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Reduced Sensitivity to Linguistic Context in Schizophrenic Thought Disorder: Evidence From On-Line Monitoring for Words in Linguistically Anomalous Sentences

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The use of linguistic context in positively thought-disordered (TD) schizophrenics was investigated through examination of their performance on an on-line word-monitoring task. Controls and non-TD schizophrenics took longer to recognize words preceded by linguistic anomalies compared with words in normal sentences. Compared with both other groups, TD schizophrenics showed significantly *smaller* differences in reaction time, suggesting that they were relatively insensitive to linguistic violations. TD schizophrenics were also less sensitive to linguistic violations in an off-line version of the task, in which they judged whether the sentences "made sense." Finally, these participants produced more errors on a verbal fluency task than did non-TD schizophrenics or normal controls. These findings are consistent with the theory that schizophrenic thought disorder arises from a deficit in the use of linguistic context to process and produce speech.

Disorder of the form of thought characterized by "loosening of associations" (Bleuler, 1911/1950) has long been considered a core feature of schizophrenia, and there have been numerous attempts to pinpoint its underlying basis. Some authors have tried to link symptoms and cognitive functions conceptually and have argued that the poor performance of schizophrenic participants in a variety of tasks is "indicative of the various difficulties created by context" (Shakow, 1962, p. 25), including a "failure to integrate correct contextual information with stored information relevant to such contexts" (Gray, Feldon, Rawlins, Hemsley, & Smith, 1991, p. 3) and a "degradation in the ability to construct and maintain an internal representation of context" (Cohen & Servan-Schreiber, 1992, p. 46). However, these formulations generalize from a wide variety of information-processing domains, and the term *context* is often used in different ways. In this study, we aimed to bridge the gap between the phenomenology of positive thought disorder and its cognitive basis by adopting a psycholinguistic approach and focusing on the use of linguistic context, covering levels of representation from syntax, through semantics to pragmatics.

Linguistic context refers to both the meaning relations between individual words and the way in which these meanings are combined with syntactic structure and knowledge of the world to process sentences (Tanenhaus & Lucas, 1987). Most of the empirical evidence for single-word context effects comes from semantic priming paradigms. Semantic priming is the decrease in the reaction time to make a lexical decision (i.e., to decide whether a letter-string is a word or a nonword) or to name a target word, if the word presented just before the target is semantically related to it (Meyer & Schvaneveldt, 1971; reviewed by Neely, 1991). This effect is traditionally explained using a model of spreading activation (Collins & Loftus, 1975) at a lexical level. However, under certain experimental conditions, extralexical higher order processes may also be involved (Neely, 1991). Although the majority of priming studies involve reading, the same phenomenon is seen when words are presented auditorily (e.g., Moss, Ostrin, Tyler, & Marslen-Wilson, 1995), although the time course is different (Marslen-Wilson & Tyler, 1980). Sentence processing involves the integration of information over more than one word to build a conceptual model or discourse representation (Foss & Ross, 1983; Kintsch, 1988). This integration process cannot be explained by spreading activation at a lexical level and presumably involves higher order extralexical processes that interact continuously with lower level representations.

There have been several studies of semantic priming in schizophrenia. Some have demonstrated greater priming effects in schizophrenic participants than in controls (Henik, Nissimov, Priel, & Umansky, 1995; Kwapil, Hegley, Chapman, & Chapman, 1990; Manschreck et al., 1988; Spitzer, Braun, Hermle, &

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Maier, 1993; Spitzer, Weisker, et al., 1994). Furthermore, Spitzer et al. (1993) showed that schizophrenics, particularly those who were thought disordered, showed greater priming when there was a mediating word between prime and target than did normal controls. These findings are consistent with Maher's (1983) proposal that thought-disordered (TD) schizophrenic participants have an activated or disinhibited semantic associative network. On the other hand, other groups have shown that priming in schizophrenic participants is no greater than in normal participants (Barch et al., 1996; Blum & Freides, 1995; Chapin, McCown, Vann, Kenney, & Youssef, 1992; Chapin, Vann, Lycaki, Josef, & Meyendorff, 1989; Henik, Priel, & Umansky, 1992; Ober, Vinogradov, & Shenaut, 1995; Vinogradov, Ober, & Shenaut, 1992) and, under certain experimental conditions, may even be reduced (Barch et al., 1996; Henik et al., 1995; Ober et al., 1995; Vinogradov et al., 1992). These contradictory results may be a result of a variety of methodological factors, particularly the failure to distinguish between TD and non-TD schizophrenics (see below). Furthermore, the mechanisms of semantic priming—intra- or extralexical—depend on the particular experimental conditions and paradigm used (Neely, 1991). Thus, it has been argued that the decreased priming shown by schizophrenic participants under certain experimental conditions reflects a deficit in higher order language processes (Barch et al., 1996; Ober et al., 1995; Vinogradov et al., 1992).

Phenomenologically, TD schizophrenic patients seem to have problems not only at the level of single words but with whole themes. Several early experiments suggested that schizophrenics have difficulty using context within and between sentences (for a review of this literature, see Maher, 1972, and Schwartz, 1982): For example, schizophrenic participants perform poorly when asked to recall normal versus linguistically anomalous sentences (Truscott, 1970) and to predict missing words in a passage of normal text (i.e., de Silva & Hemsley, 1977). In addition, schizophrenic participants are more likely than controls to interpret the primary (stronger) meaning of homonyms, even when the preceding context suggests the secondary (weaker) meaning (Chapman, Chapman, & Miller, 1964; Cohen & Servan-Schreiber, 1992). The problem with many of these studies is that it is difficult to exclude a general deficit in schizophrenics' performance (Chapman & Chapman, 1973) or the use of a variety of strategic processes that have little to do with normal language processing.

Another problem with many of the studies reviewed above is that they investigated heterogeneous groups of schizophrenic participants. Investigating specific psychotic phenomena by comparing patient groups with and without a particular symptom (Frith, 1992) not only overcomes potential confounding factors, such as medication, but highlights the phenomenon in question as the point of reference for understanding the cognitive basis of psychopathology (David, 1993). Several groups have applied this approach to thought disorder, and many have found that TD participants are particularly impaired on context-dependent linguistic tasks (Maher, Manschreck, & Rucklos, 1980; Manschreck, Maher, Rucklos, & White, 1979; Spitzer, Beuckers, et al., 1994; Spitzer et al., 1993). The importance of differentiating between TD and non-TD schizophrenics is supported by studies examining language output. Early work suggested that the speech of TD schizophrenics is difficult to predict (e.g., Manschreck et al., 1979), and, more recently, Spitzer, Beukers, et al. (1994) compared the implicit use of context by TD and non-TD schizophrenic participants by examining the distribution of pauses in spontaneous speech. Whereas the proportion of pauses before words in context was smaller than the proportion of pauses before words out of context in normal controls and non-TD patients, no such pattern was found in TD schizophrenic patients.

In this study, we examined the performance of TD schizophrenic patients on a word-monitoring task. Normal participants show a progressive increase in reaction time (RT) to recognize target words in sentences that are violated pragmatically, semantically, and syntactically (Tyler, 1992), suggesting that normal language processing depends not only on bottom-up sensory information but on top-down contextual constraints. We hypothesised that TD participants would not show the expected increase in RT across the four types of sentences. Specifically, we predicted that the TD participants would show smaller RT differences between the normal (baseline) and anomalous sentence conditions, for example, that they would be *relatively* faster to recognize target words in anomalous sentences than closely matched non-TD schizophrenics or healthy controls.

We compared the performance of the schizophrenic participants on this "on-line" implicit task, in which there was a close temporal relationship between the stimulus and the participant's response (Tyler, 1992), with an "off-line" version of the task in which participants were asked to make explicit judgments on whether the sentences made sense. This provided the opportunity to compare real-time processing with reasoning and strategic processes, which we predicted would also be specifically impaired in TD schizophrenic patients. Finally, we examined participants' performance on a task of language production—verbal fluency—that also required participants to access and retrieve appropriate lexical items according to a given context. Following previous studies (e.g., Allen, 1983; Allen, Liddle, & Frith, 1993; Joyce, Collinson, & Crichton, 1996), we predicted that schizophrenic patients as a whole would produce fewer items than would healthy control participants and that TD patients would produce a higher proportion of incorrect (i.e., contextually inappropriate) items than would non-TD patients.

Method

Participants

Schizophrenic patients, ages 18 through 65 years, were recruited from the Maudsley and Bethlem Royal Hospitals, London, United Kingdom. Diagnoses were made by staff psychiatrists and were confirmed by a psychiatrist (Gina R. Kuperberg), using a structured clinical interview and examination of the case notes. All patients met criteria for schizophrenia from the *Diagnostic and Statiscal Manual of Mental Disorders* (4th ed.; *DSM–IV*; American Psychiatric Association, 1994). An initial "screening" process took place such that patients whose speech was judged by at least two mental health professionals as either markedly incoherent or coherent were selected for further testing. All patients had positive symptoms at the time of testing. Twenty-three of the schizophrenics were in-patients, seen at least 2 weeks into admission (in the subacute phase of illness), and 4 were out-patients with chronic positive symptoms. All were receiving stable doses of antipsychotic medication (see Table 1) and 11 patients were taking anticholinergic medication. Ten healthy control participants were selected from hospital staff (nurses,

Table 1
Demographic and Psychopathological Data of Normal Controls, Non-Thought-Disordered (Non-TD) and Thought-Disordered (TD) Schizophrenic Patients

Parameter	Participant group			
	Control[a]	Non-TD[b]	TD[c]	p[d]
Gender (M/F)	8/2	8/2	17/0	.05
Race (C/AC)	7/3	6/4	11/6	1.00
Handedness (R/L)	8/2	7/3	13/4	.12
Age (years)	32 (9)	36 (16)	38 (11)	.50
Education (years)	11 (2)	10 (1)	10 (2)	.14
Premorbid verbal IQ[e]	113 (8)	109 (8)	112 (10)	.57
Anticholinergics (+/−)		4/6	7/10	1.00
CPZ equivalent[f]		490 (341)	435 (246)	.63
Duration of illness (years)		11 (13)	14 (11)	.61
BPRS				
Hallucinations		2.8 (1.5)	2.3 (1.3)	.37
Thought content		4.5 (1.7)	4.1 (1.2)	.44
Bizarre behavior		1.9 (1.3)	2.6 (1.1)	.16
Attention		2.0 (1.2)	2.8 (1.1)	.47
Total		43.7 (5.2)	48.5 (7.0)	.07
HENS		8.4 (3.4)	9.3 (5.2)	.61

Note. Means are shown with *SD*s in parentheses. M = male; F = female; C = Caucasian; AC = African Caribbean; R = right; L = left; CPZ = chlorpromazine; BPRS = Brief Psychiatric Rating Scale (averaged over four sessions); HENS = High Royds Evaluation of Negativity Score (averaged over four sessions). [a] n = 10. [b] n = 10. [c] n = 17. [d] p values are for Fisher's exact tests (two-tailed; for gender, race, handedness, and anticholinergics), one-way ANOVAs (for continuous demographic variables), and two-tailed t tests (for psychopathological variables). [e] Assessed using the National Adult Reading Test (NART; Nelson & O'Connell, 1978.) [f] Average daily oral doses of antipsychotics and weekly depot doses were converted to chlorpromazine equivalents (Bazire, 1998, p. 119).

porters, catering staff). These participants were screened to exclude past or present psychiatric diagnoses. Exclusion criteria for all participants were first language other than English, intercurrent organic illness, neurological disorder, recent substance abuse or dependence (defined according to the *DSM–IV*), and recent electroconvulsive therapy (within 6 months). Written consent was obtained from all participants before participation. Forty-seven participants initially agreed to take part. One control and 9 patients failed to complete all four sessions, leaving 37 participants (27 schizophrenic patients and 10 controls). The patients who failed to complete all four sessions did not differ from the included patients on overall psychopathology or severity of thought disorder.

Overall Procedure and Clinical Assessment of Patients

Each participant was seen on four separate occasions and performed the on-line word-monitoring task on all four sessions.[1] They also carried out the off-line sentence-judgment task and a verbal fluency task on one of the sessions. All participants were administered the National Adult Reading Test (NART; Nelson & O'Connell, 1978) as an estimate of premorbid verbal IQ (see Table 1). Each patient's symptomatology was rated using the Brief Psychiatric Rating Scale (BPRS; expanded version 4.0; Lukoff, Liberman, & Nuechterlein, 1986) and the High Royds Evaluation of Negativity Scale (HENS; Mortimer, 1989). Thought disorder of all participants (patients and controls) was assessed on each session, using items of the Thought, Language, and Communication Index (TLCI; Liddle, 1995). The TLCI uses a series of pictures presented one at a time to elicit disordered speech. Participants were asked to respond to each picture, and these responses plus those to further questions were rated according to poverty of speech, vagueness, weakening of goal, perseveration, "looseness of association" (encompassing tangentiality and derailment), peculiar word usage, peculiar sentence construction, peculiar logic, and distractibility.[2] The scale was adapted in the following way for use in this study: First, two pictures were shown on each session, so that eight different pictures were shown over the four sessions. Second, because the main purpose was to dichotomize participant groups, those who displayed unequivocal evidence of each item when describing a picture were given a score of 1, whereas those who displayed minimal evidence were given a score of 0. In the light of previous factor analyses (Liddle, 1987; Peralta, Cuesta, & de Leon, 1992), we calculated a positive thought-disorder or "verbal disorganization" score on each session by summing the following five subscores of the TLCI: looseness of association, peculiar word usage, peculiar sentence construction, peculiar logic, and distractibility. Scores were then summed over the four sessions, and patients were grouped on this basis. Altogether there were 10 control participants (each with a summary positive thought-disorder score < 4), 10 non-TD patients (each with summary positive thought-disorder score < 8), and 17 positively TD patients (each with summary positive thought-disorder scores of >17). The remaining subscores on the TLCI were also summed over the four sessions: poverty of speech, vagueness, weakening of goal, and perseveration to give a measure of "impoverished thinking" for each participant. There was no difference between the positively TD and non-TD groups in degree of "impoverished thinking," $t(25) = 0.08$, $p = .94$, or "poverty of speech," $t(25) = 0.06$, $p = .95$.

On-Line Word-Monitoring Task

Stimulus materials. The stimuli were originally devised for the study of healthy volunteers and aphasic patients (see Tyler, 1992).

[1] Both clinical rating and testing were conducted by Gina R. Kuperberg.

[2] Further details of the Thought, Language, and Communication Index can be obtained from Peter Liddle at University of British Columbia, 2255 Wesbrook Mall, Vancouver, British Columbia, V6T 2A1 Canada.

Thirty-two common nouns were chosen as target words and sentence pairs were constructed for each of them (see Table 2). The first sentence of each pair provided a minimal, and not highly constraining, context for the interpretation of the second sentence. The second sentence always took the same form: a subject noun (or noun phrase) followed by a verb, followed by an object noun (or noun phrase). The object noun was the target word. The sentence continued with at least one other clause after the target. In the example given in Table 2, the target noun is *guitar.*

The verb preceding the target noun varied such that the sentence was rendered pragmatically, semantically, or syntactically implausible. Participants were asked simply to monitor for the target word in each of these experimental conditions. The same word was used in all four conditions to exclude the possibility that any differences found between conditions were due to differences in participants' recognition of different words. To prevent participants from encountering the same word more than once in a single test session (and consequent repetition priming effects), we tested participants on four different sessions, using four different test "versions." The 32 sentence pairs were mixed in with 44 filler sentence pairs in which the sentence violation condition was varied randomly. The position of the target word in the filler sentences was also varied randomly to prevent participants from anticipating when to respond. Thus, in each test version, there were 76 sentences: 32 test sentences (8 of each prose violation condition) and 44 filler sentences. Target nouns of all four sentence types were distributed in a pseudorandom order (into four *itemclasses*) across all four versions. The same fillers were used in each version.

Procedure. Participants were presented with the target word, printed on a card, which they were asked to read aloud. The card stayed in front of the participant throughout the trial. They then listened to prerecorded sentences over headphones and were requested to press a response button when they heard the target word. The onset of each target word triggered a timing device that was stopped when the participant pressed the response button, thus recording the RT in recognizing each target word. Misses and anticipations were also recorded. Each participant was tested on four different sessions (one version per session) with approximately 4–6 days in between sessions. Nine practice sentences were presented at the beginning of each version. Each version took approximately 25 min to complete. The four test versions were administered in pseudorandom order across all participants. The investigator was unable to hear the sentences and so could not influence participants' responses in any way.

Data preparation. First, anticipations (pressing the button before the beginning of the word: all RTs less than 100 ms) and misses (not responding at all) were removed from the analysis. The distribution of RTs in all three participant groups was skewed to the right and had outliers. We therefore repeated all analyses using two different modifications of the raw data.[3] In every case, when a significant result was evident from analysis of the raw data, it was also obtained from analysis following either of the modifications.

Design. We examined the effects of group (control, TD, non-TD) and of sentence type (normal, pragmatically, semantically, and syntactically anomalous) on RT. For each main analysis, two subanalyses were conducted, giving rise to two different F values, F_1 for the subjects analysis and F_2 for the items analysis. In the subjects analysis, the RTs of each individual subject were collapsed across items to give average RTs for each sentence type and version. In the items analysis, the RTs for each of the 32 individual items (test words) were collapsed across subjects within each group to give average RTs for each sentence type and itemclass.

Off-Line Anomaly Detection Task

Procedure. At the end of their final on-line testing session, participants listened once more to the 76 sentences they had heard on their first testing session. All sentences (the 32 test items plus 44 fillers) were counted as test items. Thirty-eight sentences made sense, and 38 included some sort of linguistic violation (pragmatic, semantic, or syntactic/subcategorization). After hearing each sentence, participants were asked to indicate whether it "made sense" or not, that is, whether it was an acceptable utterance of English. The instructions were not more specific than this because of the different types of anomalies in the sentences. All participants appeared to understand the instructions. During a debriefing session at the end, many patients asked to go through some of the sentences again. This provided an opportunity to discuss some of the patients' responses to the sentences (which were available in written form).

Data analysis. Probabilities of hits and false alarms were used to calculate a nonparametric measure of sensitivity for each patient. This was A′, a signal-detection index (signal:noise discrimination level) and is a better reflection of overall sensitivity to sentential incongruity than percentage of correct judgments (discussed in Linebarger, Schwartz, & Saffran, 1983). In determining the A′ values, we used the formula developed by Grier (1971): $A' = 0.5 + (y - x)(1 + y - x)/4y(1 - x)$, where x = proportion of false positives and $y = 1 -$ proportion of false negatives.

Verbal Fluency

At the end of one of the four testing sessions, each participant carried out two verbal fluency tasks, letter and category fluency, according to standard methodology (Spreen & Benton, 1969). In a letter fluency task, participants were asked to produce as many different words as they could beginning with the letters, *F, A,* and *S* for a period of 1 min each. In the category fluency task, participants were asked to name as many instances as possible in 1 min of the following categories: articles of clothing, articles of furniture, and occupations. For both tasks, the total number of correct items was recorded. Errors were categorized as alternative forms of the same words, repetitions, perseverations (a word from a previous response category), neologisms, and associations (items that did not begin with the specified letter or fall into the specified category).

Results

On-Line Word-Monitoring Task

Anticipations and misses. The percentage of anticipations in the TD, non-TD, and control groups, respectively, was 0.5% (SD = 0.7), 0.7% (SD = 0.7), and 1.1% (SD = 1.1). The percentage of misses in the TD, non-TD, and control groups, respectively, was 3.9% (SD = 1.6), 1.1% (SD = 1.0), and

[3] The first modification involved trimming the data. Following Ulrich and Miller (1994), we removed only extreme outliers (>1,500 ms). This is particularly important in patient groups in which RTs are generally longer than those of normal controls. The cut-off value was determined as follows: Raw data distribution plots were drawn for each group of participants in each type of sentence. These showed that in all three participant groups, RTs of more than 1,500 ms were far removed (more than 2 SDs) from the rest of the distribution. Furthermore, when this cut-off value was used, outliers were not concentrated in any particular type of sentence and so would be unlikely to bias the results. The percentage of extreme outliers in the TD, non-TD, and control groups, respectively, was 1.7% (SD = 2.3), 1.1% (SD = 1.3), and 0.3% (SD = 0.5), $F(2, 34) = 1.90, p < .16$. The second modification was to apply a logarithmic transformation to the raw data. This has the advantage of not only reducing the skew but stabilizing the variance between the three participant groups.

Table 2
On-Line Word-Monitoring Paradigm: Types of Linguistic Violation

Linguistic violation	Explanation	Example
None	Baseline condition against which the other conditions are evaluated.	"The crowd was waiting eagerly; the young man grabbed the *guitar* . . ."
Pragmatic	The verb preceding the target is replaced by another verb of the same frequency. This makes the sentence pragmatically implausible with respect to our knowledge of real world events.	"The crowd was waiting eagerly; the young man buried the *guitar* . . ."
Semantic (selection restriction)	Verbs are selected so that their semantic properties are incompatible with the semantic properties of the noun.	"The crowd was waiting eagerly; the young man drank the *guitar* . . ."
Syntactic (subcategory violation)[a]	Intransitive verbs are chosen that cannot be followed by a noun in direct object position.	"The crowd was waiting eagerly; the young man slept the *guitar* . . ."

Note. From *Spoken Language Comprehension: An Experimental Approach to Disordered and Normal Processing* (p. 107), by L. K. Tyler, 1992, London: MIT Press. Copyright 1992 by MIT Press. Adapted with permission.
[a] In this condition, the sentence is rendered anomalous by a violation of the syntactic specification in the lexical entry of the verb; that is, it is a subcategory violation. However, in all of the sentences of this condition, the *meaning* of the intransitive verb was incompatible with the overall meaning of the sentence. In the example given, if one were to insert the preposition *with,* following the intransitive verb *slept,* thereby creating a grammatically correct sentence, the sentence would still be pragmatically anomalous; that is, it is unlikely a man would sleep with a guitar. In the present study, we refer to these violations as *syntactic.* However, it should be noted that they are also semantic or pragmatic violations. Indeed, all stimuli were hierarchically organized; that is, the semantic anomaly was also by definition a pragmatic anomaly and the "syntactic anomaly" was also a semantic–pragmatic anomaly.

0.2% (SD = 0.3). The number of anticipations and misses were each entered into separate 3 (group: TD vs. non-TD vs. control) × 4 (sentence type: normal vs. pragmatically vs. semantically vs. syntactically anomalous) repeated measures multivariate analyses of variance (MANOVAs), with sentence type as the within-subject variable and group as the between-subject variable. There were no significant main effects or interactions in the number of anticipations. There was a significant main effect of group in the number of misses, $F(2, 34) = 35.00$, $p < .0001$. Simple between-group contrasts showed that the TD group had significantly more misses than had the non-TD group, $t(34) = 5.88$, $p < .0001$, but that the number of misses in the non-TD group was not significantly greater than that of the control group, $t(34) = 1.72$, $p < 0.09$. There was no main effect of sentence type, $F(3, 102) = 0.31$, $p = .82$, and no Group × Sentence-Type interaction, $F(6, 102) = 1.35$, $p = .24$.

RTs: Group differences. Our main question was whether there was an effect of group (control, TD, non-TD) and of sentence type (normal, pragmatically, semantically, or syntactically anomalous) on RT. In the subjects analysis, mean RT values were entered into a 3 (group) × 4 (sentence type) × 4 (version) repeated measures MANOVA, with version and sentence type as within-subject variables and group as the between-subject variable. In the items analysis, mean RT values were entered into a second repeated measures MANOVA: 3 (group) × 4 (sentence type) × 4 (itemclass, the order in which target words were distributed across the four versions), with group and sentence type as within-subject variables and itemclass as the between-subject variable.

As anticipated, there was a significant main effect of group, with patients being slower than the controls, $F_1(2, 34) = 12.04$, $p < .0005$; $F_2(2, 56) = 292.26$, $p < .0001$. The mean overall RT was 393 ms for the TD group (SD = 73), 311 ms for the non-TD group (SD = 58), and 275 ms for the control group (SD = 50). Planned two-tailed t tests revealed that, although the TD group was significantly slower overall than the non-TD group, $t(25) = 3.1$, $p < .005$, there was no significant difference between the RTs of the TD and non-TD group in recognizing words in the syntactically violated sentences, $t(25) = 1.77$, $p = .09$. There was also a significant overall effect of sentence type, $F_1(3, 102) = 77.56$, $p < .0001$; $F_2(3, 84) = 83.32$, $p < .0001$. In the subjects analysis, there was no main effect of version, $F(3, 102) = 1.11$, $p = .4$, no two-way interaction between version and sentence type, $F(9, 306) = 1.29$, $p < .24$, and no three-way interaction between version, sentence type, and group, $F(18, 306) = 1.26$, $p < .24$.[4] There was no effect of itemclass in the items analysis ($F < 1$).

[4] The absence of a significant two-way interaction between version and sentence type rules out any effects that might have been produced by virtue of the target items being presented more than once, albeit in different contexts.

We were most interested in the *pattern* of RTs between the three subject groups across the four different sentence types. As hypothesized, there was a highly significant interaction between group and sentence type, $F_1(6, 102) = 6.21, p < .0001$; $F_2(6, 168) = 9.29, p < .0001$. This is depicted in Figure 1. The control and non-TD schizophrenic group show similar patterns of RTs that increase across the four different sentence types from normal to pragmatically to semantically to syntactically anomalous. The TD patients showed a different and strikingly "flat" pattern: Despite having longer RTs overall, there appeared to be little effect of the different linguistic violations.

In the subjects analysis, we used polynomial contrasts to examine the differences between the three groups in the linear trends in RT across the four sentence types. This showed a significant Sentence Type × Group interaction in the linear component, $F(2, 34) = 12.00, p < .0001$. Simple between-group contrasts (comparing each group to the non-TD group) were used to examine the source of this interaction: The contrast in the linear component was significantly different between the TD and non-TD group, $t(34) = 3.09, p < .004$, but not between the non-TD and control group, $t(34) = 1.4, p = .17$. This confirmed that the TD participants showed a significantly shallower trend in increasing RT over the four sentence types than did the other two groups. The linear trend across the four sentence types was used as a summary measure of on-line task performance (on-line sensitivity to the linguistic violations) in the regression analyses described below.

Another way of examining these results is to compare the relative increases in RT for each of the anomalous sentence types over and above the baseline (undisrupted) condition in the three participant groups. This would give a measure of "on-line sensitivity" to each of the linguistic violations: pragmatic, semantic, and syntactic. We therefore calculated difference scores for each participant by subtracting his or her baseline

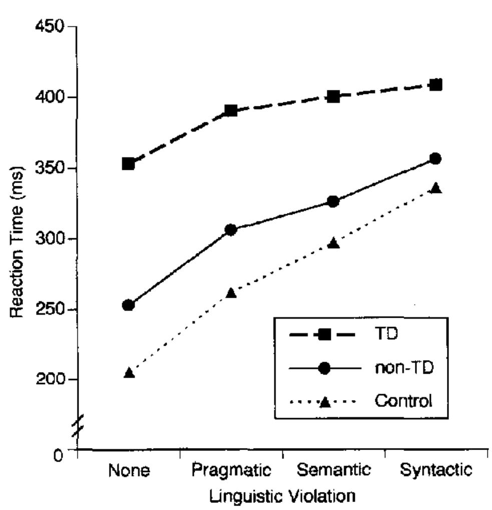

Figure 1. Mean reaction times to recognize target words in normal and linguistically violated sentences in thought-disordered (TD) schizophrenic participants ($n = 17$), non-thought-disordered (non-TD) schizophrenic participants ($n = 10$), and nonschizophrenic control participants ($n = 10$).

RTs (in the normal sentences) from his or her RTs in each sentence type. When the differences between each linguistic anomaly condition and baseline condition were entered into a second repeated measure MANOVA, there was a main effect of group, $F_1(2, 34) = 9.40, p < .001$; $F_2(2, 62) = 10.15, p < .0001$. The mean RT differences in the TD, non-TD, and control groups, respectively, were 42 ms, 76 ms, and 92 ms, indicating that after controlling for the longer baseline RTs, the patient groups were relatively *faster* to respond to words in incongruous sentences than were the controls. Again, there was a significant overall effect of linguistic violation, $F_1(2, 68) = 21.07, p < .0001$; $F_2(2, 62) = 24.97, p < .0001$, and a significant interaction between group and linguistic violation, $F_1(4, 68), p < .02$; $F_2(4, 124) = 5.56, p < .0001$ (see Figure 2). In the subjects analysis, simple "between-group" contrasts were set up such that each group was compared with the non-TD group. This revealed significant differences between the TD and non-TD groups in their sensitivity to pragmatic, $t(34) = 3.2, p < .003$, semantic, $t(34) = 2.0, p < .04$, and syntactic, $t(34) = 3.3, p < .002$, violations. There were no differences (at $p < .3$) between the non-TD and control groups in on-line sensitivity to any of the linguistic violations.

Severity of thought disorder and on-line performance. The relationship between severity of thought disorder and on-line performance within the TD group was examined by using linear regression: The positive summary thought-disorder score of each TD schizophrenic participant in each version was entered as the explanatory variable; summary on-line performance scores (the linear trend across the four sentence types; see above) for each version were entered as the outcome variable. Severity of positive thought disorder was a strong negative predictor of on-line performance ($\beta = -0.4$), $t(66) = -3.5, p < .0007$, that is, the more positively thought disordered the participants, the "flatter" their pattern of RTs across the four sentence types. Neither poverty of speech nor "impoverishment of thinking" (comprising poverty of speech, vagueness, and perseveration) independently predicted on-line performance.

Confounders. The association between thought disorder and on-line performance could have been confounded by other clinical symptoms, medication effects, or demographic variables. To explore this possibility, we entered the summary on-line performance score (the linear trend across the four sentence types, averaged over the four versions) as the dependent variable in a multiple linear regression analysis. The overall average disorganization thought-disorder scores for each schizophrenic patient were entered into the regression equation as a potentially explanatory independent variable. Other independent variables included were gender, race, handedness, years of education, NART score, dose of medication (in chlorpromazine equivalents), and duration of illness. We also included a number of clinical variables (averaged over the four sessions): negative thought-disorder score, total negative symptoms score (HENS), total BPRS score, individual BPRS scores for hallucinations, abnormal thought, content, bizarre behavior, and attention. In this model, a positive thought-disorder score was the only predictor of on-line performance ($\beta = -0.5$), $t(11) = -2.8, p < .01$. A further regression analysis, with stepwise inclusion of potential explanatory variables, yielded a model in which the only independent predictors of on-line performance were thought disorder ($\beta =$

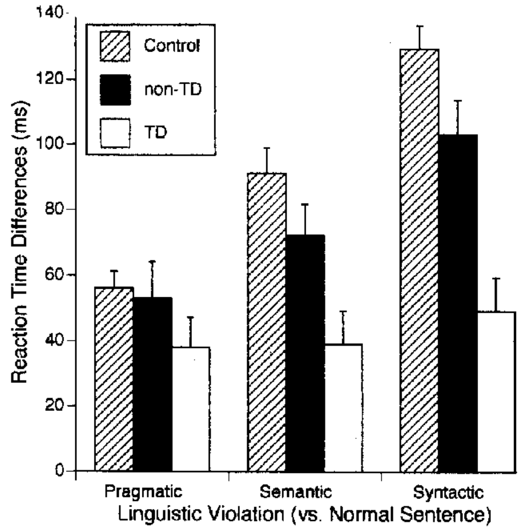

Figure 2. Mean differences in reaction times to recognize target words in linguistically violated sentences versus normal sentences, for thought-disordered (TD) schizophrenic participants ($n = 17$), non-thought-disordered (non-TD) schizophrenic participants ($n = 10$), and nonschizophrenic control participants ($n = 10$). Lines show standard errors of means.

-0.5), $t(24) = -4.7$, $p < .0001$, and negative symptoms ($\beta = -0.5$), $t(24) = -4.4$, $p < .0002$. Within the schizophrenic group, thought-disorder score and negative symptoms did not correlate (Spearman's $r = .12$, $p = .56$). Because there was a significant difference in gender and a difference in total BRPS scores that approached significance between the non-TD and TD patient groups (see Table 1), we conducted a third regression analysis to see whether these acted as confounders: thought disorder score, negative symptom score, total BPRS, and gender were entered simultaneously as independent variables. In this model, TD score ($\beta = -0.56$), $t(22) = -4.3$, $p < .0003$, and negative symptoms ($\beta = -0.51$), $t(22) = -4.4$, $p < .0002$, were still robust predictors, but neither gender ($\beta = -0.15$), $t(22) = -1.18$, $p = .25$, nor total BPRS ($\beta = -0.15$), $t(22) = -1.2$, $p = .23$, predicted on-line performance.

Effect of overall RT. The slower overall RTs in the TD patients, relative to the other two groups, might have contributed to their relative insensitivity to linguistic violations in the on-line task. We therefore conducted a linear regression analysis for all participants in which average RT was entered as the independent variable and summary on-line performance score was entered as the dependent variable. RT did not predict on-line performance ($\beta = -0.24$), $t(35) = -1.2$, $p = .22$. In a second multiple regression analysis for schizophrenic patients alone, average RT was entered together with summary positive thought-disorder score, negative symptom score, gender, and total BPRS score: Positive thought disorder ($\beta = -0.53$), $t(21) = -3.7$, $p < .001$, but not overall RT ($\beta = -0.06$), $t(21) = -0.47$ $p = .64$, predicted the RT trend over the four sentence types. When we used a median split to subdivide the TD group into fast and slow responders, there was no difference between the two groups in on-line performance, $t(15) = 0.57$, $p = .58$; that is, fast responders showed the same relatively flat pattern of RTs across the four sentence types as did slow responders.

Off-Line Anomaly Detection Task

The normal control group was extremely accurate in judging whether sentences made sense (range: percentage of correct judgments = 99–100%; A′ = 0.99–1.00). The non-TD group also performed very well (range: percentage of correct judgments = 82–99%; A′ = 0.89–0.99). Three TD participants failed to complete this task and were excluded from data analysis. The remaining TD participants had A′ scores of 0.84, except for 3 who performed particularly badly with A′ scores of 0.73–0.75. As a group, the TD participants performed worse (mean A′ = 0.87, $SD = 0.079$) than the non-TD participants (mean A′ = 0.94, $SD = 0.04$); $t(22) = 2.97$, $p < .008$. We included all schizophrenic participants in a multiple regression analysis in which the thought-disorder summary scores, as well as potentially confounding demographic and clinical characteristics listed above, were entered simultaneously as independent variables: Severity of positive/disorganized thought disorder was a strong negative predictor of off-line performance ($\beta = -0.779$), $t(8) = -2.6$, $p < .03$. In this highly conservative model, there were no other negative or positive predictors. A second regression analysis, in which TD score, total BPRS, and gender were entered as independent variables, showed that thought disorder score ($\beta = -0.52$), $t(20) = -2.6$, $p < .018$, but neither gender ($\beta = -0.16$), $t(20) = -0.84$, $p = .41$, nor total BPRS ($\beta = -0.26$), $t(20) = -1.4$, $p = .18$, predicted off-line performance.

Verbal Fluency

Three-way analyses of variance (ANOVAs) showed significant differences between the three groups on mean letter fluency correct scores, $F(2, 34) = 8.11$, $p < .001$, mean category fluency correct scores, $F(2, 34) = 11.57$, $p < .0001$, mean number of errors in the category fluency task, $F(2, 34) = 8.7$, $p < .0009$, and mean number of errors in the letter fluency task, $F(2, 34) = 14.2$, $p < .0001$ (see Table 3). We went on to test

Table 3
Verbal (Letter and Category) Fluency Scores of Normal Controls, Non-Thought-Disordered (Non-TD) and Thought-Disordered (TD) Schizophrenic Patients

			Schizophrenic			
	Control		Non-TD		TD	
Score	*M*	*SD*	*M*	*SD*	*M*	*SD*
Total correct output						
Letter fluency	18	5	14	3	12	3
Category fluency	18	4	14	3	11	4
Total no. of errors[a]						
Letter fluency	1	1	2	2	6	3
Category fluency	1	1	2	2	5	4

Note. Mean fluency scores over 60 s are shown.
[a] Calculated by summing alternative forms of the same words, repetitions, *perseverations* (a word from a previous response category), neologisms, and *associations* (out of category or letter items).

our first a priori hypothesis (see introduction), combining letter and category fluency scores, and accounting for several potentially confounding variables: A multiple linear regression analysis in which diagnosis together with gender, years of education, and NART were entered as independent variables (covariates), showed, as predicted, that there was a significant difference in total correct output (letter + category) between the schizophrenic participants as a whole and normal controls ($\beta = 0.53$), $t(32) = 4.46$, $p < .0001$. Within the schizophrenic group, thought disorder correlated with the proportion of errors ($r = .54$, $p < .002$, $n = 27$), but not with the total number of items produced ($r = -.25$, $p = .2$, $n = 27$). The proportion of errors did not correlate with the total number of items produced ($r = -.33$, $p = 0.1$, $n = 27$). To further explore the relationship between thought disorder, error production, and the total number of items produced, we conducted two further multiple linear regression analyses, in which the potentially confounding variables of gender, years of education, NART score, as well as total BPRS and HENS (negative symptoms score) were entered simultaneously as covariates, together with summary positive thought-disorder scores.[5] These indicated that, within the schizophrenic group, although positive thought disorder did not predict total output ($\beta = -0.1$), $t(20) = -0.44$, $p = .66$, it did predict the proportion of errors produced ($\beta = 0.4$), $t(20) = 2.3$, $p < .03$, confirming our second a priori hypothesis. Years of education was a negative predictor of the proportion of errors produced ($\beta = -0.6$), $t(20) = -3.5$, $p < .001$.

Performance in All Three Tasks: Correlational Analyses

We examined the relationship between thought disorder, performance on the on-line word-monitoring task (summary "trend" score of RTs across the four sentence types), the off-line sentence judgment task (A'), and the proportion of errors produced in verbal fluency within the schizophrenic group. We found a significant positive correlation between on- and off-line performance (Spearman's $r = .45$, $p < .02$, $n = 24$), a significant negative correlation between the proportion of errors in the verbal fluency tasks and performance on the on-line task (Spearman's $r = -.52$, $p < .005$, $n = 27$), and a negative correlation between performance on the off-line task and the proportion of errors in the verbal fluency task that approached significance (Spearman's $r = -.37$, $p = .07$, $n = 24$). Performance on all three tasks showed significant (ps $< .03$) correlations with severity of thought disorder (Spearman's rs $> .44$).

Discussion

On-Line Word-Monitoring Task

We demonstrated that TD schizophrenic patients were faster (relative to their own baseline RTs) to respond to target words preceded by linguistic violations than were non-TD patients or healthy controls. Before going on to discuss theoretical implications of these findings, we consider some alternative explanations.

One possibility is that the relative insensitivity to linguistic violations of the TD patients was a direct consequence of their longer overall RTs. This seems unlikely because the direction of our findings is contrary to that predicted on purely psychometric grounds. Specifically, Chapman, Chapman, Curran, and Miller (1994) have argued that longer overall RTs can lead to an *overestimation* of RT differences between related and unrelated word pairs in semantic priming paradigms; in this study, the RT differences between normal and anomalous sentences were *smaller* in the TD patients than in control groups. It remains possible that the smaller RT differences in the TD patients reflects a floor effect in their performance. Again this seems unlikely: First, the average RT of the TD patients (393 ms) was faster than those seen in normal elderly participants performing the same word-monitoring task who display the normal increase in RT across the four sentence types (Tyler, 1992). Second, within the TD patients, fast responders showed the same relatively flat pattern of RTs across the four sentence types as did slow responders. Third, overall RT failed to predict on-line performance in a regression model. The greater variability in RTs shown by the TD group may have masked a normal pattern of RTs across sentence types by reducing the signal:noise. The TD group also had more misses, which in itself can lead to a decrease in statistical power (Ratcliff, 1993). However, our results held up to two modifications of the raw data: a conservative truncation and a logarithmic transformation.

Several factors, independently associated with thought disorder or performance on working memory or linguistic tasks, could have acted as confounders, including verbal IQ (Miller, 1984), gender (Perry, Moore, & Braff, 1995), handedness (Manschreck, Maher, Redmond, Miller, & Baudette, 1996), duration of illness (Thomas, King, Fraser, & Kendell, 1990), antipsychotic medication (Barch et al., 1996), and anticholinergic medication (Tune, Strauss, Breitlinger, & Coyle, 1982). However, there were no significant differences between the TD and non-TD groups on symptoms other than thought disorder (as assessed by the BPRS) or most of the demographic variables listed in Table 1. Although there was a difference in gender distribution between the TD and non-TD groups, neither gender alone, nor in conjunction with other potential confounders, predicted performance in the on-line task. It could be argued that the TD participants were "iller" than the non-TD schizophrenic participants. However, their total BPRS scores were only slightly and nonsignificantly higher than that of the non-TD group and, again, did not predict on-line performance in a regression analysis.

It is unlikely that TD schizophrenic participants simply could not perform the task or that there was a speed–accuracy tradeoff: Their rate of misses, although higher than in the other two groups, was very low at 3.9%, and their misses were not concentrated in any particular sentence type. The RTs of even the TD patients were very fast, making it unlikely that they were using unnatural time-consuming "garden-pathing" strategies to respond to targets (e.g., reviewing the sentence to see if the given

[5] The total number of errors or correct items is dependent on the total number of items produced. We therefore used two measures in the regression analyses that should be independent: proportion of errors and total number of words produced. We classified neologisms as "contextually inappropriate." However, the results of the regression analyses were the same when the proportion of errors excluding neologisms was used as the dependent variable.

target corresponded with a heard word). We therefore interpret our findings as suggesting that TD schizophrenics are impaired in using linguistic context to process speech *on-line.*

The ability to use linguistic context on-line is essential in speech *production* that involves a stage of conceptual preparation, guiding the retrieval of appropriate words from the lexicon (Levelt, 1989). These higher order semantic–lexical connections are thought to be reciprocally interconnected or shared by speech input and output systems (Levelt, 1989; Monsell, 1987). If such connections are disturbed, inappropriate items may intrude into speech (see Maher, 1983). Thus, it is possible that the same deficit in patients' ability to use linguistic context to perform the on-line word-monitoring task underlies the disorganized speech characterizing schizophrenic thought disorder.

There are several interpretations of this deficit that are not mutually exclusive and that cannot readily be distinguished by our data.

The first possibility is that in the TD schizophrenic patients, there is a failure of feedback activation from higher level representations to the lexical level, leading to relative "hypoactivation" of the appropriate lexical item. This theory presumes an interactive model of normal language processing with top-down contextual influences acting at the stage of lexical selection (Elman & McClelland, 1984; Marslen-Wilson & Welsh, 1978).

The second interpretation assumes that context operates at a stage when pragmatic, semantic, and syntactic/subcategorization information is integrated to construct higher level representations of meaning (Foss & Ross, 1983; Marslen-Wilson, 1987). Integrative processes are sensitive to a wide range of contextual influences, so this explanation would account for the relative insensitivity to the different linguistic violations in the TD group. It would also be consistent with recent electrophysiological findings suggesting that schizophrenic patients, particularly those with thought disorder (Andrews et al., 1993), are impaired in their ability to integrate words into normal sentences (Nizniewicz et al., 1997).

A third possibility is that TD schizophrenic participants are impaired in using information at higher levels of representation to check the selection of the target word after it has been recognized. This checking or monitoring process may be the same as that used to monitor and edit out errors during speech production. In normal individuals prearticulatory speech output is thought to be monitored by means of an internal loop to the speech comprehension system (Levelt, 1989; Monsell, 1987), and speech errors can be detected within 100–300 ms (Levelt, 1989), suggesting that monitoring occurs within the time scale of interest in the current study. Several authors have proposed that thought disorder or schizophrenia is secondary to a deficit in self-monitoring (Frith & Done, 1988; Harvey, 1985) and editing (MacGrath, 1991; Maher, 1983). Leudar, Thomas, and Johnston (1992) found that the internal (i.e., prearticulatory) error detection of speech output was twice as frequent in controls as in schizophrenic patients, but the relationship between error detection and severity of thought disorder was not examined.

Fourth, an impairment in the use of linguistic context may be conceived of as a more general deficit in the use of context, indexed by a variety of cognitive operations, including pigeonholing (see Hemsley, 1975; Schwartz, 1982), working memory (Goldman-Rakic, 1994), and using the "internal representation of context" to guide action (Cohen & Servan-Schreiber, 1992). Some of these cognitive operations may be intrinsic to normal language processing (see, e.g., Ratcliff & McKoon, 1988). An impairment in the use of linguistic context by the TD schizophrenic patients could also be conceived as reflecting an even more global deficit in information processing—a disorder of attention (Doherty, 1996; Landre & Taylor, 1995; Nuecheterlein, Edell, Norris, & Dawson, 1986; Shakow, 1962), attentional fluctuation (Maher, 1972), or distractibility (Harvey & Serper, 1990; Oltmanns, Ohayon, & Neale, 1978). This would be consistent with our observations of more variable RTs and more "misses" in the TD group. Many of these cognitive deficits have been proposed as explanations not only of thought disorder but of other symptoms of schizophrenia (Cornblatt & Erlenmeyer-Kimling, 1985; Hemsley, 1975). Although overall severity of psychopathology, as measured using the BPRS, failed to predict patients' sensitivity to linguistic context in the on-line task, a global measure of negative symptomatology contributed significantly to the variation in on-line performance within the schizophrenic group, independently of thought disorder. Our patients had a relatively narrow range of negative symptoms, limiting the conclusions we can draw from this post hoc observation. Nonetheless, this finding is intriguing in view of the fact that negative symptoms, like thought disorder, are associated with deficits of selective attention (Nuecheterlein et al., 1986).

The explanations above are consistent with the fact that the TD participants showed longer RTs than did the non-TD participants in all conditions except the syntactically violated sentences in which there was no supportive context. They also account for others' observations of reduced semantic priming in schizophrenic patients under certain experimental conditions (Barch et al., 1996; Ober et al., 1995; Vinogradov et al., 1992). They assume a model of normal language comprehension in which higher order conceptual representations are constructed incrementally as participants process speech.[6] A fifth explanation that does not make this assumption and that would also account for the relatively flat pattern of RTs over the four sentence types in the TD group, is that these patients are particularly susceptible to abnormal weak-associative lexical effects operating within the anomalous sentences. This is consistent with Spitzer et al.'s (1993) demonstration of greater *indirect* priming in TD patients. Similarly, TD patients may be impaired in their ability to *inhibit* distracting words within a normal or hyperactive lexical network. This would be supported by findings suggesting that

[6] Sentence context in normal participants is thought to operate not only through a message level of representation but through connections among individual words. In the present study, 15% of the sentences contained a word that was weakly semantically or associatively related to the target word (separated from targets by two to five words on average). However, the same lexically related words were present in both normal and anomalous sentences, making it unlikely that they contributed to the increasing RTs across the four sentence types in the control participants. All the normal sentences were meaningful but of low contextual constraint (e.g., "the man grabbed the *guitar* . . ."), ruling out associative lexical priming between the target noun and its preceding verb in the normal sentences (e.g., "the man *played* the *guitar* . . .") as contributing to the faster RTs in the baseline condition.

schizophrenics are impaired in their ability to inhibit alternative meanings of ambiguous words (Bullen & Hemsley, 1987) and show deficits in other tasks indexing such putative inhibitory processes, such as negative priming (see Hemsley, 1994). However, this explanation would predict that the TD patients would show faster, rather than slower, RTs to recognize words in the anomalous sentences in comparison with controls.

Off-Line Anomaly Detection Task

The on-line nature of the word-monitoring task can be contrasted with the off-line version of the task that tested patients' ability to reflect on the meaning of the final representation of the sentences. Some of the explanations TD patients gave for their answers (e.g., for the *sentence*: ". . . the woman swallowed the boat"; *Reply:* "sense"; *Explanation:* "the woman could swallow a chocolate boat") are consistent with the observations of Tamlyn et al. (1992) who noted that schizophrenic patients, particularly those who were thought disordered, tended to give illogical explanations when asked to make true–false judgments on a "silly sentence" task. Unlike the on-line task, off-line performance was evaluated only once, and the effect of different linguistic violations was not examined. Moreover, performance on off-line verbal tasks is more vulnerable to general cognitive deficits than the more "automatic" on-line procedures. However, even when we controlled for the NART score and years of education, TD patients still performed worse on this task than did control groups, extending previous studies suggesting that schizophrenics have difficulty in discriminating normal from linguistically violated sentences (Amand, Wales, Jackson, & Copolov, 1994).

Verbal Fluency

Our finding of a reduced number of items produced by schizophrenic patients on verbal fluency tasks accords with several previous studies (e.g., Allen, 1983; Allen et al., 1993; Joyce, Collinson, & Crichton, 1996) and is thought to reflect impaired *access* to items stored in verbal memory (Allen, 1983; Allen et al., 1993). Although the positively TD patients produced the same number of words in total as did the non-TD patients, a significantly higher proportion of these words were errors. That the proportion of errors did not correlate with the total number of words produced and that thought disorder predicted the former but not the latter, support the idea that the ability to access and to select contextually appropriate items, are independent processes (Marcel, 1983) and that positive thought disorder is particularly associated with an impairment of appropriate selection. The mechanism by which appropriate items are normally selected is unclear. One theory is that, following unselective activation, task-inappropriate items are suppressed or inhibited (Perret, 1974). Further work using tasks specifically designed to tease out these processes (Burgess & Shallice, 1996; Nathaniel-James & Frith, 1996) will be valuable in examining these relationships more closely.

Further Questions

Each task used in this study was designed to tap into a different aspect of language processing: The on-line task indexed a rapid, ongoing interaction between the lexicon and higher levels of representation, the off-line task involved higher order strategic processes, and the proportion of errors produced on the fluency tasks indexed appropriate selection of items from long-term verbal memory stores. Our finding of significant correlations between severity of thought disorder, proportion of errors produced on verbal fluency, sensitivity to linguistic context in the on-line monitoring task, and ability to detect linguistic violations in the off-line task, supports the theory that the impaired performance of TD patients on each of these tasks may reflect a common underlying impairment in the use of linguistic context, although the precise relationship between these factors merits further scrutiny.

Several authors have noted that positive thought disorder is itself heterogeneous and is unlikely to be a unitary construct (e.g., Andreasen, 1986). This heterogeneity could be further investigated by examining the relationship between different subcomponents of positive thought disorder (e.g., tangentiality, illogical speech, neologisms) and sensitivities to each of the linguistic violations on the on- and off-line tasks. Another question is whether, within the same patients, on-line sensitivity to linguistic context changes with severity of thought disorder over time. This could be addressed by constructing "processing profiles" of individual patients (see Tyler, 1992). This cognitive–neuropsychological approach has recently been advocated in psychiatry (David, 1993) and has some precedent in schizophrenia (Shallice, Burgess, & Frith, 1991). Preliminary work in patients whose severity of thought disorder varied over the four sessions indicates that performance on the on-line task varied in parallel, suggesting on-line sensitivity to linguistic context is a state rather than a trait feature of schizophrenic thought disorder.

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