Sensitivity to linguistic anomalies in spoken sentences: a case study approach to understanding thought disorder in schizophrenia

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ABSTRACT

Background. As a group, positively thought-disordered (TD) schizophrenic patients are relatively impaired in their ability to use linguistic context to process sentences online (Kuperberg *et al.* 1998). This study investigates the heterogeneity in the use of linguistic context both between individual TD patients and within the individual patients as severity of thought disorder changes over time.

Methods. Seventeen TD schizophrenics performed an online word-monitoring task on four separate occasions. In each patient, baseline reaction time (RTs) to target words in normal sentences were subtracted from RTs to target words in pragmatically-, semantically- and syntactically-violated sentences to obtain a measure of online sensitivity to each type of linguistic violation, and these were compared with normative data of a healthy volunteer and a non-TD schizophrenic control group. In addition, the co-variation of severity of thought disorder and sensitivity to linguistic context within all individual TD patients over the four testing sessions, was examined.

Results. There was marked heterogeneity between individual TD patients in their sensitivity to different types of linguistic violations: some were selectively insensitive to pragmatic violations, while others were insensitive to semantic and syntactic (subcategorization) violations. There was also an inverse relationship between severity of thought disorder and sensitivity to linguistic violations within individual patients over the four sessions.

Conclusions. It is likely that a single cognitive deficit does not account for all types of schizophrenic thought disorder, but rather that there are multiple deficits affecting specific levels of linguistic processing. In these schizophrenic patients, impairment in the use of linguistic context was related to the state, rather than the trait, of thought disorder.

INTRODUCTION

Positive thought disorder, characterized by tangential and disorganized speech, has long been considered a central feature of schizophrenia. There has been a debate as to whether it results from a deficit at the level of speech production (Chaika, 1982) or, as its name suggests, is truly a disorder of underlying thought (discussed by Critchley, 1964). What is

uncontroversial is that thought disorder can only be assessed and rated by the form of language produced. Thus, another approach is to view it as a disorder of language and to examine it at the level of pragmatics, semantics and syntax. We have previously probed these levels of linguistic processing in a group of thought-disordered (TD) schizophrenic patients using an online word-monitoring paradigm originally devised by Marslen-Wilson *et al.* (1988) and discussed also by Tyler (1992). In this paradigm, subjects are asked to monitor spoken sentences for target nouns in normal sentences (e.g. '…the young man grabbed the guitar…')

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and anomalous sentences. The anomalous sen tences are constructed by manipulating the relationship between the object noun/target word ('guitar' in these examples) and its preceding verb. In pragmatically-violated sen tences (e.g. '…buried the guitar…'), the verb renders the sentence unlikely with respect to our knowledge of real world events; in semantic selection-restriction violations, the featural sem antic properties of the verb are incompatible with those of the noun (e.g. '…drank the guitar…'); in syntactic subcategorization vio lations, intransitive verbs which cannot be followed by a noun in the direct object position, are used (e.g. '…slept the guitar…')[1]†. The latency (reaction time, RT) to recognize target words, reflects the ease with which listeners process the target word with respect to its preceding linguistic context. Normal control subjects show progressively longer RTs to recognize target words in sentences that are violated pragmatically, semantically and syn tactically (Marslen-Wilson *et al.* 1988; Tyler, 1992). We showed that non-TD schizophrenic patients showed the same pattern of increasing RT across the four sentence-types. However, TD subjects, despite having longer RT latencies overall, showed a relatively 'flat' pattern of RT across the four sentence-types, suggesting that, as a group, thought-disordered patients are relatively impaired in their use of different types of linguistic information to process sentences online (Kuperberg *et al.* 1998).

However, a characteristic feature of thought disorder is its variability; there is variation between individuals in the type of speech produced and there may be marked fluctuations in the severity of thought disorder within individuals over time. The problem with com paring the cognitive performance of groups of patients is that, as a result of averaging artefacts, both inter-individual and intra-individual heter ogeneities may be masked. This criticism has often been raised with respect to the use of group studies to study neuropsychological syn dromes (e.g. Caramazza, 1986).

A complementary approach to the exam ination of group data is to look at individual cases. This 'case study approach' has a precedent in schizophrenia where it has been used to

describe variation in the neuropsychological profiles between individual patients (see Shallice *et al.* 1991; Laws *et al.* 1996) as well as changes in the cognitive performance of individual patients whose symptoms change over time (Tracy *et al.* 1995). It has also been used to study individual positive symptoms such as auditory hallucinations (David & Lucas, 1993), delusions (David & Howard, 1994), and, more recently, thought disorder (Oh *et al.* 1998).

This current investigation complements our previous study that examined group data (Kuperberg *et al.* 1998). We take an individual case-study approach to ask two questions.

First, do individual patients show variation in their ability to use different forms of linguistic context, or do all TD patients show a global impairment in the use of linguistic context? In our previous analysis of group data (Kuperberg *et al.* 1998), when we examined RT differences between the normal sentences and each of the three different types of anomalous sentences, we found that, in comparison with both healthy volunteers and non-TD schizophrenic patients, the TD schizophrenic group showed significantly smaller RT differences for each of the different types of anomaly. This finding could result either from a global impairment in the use of linguistic context in each individual, or as a result of different individuals being selectively insensitive to different linguistic anomalies. The question of inter-individual heterogeneity is of relevance when we consider the nature of the underlying cognitive deficit accounting for the impairment in the use of linguistic context within sentences. Dissociations between individual TD patients would suggest that there are multiple deficits at specific levels of language processing. On the other hand, if each patient were relatively insensitive to all types of linguistic violation, this would suggest a single global impairment in the use of context, possibly mediated by a more general cognitive deficit.

To address this question, we conducted a fine-grained analysis of each individual TD subject, comparing their RTs to targets in each of the anomalous sentence-types with their baseline RTs to targets in non-violated sentences. The online word-monitoring paradigm used in this study is particularly well suited to the analysis of sensitivity to different types of linguistic context in individual subjects, and indeed was originally

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† The notes will be found on page 356.

developed to examine online language comprehension in individual aphasic patients (Tyler, 1992).

Our second question was: are the variations in the severity of thought disorder over time shown by individual patients paralleled by changes in sensitivity to linguistic context? Although the course and fluctuation in severity of schizophrenic thought disorder has been well-described (Harrow & Marengo, 1986; Marengo & Harrow, 1997), there have been few investigations of how such fluctuations co-vary with changes in cognitive performance. Some studies have measured patients' performance on general tests of attention (such as the continuous performance task) at a single point in time, proposing that such attentional deficits may be vulnerability factors for the development of positive thought disorder (Nuecheterlein *et al.* 1986; Strauss *et al.* 1993; Pandurangi *et al.* 1994). However, if as we have argued, an impairment linguistic context is a cognitive deficit underlying the symptom of positive thought disorder, then we would predict that the more severe a particular patient's thought disorder, the more impaired he or she would be in using linguistic context. This relationship should hold up if a patient is initially tested when severely thought-disordered and again when the thought disorder has resolved, and vice versa.

In our previous analysis of the group data, we collapsed across different time-points to compute an average TD score and an average measure of sensitivity to linguistic context for each participant (Kuperberg *et al.* 1998). In the current investigation, we first give a detailed description of two patients whose severity of thought disorder varied considerably across the four testing sessions. We then test the hypothesis that the changes in thought disorder severity over the four testing sessions within individual patients, predicts sensitivity to linguistic context over the same four sessions.

METHOD
Participants, clinical assessment and overall procedure
Twenty-seven schizophrenic patients recruited from the Maudsley and Bethlem Royal Hospi-

tals, London and all meeting DSM-IV criteria for schizophrenia, and ten healthy volunteers were seen on four separate occasions over a period of 2–3 weeks and performed the online word-monitoring task on each occasion. Exclusion criteria were: first language other than English, intercurrent organic illness, neurological disorder, recent substance abuse or dependence (defined according to DSM-IV) and recent electroconvulsive therapy (within 6 months).

As previously described (Kuperberg *et al.* 1998), the schizophrenic group was dichotomized into TD and non-TD groups using an adapted version of the Thought Language and Communication Index (TLCI: Liddle, 1995). This index uses a series of pictures presented one at a time to elicit disordered speech. On each testing session, subjects were asked to describe each picture and these responses plus those to further questions were rated; subscores for looseness of association, peculiar word usage, peculiar sentence construction, peculiar logic, and distractibility were summed to give a positive thought disorder score on each testing session. Scores were then summed over the four sessions to give an overall positive TD score, and patients were grouped on this basis: ten were classified as non-thought-disordered (each with an overall positive TD score < 8) and 17 as positively thought-disordered (each with an overall positive TD score of > 17). The TLCI was also administered to the normal volunteers: each had overall positive TD scores < 4.

Each patient's symptomatology was rated on each session using the Brief Psychiatric Rating Scale (BPRS, expanded version 4.0: Lukoff *et al.* 1986) and the High Royds Evaluation of Negativity Scale (HENS: Mortimer, 1989). All participants were also administered the National Adult Reading Test (NART: Nelson & O'Connell, 1978) as an estimate of pre-morbid verbal IQ.

Demographic and psychopathological data of all individual subjects classified as thought-disordered as well as summary data of the three subject groups (TD, non-TD schizophrenics and normal volunteers) are shown in Table 1. Two-tailed Fisher's Exact Tests (for race and anticholinergics), and one-way ANOVAs (for continuous demographic variables) showed no significant differences between the three subject

Table 1. *Demographic and psychopathological data of the healthy volunteer, non-thought-disordered* (*non-TD*) *and thought-disordered* (*TD*) *schizophrenic groups, and of individual TD patients*

Group	Gender (M/F)	Age (years)	Education (years)	Pre-morbid verbal IQ*	Anticholinergics (±)	CPZ equiv.†	Illness duration (years)	BPRS total	HENS	TLCI
Control[a]	8/2	32 (9)	11 (2)	113 (8)	NA	NA	NA	NA	NA	NA
non-TD[b]	8/2	36 (16)	10 (1)	109 (8)	4/6	490 (341)	11 (13)	43·7 (5·2)	8·4 (3·4)	4·6 (2·4)
TD[c]	17/0	38 (11)	10 (2)	112 (10)	7/10	435 (246)	14 (11)	48·5 (7·0)	9·3 (5·2)	27·4 (8·3)
Individual TD patients										
R.F.	M	34	10	21	−	500	4	50	16	38
G.B.	M	35	7	16	+	400	8	44	13	27
K.V.	M	35	11	31	+	1200	22	53	9	37
P.M.	M	31	8	17	+	200	1	48	12	23
D.S.	M	34	8	22	−	150	9	48	19	32
C.A.	M	37	14	39	+	200	12	36	9	17
A.H.	M	44	8	44	+	250	7	46	3	23
W.D.	M	48	8	29	+	666	25	54	9	37
R.R.	M	55	11	26	+	250	30	49	9	41
U.I.	M	18	10	33	+	500	1	60	16	17
S.M.	M	25	9	28	+	500	2	57	8	24
A.M.	M	25	9	39	+	400	5	57	4	23
B.D.	M	36	10	30	−	375	19	56	13	19
A.P.	M	40	10	50	+	625	12	40	4	27
G.H.	M	45	11	31	+	450	15	47	9	19
M.F.	M	47	10	44	+	400	27	41	4	38
J.H.	M	61	9	38	+	333	35	39	11	19

For the three subject groups, means are shown with s.d. in parentheses. BPRS, Brief Psychiatric Rating Scale (averaged over four sessions); HENS, High Royds Evaluation of Negativity Score (averaged over four sessions); TLCI, positive TD score of Thought Language and Communication Index (summed over four sessions); CPZ, chlorpromazine; M, Male F, Female; NA, not applicable.

[a] $N = 10$; [b] $N = 10$; [c] $N = 17$.

* Assessed using the National Adult Reading Test (NART, Nelson, 1978).

† Average daily oral doses of anti-psychotics and weekly depot doses were converted to chlorpromazine equivalents (Bazire, 1994).

groups (in all cases, $P > 0.12$), although the difference in gender distribution did just reach significance ($P = 0.05$). Two-tailed t tests revealed no significant differences in HENS ($P > 0.61$) or total BPRS ($P > 0.07$) scores between the TD and non-TD schizophrenic groups.

Stimuli and the word-monitoring task

The stimuli and procedure for the online word-monitoring task have been described previously (see Marslen-Wilson *et al.* 1988; Tyler, 1992; Kuperberg *et al.* 1998) but are summarized here again for clarity.

Thirty-two common nouns were chosen as target words and sentence-pairs were constructed for each of them. 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. The verb preceding the target noun varied such that the sentence was rendered pragmatically, semantically or syntactically implausible (defined as outlined in the Introduction). The 32 sentence-pairs were mixed in with 44 filler sentence-pairs in which the sentence violation condition was varied randomly. Sentences were subdivided into four different test 'versions'. Thus, in each test version, there were 76 sentences: 32 test sentences (eight of each sentence violation condition) and 44 filler sentences. Target nouns of all four sentence-types were distributed in a pseudo-random order (into four 'itemclasses') across all four versions. The same fillers were used in each version. On each of the four testing sessions (with approximately 4–6 days in between sessions), subjects encountered a different version.

Subjects listened to these pre-recorded sentences over headphones. Their task was to press a response button as soon as they heard the target word (in all cases, the object noun). Before each sentence trial, the target word was presented visually, on a card. The onset of each target word silently triggered a timing device that was stopped when the subject pressed the response button. In this way, the RT to recognize each target word on each trial was recorded. The RT for each trial was recorded by the experimenter.

Data analysis

Data preparation

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. We then repeated all analyses with two modifications of the raw data: the first was trimming the data, following Ulrich & Miller (1994), only extreme outliers were removed. This is particularly important in patient groups where reaction times are generally longer than normal controls. We chose a cut-off value of 1500 ms by plotting raw data distribution plots for each group of subjects in each type of sentence. These plots showed that in all three subject groups, RTs of more than 1500 ms were far removed (more than two s.d.s) 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 second modification was by applying a logarithmic transformation. This has the advantage of not only reducing the skew, but stabilizing the variance between the three subject groups. 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.

Data analysis

For each individual thought-disordered patient, we used ANOVAs to examine the sensitivity to each type of linguistic information. In these ANOVAs, each item (target word) was considered a 'case' and test version and sentence-type were the factors (each with four levels). In each ANOVA, we set up planned contrasts between each violation condition and the undisrupted baseline condition. We also compared difference scores (baseline RT to recognize target words in normal sentences subtracted from RT to recognize target words in a particular experimental condition) to the confidence intervals of difference scores for the two control groups: non-TD schizophrenic patients and healthy volunteers (see below). Both these methods have been used successfully by Tyler (1992) in her examination of individual aphasic patients.

To address the question of whether there is an inverse relationship between online sensitivity to linguistic context and severity of positive thought disorder within individual subjects over time, we used a regression model in which the thought disorder score of each individual thought-disordered subject on each testing session was entered as a within-subject predictor variable. The rationale for using this method of analysis, together with further details, are given in the Results section.

RESULTS

Online sensitivity to pragmatic, semantic and subcategorization violations of individual subjects

We were primarily interested in whether, following a particular linguistic anomaly, individual thought-disordered patients showed significant differences in RT in comparison with their own baseline RTs (in recognizing target words in normal sentences). The average RT differences between the baseline (undisrupted) condition and the three violation conditions, for each TD patient, are shown in Table 2. The results of planned contrasts between normal sentences and each anomalous sentence-type in separate ANOVAs for each TD patient are also shown in Table 2: an asterix is used to indicate when a particular patient's RT to recognize a target in one of the anomalous sentence-types was significantly longer than in the normal sentences.[2]

Individual ANOVAs alone are not sufficient for deducing the sensitivity of an individual patient to a particular violation. A complementary approach is to compare RT differences for individual patients with the averaged RT differences of the two control groups (non-TD patients and normal volunteers). We therefore followed Tyler (1992) by determining whether an individual's RT difference fell outside the 95 % confidence intervals of each control group. These confidence limits are shown at the top of Table 2. Patients' difference scores that lay within the 95 % confidence limits set by the non-TD control group are indicated.

From Table 2, it can be seen that nine patients (R.F., G.B., K.V., P.M., D.S., C.A., A.H., W.D., R.P.) failed to show significant differences

Table 2. *Reaction time differences between each anomaly-type and baseline (*normal sentences*) in the two control groups (*healthy volunteer and non-thought-disordered schizophrenics*) and in individual thought-disordered schizophrenics*

	Normal–pragmatic	Normal–semantic	Normal–categorical
Control groups (Cls)			
Healthy volunteers	51–73	53–91	89–128
Non-TD schizophrenics	39–84	46–91	86–131
Individual thought-disordered patients			
R.F.	26	8	−17
G.B.	−5	1	−1
K.V.	21	−4	35
P.M.	6	−17	−4
D.S.	32	−4	3
C.A.	33	−5	28
A.H.	82†	20	−1
W.D.	55†	3	27
R.P.	95†	58†	18
U.I.	43*†	45	57
S.M.	63*†	−12	0
A.M.	7	102*†	66
B.D.	66†	93*†	51
A.P.	−28	79*†	133*†
G.H.	34	82*†	140*†
M.F.	83*†	84*†	67*
J.H.	125*†	84*†	127*†

For the two control groups, 95 % confidence intervals (CIs) are shown. For the individual thought-disordered patients, average differences in RT between each type of anomaly and normal sentences are shown (non-TD, non-thought-disordered; TD, thought-disordered).
* Significant difference in RT as compared to normal sentences, $P < 0.05$.
† RT difference lies within the confidence intervals (or greater than the upper confidence limit) of the non-TD group.

in RT between normal and the three types of anomalous sentences. However, in three of these patients (A.H., W.D., R.P.) the RT differences between normal and pragmatically-anomalous sentences lay within confidence limits of non-TD control group and in one patient (R.P.) this was also the case for semantically-anomalous sentences. Two patients (M.F., J.H.) showed statistically-significant differences between normal and all three types of anomalous sentences. Two patients (U.I., S.M.) showed statistically significant differences only between baseline and pragmatically-anomalous sentences. Four patients (A.M., B.D., A.P., G.H.) showed statistically significant differences between baseline and semantically-anomalous sentences; of note, in two of these patients (A.M., B.D.) these RT differences were greater than the upper confidence limit of non-TD group. A.P. and G.H. also showed significantly different RTs between normal and sub-categorically-anomalous sentences.

Online sensitivity to linguistic anomalies over time

In the previous section, we focused on inter-individual variation in sensitivity to different types of linguistic anomalies, averaging both TD scores and RTs over testing sessions. However, all the subjects who performed the online task were clinically assessed on each testing session. This allowed us to examine how online sensitivity to linguistic context co-varied with changes in the severity of thought disorder over time, within each individual.

Qualitative examination of two individual patients

Fig. 1 shows a frequency distribution of the range (maximum score – minimum score) in thought disorder severity over the four testing sessions, shown by the 17 TD patients. Although, in most of these patients, scores were reasonably stable, there were two clear outliers – C.A. and G.H. C.A.'s thought disorder score changed 6 points over the four sessions and G.H.'s thought disorder score changed 7 points over the four testing sessions. When initially tested, C.A. was markedly thought-disordered; however, this improved rapidly so that by the fourth session, his positive TD score fell within the range of scores shown by the non-TD schizophrenics. In
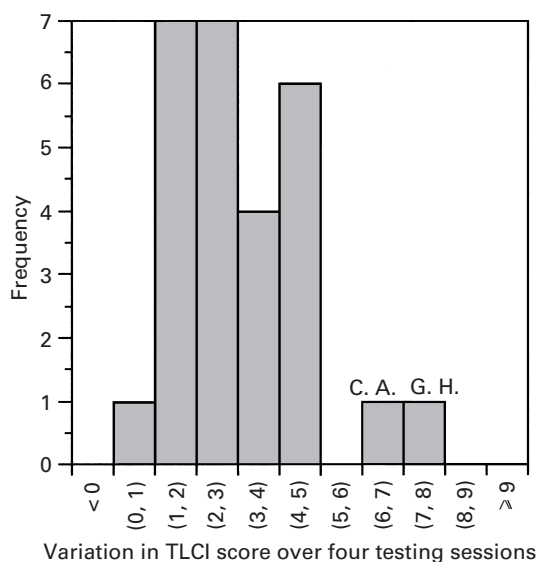

FIG. 1. Histogram showing frequency distribution of the variation of positive thought disorder scores as measured by the TLCI. The x-axis indicates the variation of scores over the four testing sessions (the minimum score subtracted from the maximum score) shown by all thought-disordered subjects ($N = 17$). For example, a range of (4, 5) means that the minimum TLCI score subtracted from maximum TLCI score over the four testing sessions fell between 4 and 5 (inclusive) and from this histogram it can be seen that six patients showed a range in TLCI scores over the four sessions between 4 and 5. G.H. and C.A. are clearly outliers, showing the greatest range of positive TD scores over the four sessions.

contrast, G.H., on his first three testing session, had a low TD score, but had relatively high TD scores on the final testing sessions. Fig. 2 demonstrates the pattern of RTs across the four sentence-types between sessions for these two patients: when rated as least thought-disordered, both patients showed the same incremental increase in RT across the four sentence-types as that observed in the non-TD and normal volunteer groups. However, when most thought-disordered, this relationship broke down. The number of trials (eight) per condition on each testing session was too low to test for significant changes between testing sessions in these two individual patients. We therefore went on to examine changes in sensitivity to linguistic context over time for the whole group of TD patients.

Quantitative examination of changes over time, for all thought disordered subjects

To address the question of whether there was an inverse relationship between online sensitivity to
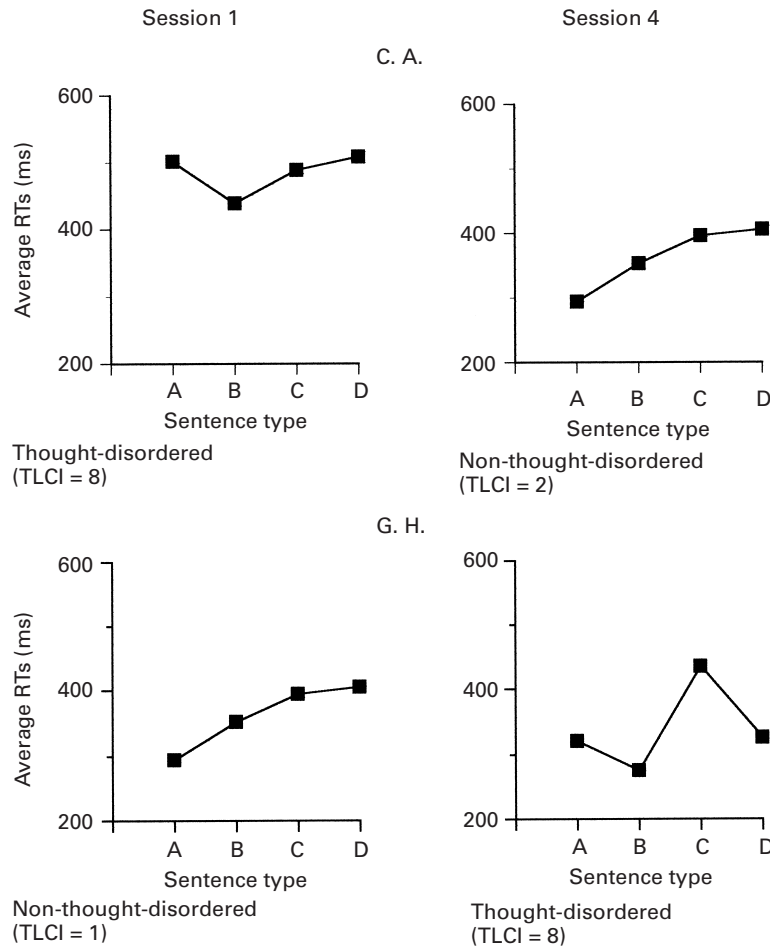
F<small>IG</small>. 2.   Mean reaction times to recognize target words in normal and linguistically-violated sentences, of two patients (C.A. and G.H.), on the first and last testing sessions. A, normal sentences; B, pragmatically-anomalous sentences; C, semantically-anomalous sentences; D, subcategorically-violated sentences. TLCI scores are the positive TD score (derived as described in Methods section) on individual testing sessions.

linguistic context and severity of positive thought disorder within individual subjects over time, we carried out a repeated-measures MANOVA, focusing on the within-subject variation across the four testing sessions. This analysis was conducted as follows.

1 We sought a summary measure of sensitivity to all three types of linguistic context for each individual subject on each testing session, to be used as the dependent variable. As previously described (Marslen-Wilson *et al.* 1988; Tyler 1992; Kuperberg *et al.* 1998), when we collapsed the four different time-points, both control groups (normal volunteers and non-TD schizophrenics) showed an incremental increase

in RT from normal to pragmatically- to semantically- to syntactically-anomalous sentences. As a group, the TD patients showed a 'flatter' pattern of RTs across the four sentence-types (Kuperberg *et al.* 1998). In the current analysis, therefore, we calculated the linear trend in reaction time to recognize target words in normal, pragmatically-, semantically- and syntactically-violated sentence (in that order), for each subject on each testing session. We defined this linear trend as the summary measure of online sensitivity to linguistic context on each testing session, and used this as the dependent variable in the MANOVA.

2 Because we were interested in whether

severity of thought disorder predicted sensitivity to linguistic context within individual subjects (i.e. over the four testing sessions), we used: (*a*) testing sessions as a within-subject factor; and (*b*) thought-disorder score on each testing session as a varying within-subject covariate, in the MANOVA.

3 Our hypothesis was that variation of thought disorder over the four testing sessions, within individual patients, would predict sensitivity to linguistic context on the online word-monitoring task over the same four testing sessions. This was indeed the case: the within-subject covariate (severity of thought-disorder on each of the four testing sessions) varied inversely with online sensitivity to linguistic context over the four testing sessions, $F(1, 47) = 5.6$, $P < 0.02$, i.e. the more positively thought-disordered the subject, the 'flatter' his/her pattern of RTs across the four sentence-types. In contrast, testing session *per se* (the other within-subjects factor) failed to predict severity of thought-disorder, $F(3, 47) = 0.2$, $P > 0.89$.

4 One possibility is that, in these patients, severity of thought disorder over the four testing sessions, indexed fluctuations in the overall severity of illness. In order to rule out this possibility, we repeated the analysis, substituting overall psychopathology (total BPRS score) for TD score as the varying within-subject covariate on each of the four testing sessions. Total BPRS score, however, failed to predict online sensitivity to linguistic context, $F(1, 47) = 0.03$, $P > 0.8$.

DISCUSSION

Inter-individual heterogeneity

In this study, we have demonstrated inter-individual variation in online sensitivity to different types of linguistic information, within a group of TD schizophrenic patients. Before discussing the implications of this finding, we will examine the processing profiles of individual patients in more detail.

Interpretation of results

As Tyler (1992) noted in her analysis of aphasic patients, the interpretation of whether an individual patient is sensitive to particular types of linguistic anomaly can sometimes be difficult. This is because we are using two statistical criteria to measure each patient's sensitivity to

each linguistic anomaly: first, the RT to an anomaly as compared to baseline RTs (in normal sentences), and, second, this RT difference in relation to the confidence intervals of the control (non-TD) group. In most cases, the results were unambiguous: for example, in six patients (R. F., G. B., K. V., P. M., D. S., C. A.), RT differences between the normal and all three types of anomalous sentences were non-significant, and fell below the lower confidence limit of both control groups. Conversely, two patients (M. F., J. H.) showed statistically-significant differences between normal and all three types of anomalous sentences, and these RT differences fell within the confidence limits of the normal control group. In three patients (J. H., A. M. and B. D.) the RT difference between normal and violated sentences lay above the upper confidence limits of the control groups. One possibility is that the greater RT differences shown by these patients is a direct consequence of their longer overall RTs (a frequent observation in schizophrenic patients), as discussed in the context of semantic priming paradigms by Chapman *et al.* (1994). An alternative explanation is that the 'extra-sensitivity' to particular linguistic violations reflects a greater dependence upon particular types of linguistic information to interpret speech input, than unimpaired listeners (discussed by Tyler 1992).

In cases of ambiguity, where a RT difference was not significant but still fell within the control group confidence limits, we interpret the results conservatively (i.e. going against our *a priori* hypothesis that TD patients are relatively insensitive to different types of linguistic context). For example, although the RT differences between normal and pragmatically-violated sentences in patients A. H., W. D. and R. P., were non-significant, they lay within confidence limits of non-TD control group. We interpret this as suggesting that A. H., W. D. and R. P. were able to process pragmatic information online.

Adopting these criteria, six patients (R. F., G. B., K. V., P. M., D. S., C. A.) were globally insensitive to all types of linguistic violations, suggesting that these patients were unable to use pragmatic, semantic or subcategorization information online to develop a sentential representation of meaning. At the other extreme, two patients (M. F. and J. H.) were sensitive to all types of linguistic anomalies.

*Dissociations between different levels of
linguistic processing*

Some patients (U.I., S.M., A.H., W.D.) were
sensitive to pragmatic violations but not to
semantic or subcategorization violations. In
contrast, patients A.P. and G.H. showed sen-
sitivity to both semantic and subcategorization
information but not pragmatic violations. 'Prag-
matic processing' is a rather loosely-defined
term and has been used to refer to a wide range
of cognitive processes, many operating upon
narrative and discourse-level material such as
non-literal language, stories, jokes and conver-
sations. As explained in the Introduction, in the
current study, we use the term 'pragmatic
processing' in a narrow and specific sense to
refer to the use of 'real-world knowledge' within
simple sentences that do not violate selection
restriction or subcategorization (lexically-
encoded) constraints (see discussion in Marslen-
Wilson *et al.* 1988; Tyler, 1992). Thus, the
sentence 'the young man buried the guitar'
appears odd only because of what we know
about guitars and the likelihood of their being
buried (particularly in the context of 'a crowd
was waiting eagerly...'). Pragmatic processing
can be differentiated from the processing of
semantic selection-restriction and syntactic sub-
categorization information: pragmatic pro-
cessing relies entirely on accessing real-world
knowledge and is thought to be located outside
the lexicon. On the other hand, both early
linguistic theory (Chomsky, 1965) and more
modern theories of thematic structure (e.g.
Jackendoff, 1978) have placed not only syntactic
subcategorization information, but also selec-
tion information, within the lexicon.[1] Thus, it
seems that TD patients can be impaired in using
knowledge online both within and outside the
linguistic domain.

Of note, none of the TD patients were
insensitive to syntactically-violated sentences
only. Nonetheless, two patients who were in-
sensitive to semantic violations, were also in-
sensitive to subcategorical violations in associ-
ation with semantic selection-restriction vio-
lations. Given the syntactic violations (e.g. ...the
man slept the guitar...) used in this study could
also be considered semantically- and prag-
matically-violated,[3] these findings are not in-
consistent with the idea that thought disorder

reflects a problem of semantic/pragmatic pro-
cessing rather than syntactic processing (Besche
et al. 1997). Further studies are required to
determine whether TD patients are impaired in
processing purely syntactic information (un-
related to lexico-semantic information) in online
sentence comprehension.

Our previous study showed that, in com-
parison with non-TD schizophrenics and normal
control subjects, TD schizophrenics, as a group,
are relatively impaired in their sensitivity to
three different types of linguistic violation as
they process speech online (Kuperberg *et al.*
1998). The variation in processing profiles
between TD individuals described here suggests
that the relative insensitivity to different ling-
uistic violations demonstrated by the group as a
whole, cannot be simply explained by a single
global impairment in the use of context indexed
by more general cognitive operations, such as
pigeonholing (see Hemsley, 1975; Schwartz,
1982), working memory (Goldman-Rakic,
1994), using the 'internal representation of
context' to guide action (Cohen & Servan-
Schreiber, 1992) or post-lexical integration (Foss
& Ross, 1983; Marslen-Wilson, 1987). The
variability and dissociations in processing
profiles between individual TD patients suggest
that deficits may occur both outside the linguistic
system (at the level of pragmatic processing)
and/or within the lexicon (at the level of
processing selection restriction and subcate-
gorization information).

Intra-individual heterogeneity

The second main finding of the current study
was an inverse relationship between online
sensitivity to linguistic context and severity of
positive thought disorder, within individual
subjects over time. This inverse relationship was
statistically significant when we examined the
within-subject relationship between thought dis-
order and sensitivity to linguistic context over
the four testing sessions, across all thought-
disordered subjects. It is most clearly demon-
strated by patients C.A. and G.H. who, when
non-thought-disordered, showed an incremental
increase in RT across the four sentence types,
but when thought-disordered, showed a break-
down in this relationship.

The fact that G.H. was first tested when non-
thought-disordered and C.A. was first tested

when thought disordered, suggests that it is unlikely that the improvement in sensitivity to linguistic context was due to practice effects. However, there are other potential confounders to consider: first, the improvement in performance in the online task might reflect an improvement in overall clinical status, rather than positive thought disorder *per se*. This, however, seems unlikely as there was no relationship between overall psychopathology (total BPRS score) and sensitivity to linguistic context on each of these sessions within individual subjects over the four testing sessions. For example, the overall BPRS scores of patients C.A. and G.H. varied minimally (by a maximum of 4 points) between the four testing sessions. It is also unlikely that changes in sensitivity to linguistic context over time reflected the effects of medication, as the dose of antipsychotic drugs for all patients remained stable over the four testing sessions.

These findings therefore support the idea that an impairment in the use of linguistic context is specifically related to presence of positive thought disorder. This provides further evidence of an association between the phenomenon of thought disorder – a clinically-rated disorder of language – and a deficit in a task which taps into the fast and online use of different types of linguistic information to process spoken sentences. If the cognitive mechanism by which we use linguistic information to process speech online is indeed shared by speech output systems (Monsell, 1987; Levelt, 1989), then a deficit in the ability to use linguistic context online, could account for the disorganized speech characterizing schizophrenic thought disorder.

The question of whether changes in particular positive symptoms are paralled by changes in putative cognitive deficits, falls under the larger issue of whether such deficits are state- or trait-related (Nuechterlein & Dawson, 1984; Goldberg *et al*. 1993). Most studies addressing this issue in schizophrenia as a whole have examined changes in task performance in a group of schizophrenics, at two points in time, without specifically looking at intra-individual change (Prescott *et al*. 1986; Sweeney *et al*. 1986). The examination of two individual patients in the current study, together with the group analysis in which we specifically examined the co-variation of individual subjects' sensitivity to

linguistic context and severity of thought disorder over time, suggests that an insensitivity to linguistic context is a reflection of the state, rather than the trait, of schizophrenic thought disorder.

Conclusion and future directions

This study illustrates how a fine-grained case study approach can complement group studies of language processing in schizophrenia. We have demonstrated heterogeneity both between individual TD schizophrenic patients and within individuals over time, in the ability to use different types of linguistic information to process sentences online.

Variability between individual TD patients in their sensitivity to different levels of linguistic information, suggests that the deficits underlying thought disorder are heterogeneous and may impact upon both the online use of real-world pragmatic knowledge as well as the use of information held within the lexicon. An important question for future studies is whether deficits at specific levels of linguistic processing can be linked to particular subtypes of positive thought disorder.

The co-variation of sensitivity to linguistic context and severity of thought disorder over time, within individual patients, suggests that the deficit in the ability to use linguistic information online to process speech is state- rather than trait-related. Further studies with a larger numbers of subjects and longer periods between testing sessions will clarify this issue.

The underlying mechanism linking any cognitive function (in this case, the ability to use different types of linguistic information) with its behavioural manifestation (in this case, disordered speech) lies, of course, in brain function. Studies using both event-related potentials (e.g. Kutas & Hillyard, 1984; Osterhout & Holcomb, 1992; Hagoort *et al*. 1993) and functional magnetic resonance imaging (Kuperberg *et al*. 2000) suggest that the use of different types of linguistic context in healthy volunteers has distinct neural correlates. We are currently employing both these techniques to test the hypothesis that thought-disordered schizophrenic patients show a dysfunction in the neural networks mediating the use of different types of linguistic information.

NOTES

[1] We follow Marslen-Wilson *et al.* (1988) and Tyler (1992) in making the distinction between pragmatic violations that can only be inferred with respect to our real-world knowledge, on the one hand, and selection and subcategorization violations that are considered to be lexically-encoded (Chomsky, 1965; Jackendoff, 1978), on the other hand. However, we do not imply that real-world knowledge is not used in processing the other types of anomalous sentences: the semantic selection-restriction anomaly is also, by definition, a pragmatic anomaly. The key difference between the selection violations and the pragmatic violations is that featural semantic relations between verb and object noun are not violated in the pragmatically-violated sentences. Similarly, the subcategorization anomaly could also be considered semantically/pragmatically-anomalous (see note 3), although this is more controversial.

[2] Because we included 'version' as a factor in each of these ANOVAs, we were able to examine the interaction between version and sentence-type. In none of these analyses where there was a significant effect of sentence-type, was there a significant two-way interaction between version and sentence-type. It is therefore unlikely that any significant effects of sentence-type could have been produced by virtue of the target items being presented more than once, albeit in different contexts.

[3] In the current study, in all the syntactically (subcategorically)-violated sentences, 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, i.e. it is unlikely a man would sleep with a guitar. From a linguistic perspective, a subcategorization violation differs from other forms of syntactic violations, in that the object noun renders the sentence ungrammatical via its semantic properties, and part of the verb's semantic specification is probably encoded in the subcategorization frame (Fisher *et al.* 1991). Indeed, several authors have claimed that subcategorization frames are relatively straightforward projections from certain semantic features (Jackendoff, 1978; Bresnan, 1979; Chomsky, 1981). By this account, the meaning of a verb and its syntactic aspects (specified on the subcategorization frames) are tightly intertwined.

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