for relative sentences for patients versus controls. Indeed, the effects of presentation rate on language understanding in schizophrenia disorder may be complex, as seen in the significant diagnostic group × presentation rate interaction obtained for simple sentence constructions, with controls showing a greater reduction in accuracy between the slow versus fast rates, compared to patients. There are at least two possible interpretations of the diagnostic group × presentation rate interaction for simple sentences: (1) the faster presentation rate may have assisted patients in maintaining context for the simple sentence constructions; or (2) the accelerated rate may have been more disruptive to the understanding of simple sentences at higher levels of performance accuracy; that is, controls’ greater reduction in accuracy for simple sentences at the accelerated rate may have been due to their higher overall accuracy about simple sentences (89%) compared to patients’ overall accuracy about simple sentences (76%). Finally, comprehension accuracy was correlated with functioning in the domains of memory, semantic knowledge, and temporal auditory processing.

The present findings provide a refinement of the previous literature, in which it had been shown that patients are sensitive to syntactic structure (Rochester et al. 1973; Carpenter 1976; Grove and Andreasen 1985) but are characterized by reduced comprehension for grammatically complex sentences (Morice and McNicol 1985; Condray et al. 1992; Condray et al. 1996). Consideration of the present data, however, must include recognition of certain interpretive challenges. An important qualification pertains to how receptive syntax function is formulated, with a crucial question concerning which functional components are entered into the model. It is generally assumed that receptive syntax involves multiple functional components. It is therefore possible that an increase in syntactic complexity may merely burden further cognitive functions that are commonly deployed across a broad range of information processing tasks (e.g., the holding online of incoming information in short-term storage, the accessing of long-term memory and semantic knowledge networks, the rapid processing of sequential stimuli). Thus, one interpretation is that a generalized cognitive deficit (Chapman and Chapman 1989)—in combination with variations in task structure, complexity, or both—produced the more precipitous decline in patients’ receptive syntax function in the present study. It is also possible, however, that increased syntactic complexity requires the involvement of one or more additional functional components (e.g., transformation operations such as movement). An alternative explanation, therefore, is that disturbances in specific components of receptive syntax function may be responsible for patients’ reduced understanding accuracy about grammatically complex constructions; for example, a disturbance in transformational operations, such as syntactic movement, produced difficulty in connecting “Who” with “did X” versus “was done X.” It is important to emphasize that these two accounts do not represent mutually exclusive alternatives, with combinations of the logic yielding additional, equally viable explanations; for example, a unique, specific deficit in function(s) used in linguistic analyses that is superimposed on the generalized cognitive deficiency. The two accounts are also not exhaustive. As an additional consideration, performance accuracy may have reflected a methodology confound whereby accuracy was influenced by an interaction of memory function and within-sentence word order. Specifically, the ordering of main and embedded relative clauses in both types of relative sentences is such that the pattern of accuracy could merely reflect a primacy-recency effect (Underwood et al. 1978), with accuracy a function of the position held by the clause within the sentence. As a result, greater accuracy would be expected for information in initial and last positions (main clauses), compared to the level of accuracy for information occupying the middle positions (relative clauses). All of these possibilities require empirical testing.

Of interest, the proportion of variance in comprehension accuracy that was accounted for by selected cognitive functions ranged from 20 percent to 39 percent. This pattern suggests that receptive syntax function includes, but is not fully explained by, an online interface with cognitive functions such as memory, semantic knowledge, and temporal auditory processing. Such an interpretation is consistent with a modularity formulation (Fodor 1983), as well as with recent formulations of cognitive function as a dynamic and distributed process (see Carpenter et al. 2000). It is important to recognize, however, that the correlation data from the present study must be qualified by certain limitations: (1) the cognitive measures employed are not absolute and (2) the model is not exhaustive (e.g., potential specification errors, see Pedhazur 1982). Finally, general intellectual ability (WAIS–R scores) was associated with language comprehension accuracy in normal controls. In contrast, general intellectual ability (WAIS–R scores) was not significantly correlated with language comprehension accuracy in schizophrenic patients. This latter pattern may indicate that receptive syntax dysfunction in schizophrenia is not associated with compromised general cognitive ability.
A final consideration concerns the effects on memory of the pharmacological agents used to treat the schizophrenia patients in the present study. Findings of recent clinical and nonhuman primate studies suggest that working memory is influenced by agents associated with antagonism of dopamine D2 receptors; specifically, verbal working memory in schizophrenia patients was influenced by such medications (Green et al. 1997; for a review, see Meltzer and McGurk 1999), and impairment of working memory function in adult monkeys was produced by chronic administration of haloperidol (Castner et al. 2000). If memory capacity does influence receptive syntax function, then administration of neuroleptic medications may have influenced patients’ syntax processing.

In summary, findings from the present study suggest the hypothesis that receptive syntax operations are disrupted in schizophrenia, and this disturbance may not be completely explained by compromised general cognitive ability.

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The Authors

Ruth Condray, Ph.D., is Assistant Professor of Psychiatry, and Stuart R. Steinhauer, Ph.D., is Research Associate Professor, University of Pittsburgh School of Medicine, Pittsburgh, PA. Daniel P. van Kammen, M.D., Ph.D., is Director, Global Clinical Research and Development, Robert Wood Johnson Pharmaceutical Research Institute, Raritan, NJ; Professor Emeritus, University of Pittsburgh School of Medicine; and Adjunct Clinical Professor, University of Pennsylvania, Philadelphia, PA. Annette Kasparek, B.S., is Senior Research Associate, University of Pittsburgh Medical Center, Pittsburgh, PA.