The Influence of a Working Memory Load Manipulation on Language Production in Schizophrenia

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Abstract

The present study examined the hypothesis that working memory deficits contribute to both negative thought disorder and some components of formal thought disorder (discourse coherence and fluency deficits) in individuals with schizophrenia. We examined the language produced by 44 patients with either schizophrenia or schizoaffective disorder during baseline and a dual-task condition designed to decrease working memory capacity. Results indicated that decreasing working memory capacity significantly increased negative thought disorder, but not discourse coherence or fluency deficits. However, both negative thought disorder and discourse coherence deficits were significantly correlated with working memory deficits. In addition, increases in negative thought disorder and discourse coherence deficits in the dual-task condition were negatively correlated, consistent with the hypothesis that these two types of language deficits may reflect alternative manifestations of working memory deficits.

Keywords: Schizophrenia, language production, formal thought disorder, negative thought disorder, and working memory.

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Language production disturbances have long been recognized as a cardinal symptom of schizophrenia (Bleuler 1950; Kraepelin 1950) and can be roughly grouped into two categories: formal thought disorder and negative thought disorder. Formal thought disorder typically refers to speech abnormalities that occur when the speaker violates the syntactic and semantic conventions that govern language use (Andreasen 1986) or when connections between sentences are unclear. This includes phenomena such as perseverations, tangentiality, loss of goal, pronominal reference errors, and neologisms (Andreasen 1986). Negative thought disorder is generally conceptualized as a decrease in speech productivity and complexity. This category of thought disorder includes disturbances in verbal productivity, syntactic complexity, blocking, pausing, and poverty of speech (Alpert et al. 1993; Barch and Berenbaum 1997). Although the specific mechanisms leading to either of these types of language deficits are still unclear, several theorists have suggested that cognitive deficits may contribute to either or both formal thought disorder and negative thought disorder in schizophrenia (Nuechterlein et al. 1986; Serper 1993; Strauss 1993). Interestingly, it has also been suggested that different types of cognitive deficits may contribute to each type of language disturbance, as many studies have found either no correlation or a negative correlation between formal thought disorder and negative thought disorder in schizophrenia (e.g., Andreasen 1979; Andreasen and Olsen 1982; Harvey and Pedley 1989; Harvey and Serper 1990). However, the goal of this study was to examine the alternative hypothesis that working memory deficits in schizophrenia contribute to disturbances in *both* formal thought disorder and negative thought disorder.

Despite a wealth of research examining language disturbances in schizophrenia, the precise causal mechanisms of formal thought disorder and negative thought disorder are still unknown. One hypothesis is that individuals with schizophrenia have cognitive deficits that influence language production, and that such deficits may contribute to either formal thought disorder or negative thought disorder, or both. In particular, several researchers have suggested a relationship between language disturbances and a specific cognitive deficit in schizophrenia—working memory dysfunction (e.g., Docherty et al. 1996). Working memory is typically defined as the ability to temporarily

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maintain and manipulate information (Baddeley 1986). A number of studies have shown that people with schizophrenia have deficits on working memory tasks (Gold et al. 1997; Goldberg et al. 1998). Further, the literature on language production in healthy populations suggests that working memory may be important in language production (Levelt 1989). For example, Levelt has argued that language production requires the simultaneous performance of multiple tasks, including (1) generating a message plan; (2) maintaining the message plan and prior discourse information; and (3) monitoring outgoing speech for errors and correcting it as necessary. It has been argued that some or all of these components of language production require working memory, and some empirical data support this hypothesis (Daneman 1991). Thus, if people with schizophrenia have deficits in working memory, it is possible that these deficits impair one or more components of language production, and thus contribute to disturbed speech. For example, it has been suggested that disturbances in the ability to generate a message plan may contribute to negative thought disorder (Barch and Berenbaum 1997). In addition, it has been suggested that disturbances in the ability to maintain/monitor a message plan and prior speech may contribute to formal thought disorder (e.g., Barch and Berenbaum 1996; Barch et al. 1997; Hoffman 1987). As noted above, both of these components of language production are thought to require working memory resources (Levelt 1989).

Despite the hypothesis that working memory deficits may lead to language production disturbances, the literature on the relationship between language production disturbances and working memory in schizophrenia is unclear. Some studies have found correlations between deficits on tasks that may tap working memory and global measures of formal thought disorder, and/or referential errors in people with schizophrenia (e.g., Harvey and Pedley 1989; Serper 1993; Docherty et al. 1996; Cohen et al. 1999), while other studies have not found such a relationship (Nuechterlein et al. 1986). Further, some studies have found a relationship between negative thought disorder, specifically poverty of speech, and working memory deficits in schizophrenia (Nuechterlein et al. 1986; Barch and Berenbaum 1997). This latter finding runs counter to the hypothesis that formal thought disorder and negative thought disorder are distinct deficits in schizophrenia, in that one would not predict that both types of thought disorder would be associated with deficits in working memory if they each arise from different cognitive disturbances (Strauss et al. 1993). Thus, the existing literature on the cognitive correlates of language production disturbances in schizophrenia is somewhat confusing. As of yet, it is not clear whether formal thought disorder is reliably related to working memory disturbances in schizophrenia, and it is not clear whether formal thought disorder and negative thought disorder have the same or different cognitive substrates.

There are at least two possible reasons for the ambiguity in the literature about the relationship between working memory and language disturbances in schizophrenia. The first is that formal thought disorder is not a unitary construct as indicated by factor analytic studies (Peralta et al. 1992; Cuesta and Peralta 1999) and may actually include several different components, some of which may have different causal mechanisms. Thus, studies examining the relationship between working memory and global measures of formal thought disorder may produce mixed results because not all components of formal thought disorder are related to working memory. For example, Berenbaum and Barch (1995) found greatest validity for four categories of formal thought disorder, specifically with formal thought disorder divided into disturbances in discourse coherence (DC), disturbances in fluency (FLU), disturbances in content (CON), and disturbances in social convention (SC). On the basis of previous research, Barch and Berenbaum (1996) suggested that DC and FLU may be related to cognitive deficits (potentially working memory deficits) whereas CON and SC may not be.

A second possible reason for the ambiguity in the literature about the relationship between working memory and language disturbances in schizophrenia is that, contrary to previous suggestions, formal thought disorder and negative thought disorder may not reflect distinct deficits with different cognitive correlates in schizophrenia. Instead, at least some subtypes of formal thought disorder and negative thought disorder may be alternative manifestations of the same basic disturbance in working memory. In previous work we have suggested that a reduction in working memory capacity in schizophrenia can lead to either of two outcomes: (1) a decrease in the amount of verbal output without formal thought disorder; or (2) an adequate amount of verbal output with increased formal thought disorder (Barch and Berenbaum 1994). In the first case, decreasing verbal output might decrease demands on the working memory system (e.g., those associated with the generation of a message), leaving more resources available for other components of language production, such as the maintenance of the discourse topic or prior speech. The result of this decreasing verbal output might be less speech (e.g., increased *negative* thought disorder) but decreased formal thought disorder (e.g., clearer connections between ideas and sentences). In the second case, if the individual does not decrease the amount of speech output (i.e., continuing to place demands on message generation), fewer working memory resources would be available for other components of speech production, potentially leading to greater formal thought disorder (e.g.,

unclear connections between sentences or a loss of topic). Therefore, when faced with decreased working memory capacity, a patient with schizophrenia may react in one of two ways, either by reducing verbal output (and thereby increasing negative thought disorder) or by maintaining the amount of language (but displaying formal thought disorder).

The goals of the current study were two-fold. The first goal was to examine the impact of a working memory manipulation on language production in people with schizophrenia. To do so, people with schizophrenia produced speech while performing a second task that also demanded working memory resources. We predicted that increasing the working memory load would increase both formal thought disorder and negative thought disorder. More specifically, of the different formal thought disorder categories we predicted that decreases in working memory capacity would increase DC and FLU but not CON or SC. The second goal was to determine whether individual differences in the degree of formal thought disorder versus negative thought disorder reflect alternative manifestations of coping with decreased working memory capacity. We predicted that people who displayed reduced verbal productivity in response to a reduction of working memory capacity would not display increased formal thought disorder, even if they displayed formal thought disorder at baseline. Alternatively, we predicted that people who did not reduce verbal productivity in response to a reduction in working memory capacity would exhibit increased formal thought disorder, even if they did not display thought disorder at baseline.

Methods

Participants. Participants were 44 *DSM–IV* diagnosed schizophrenia ($n = 41$) or schizoaffective ($n = 3$) patients. Participants were either inpatients ($n = 16$) at Mayview State Hospital or outpatients ($n = 28$) at the Schizophrenia Treatment and Research Center at Western Psychiatric Institute and Clinic. All participants were medicated and had been receiving the same medications and dosages for at least 2 weeks. Inpatients were clinically stable enough to participate in research. Patient diagnoses were based on the Structured Clinical Interview for *DSM–IV* (SCID; Spitzer et al. 1990), an interview with a primary caretaker, and a review of the participant's medical records. One of the authors (D.M.B.) or a trained research assistant completed the diagnostic interviews. Potential participants were excluded for (1) substance abuse within the previous 6 months; (2) neurological illness or history of head trauma with loss of consciousness; (3) mental retardation (based on chart diagnoses); (4) non-native English speaker; and (5) color blindness. Additional clinical and demographic information was added to table 1 to better characterize the study participants. Daily oral doses of antipsychotics for participants were converted to chlorpromazine equivalents according to guidelines suggested by Davis et al. (1983). Depot doses were converted to average daily dosages using the guidelines suggested by Baldessarini (1985). All participants signed informed consent forms (in accordance with either the University of Pittsburgh or Mayview State Hospital institutional review boards). All participants were paid for their participation.

The Positive and Negative Symptom Scale (PANSS; Kay 1991) was used to evaluate participant's current clinical state (table 1). Ratings were completed by either one of the authors (D.M.B.) or a trained research assistant who regularly participated in training and reliability sessions. Symptoms were clustered into the three syndromes suggested by Liddle (1987): (1) poverty (blunted affect, lack of spontaneity and motor motivation, emotional and social withdrawal); (2) reality distortion (unusual thought content, hallucinations and delusions); and (3) disorganization (conceptual disorganization, mannerisms, poor attention, abstract thinking). Both raters rated a subset of 10 participants. Interrater reliability, measured using intraclass correlations (Shrout and Fleiss 1979) with raters treated as random effects and the individual rater as the unit of reliability, was 0.97 for the total PANSS score, 0.95 for poverty, 0.93 for reality distortion, and 0.91 for disorganization.

Procedure. Each participant completed five tasks, with order counterbalanced across participants: (a) the Vocabulary subtest of the Wechsler Adult Intelligence Scale–Revised (WAIS-R; Wechsler 1981); (b) an interview; (c) a category monitoring task; (d) a second interview concurrent with the category monitoring task; and (e) the Speaking Span. All testing was completed in one session.

Single-task interview. Participants completed both a single- and a dual-task interview. The single-task interview was administered to obtain baseline measures of language production. Two equivalent interviews were constructed. Seventeen pairs of open-ended questions were created (e.g., "Describe a typical day for you" and "Describe yourself for me") and one question from each pair was randomly assigned to interview A or interview B. The interview used for the single versus dual task (e.g., A or B) was counterbalanced across subjects. Interview questions were asked in the same order for each participant. There was no time limit for the interview.

Category Monitoring task. The Category Monitoring task was administered as a measure of verbal working memory (Barch and Berenbaum 1994). This task

Table 1. Demographic and clinical information

Variable	Mean	Standard Deviation
Age	39.2	8.5
Sex (% male)	57	—
Race (% Caucasian)	60	—
Education	12.9	2.0
Parental education	12.1	2.7
Length of hospitalization (days)	20.7	9.2
Age at first hospitalization (yrs)	21.3	5.5
Number of hospitalizations	12.3	12.3
Chlorpromazine equivalents	2,867.2 ($n = 39$)	12,194.6
Percent taking antipsychotics	98	—
Percent taking antiparkinsonians	50	—
Percent taking mood stabilizers	41	—
Percent taking antidepressants	23	—
Percent taking benzodiazepines	20	—
PANSS: Total score	73.0	17.8
Poverty	12.5	5.5
Reality Distortion	10.6	3.3
Disorganization	10.4	3.2

Note.—PANSS = Positive and Negative Symptom Scale.

was administered once by itself and once during the dual-task interview. This task was patterned after the Continuous Performance Test (CPT; Rosvold et al. 1956) in that participants needed to monitor the presented stimuli in order to respond to a predetermined target held in memory, such that there were constant memory demands regarding whether or not the stimulus was currently on the screen. To increase task difficulty and cognitive load, the following changes were made: (a) participants responded to every stimulus, target or nontarget, not just following target trials; (b) whole-word stimuli were used rather than single letters; and (c) a category of target stimuli was used instead of a single target. In this task, whole words appeared one at a time in the middle of the computer screen. Participants were told to press one key on a keyboard for a target stimulus and another key for a nontarget stimulus, using their dominant hand. Two sets of stimuli were created, one in which the targets were animals and one in which the targets were parts of the body. Each set contained a total of 220 nontargets and 55 targets. The set of stimuli used for the Category Monitoring task alone (i.e., single task) versus the Category Monitoring task concurrent with an interview (i.e., dual task) was counterbalanced across participants. Stimuli were presented in a pseudo-randomized fashion, such that within every five trials, four nontargets and one target were presented. For the single task, participants received 160 nontarget stimuli and 40 target stimuli, randomly chosen from the full set. Target and nontarget words were matched for mean word length and mean frequency (Francis and Kucera 1982). When run as a dual task, stimuli were presented until the participant completed the interview. Response timing began with the presentation of the word and ended either when the participant responded or after 3 seconds, whichever came first. A new word appeared 1 second after termination of the previous trial. To ensure the participant's continued attention, a prompt appeared on the screen after every two nonresponses. The dependent measure was d-prime. For the dual-task version, the number of trials administered varied across participants. Thus, a correction for the number of trials administered was applied to dual-task d-prime (Nuechterlein 1991).

Dual-task interview. The dual-task interview was conducted concurrently with the Category Monitoring task and was used to study the impact of decreased processing capacity on language production. This Category Monitoring task requires simultaneous maintenance of target information and processing of incoming stimuli and therefore can be considered a working memory task. If language production also utilizes working memory resources (Levelt 1989), then the Category Monitoring task and interview should compete for the same cognitive resources required for maintenance and manipulation of information. On the basis of the hypothesis that limited working memory capacity leads to at least some of the language disturbance observed in schizophrenia, the dual-task condition should reduce performance on the Category Monitoring task as well as reduce resources available for language production.

Speaking Span. The Speaking Span, an analog to the Reading Span Test (Daneman and Carpenter 1980), was administered to obtain a measure of individual differences in verbal working memory. The Speaking Span is similar in design and presentation to the Reading Span (Daneman and Merikle 1996), but was designed to measure working memory for language production rather than comprehension (Daneman and Green 1986). Participants saw a series of words on the computer screen. The series began with a presentation of two words, one at a time, and increased by one word every three trials to a maximum of six words per trial. The participant was asked to remember each of the presented words until the end of the trial. At that time, the participant was asked to compose a grammatically correct English sentence using each word that was presented. For example, if the patient saw three words he or she would make three sentences, each sentence using one of the presented words. Participants were instructed not to change the form of the word. After the participant produced the sentences, the next trial (series of words) was administered. Participants were presented with three trials of each length, for a total of 15 trials. Words were presented on a Macintosh computer, using PsyScope software (Cohen et al. 1993), and responses were recorded manually by the experimenter. The dependent variable was the total number of words for which the participant was able to create sentences.

Formal thought disorder ratings. Transcripts from both interviews were transcribed by an undergraduate research assistant and checked for accuracy by an additional research assistant. Four trained undergraduate research assistants, blind to interview condition, rated each subtype of thought disorder from the Scale for the Assessment of Thought, Language, and Communication (TLC; Andreasen 1986), using the revised definitions described by Berenbaum et al. (1985). To prevent rater drift after initial training, the raters continued rating practice transcripts on a weekly basis. When rating thought disorder, the research assistants simultaneously listened to the recorded interview and read the transcripts. The number of instances of each subtype of thought disorder disturbance was calculated (self-reference, stilted speech, and verbigerations were not included in the present analyses due to infrequency). Dependent variables for each of four categories of formal thought disorder were created by summing the number of instances of each subtype within a category, to create a total score for single-task interview and a total score for the dual-task interview. The four categories of thought disorder were (1) disturbances in discourse coherence (DC) (non sequiturs, tangential responses, derailments, loss of goal, distractibility, and pronominal reference errors; alpha = 0.72); (2) disturbances in fluency (FLU) (neologisms, word approximations, incoherence; alpha = 0.56); (3) disturbances in content (CON) (perseverations and illogicality; alpha = 0.28); and (4) disturbances in social convention (SC) (poverty of content, circumstantiality; alpha = 0.77). These four categories of thought disorder are somewhat similar to those obtained in some factor analytic studies of the TLC (Cuesta and Peralta 1999), but were created on the basis of expert judge ratings and correlations with external validity indicators (e.g., cognitive and linguistic variables) as well as correlational analyses (Berenbaum and Barch 1995). Interrater reliability for these four categories of thought disorder using intraclass correlations (Shrout and Fleiss 1979) treating the raters as random effects and the mean of the raters as the unit of reliability ranged from good to excellent, with an average of 0.74 (see table 2).

Table 2. Variable descriptive statistics

	Single Task:			Dual Task:			
Variable	**Mean**	**SD**	**ICC**	**Mean**	**SD**	**ICC**	***t***
Speaking Span	26.61	7.02	—	—	—	—	—
Category Monitoring	3.30	0.71	—	2.57	0.72	—	7.00**
Thought Disorder Ratings							
Discourse Coherence	1.59	1.2	0.90	1.62	0.97	0.80	–0.23
Fluency	0.66	0.46	0.96	0.69	0.59	0.93	–0.50
Content	0.17	0.18	0.69	0.17	0.27	0.76	0.02
Social Convention	0.002	0.009	0.73	0.0005	0.003	0.18	1.97*
Negative	–1.02	2.63	[1]	1.01	2.49	[1]	–3.24**

Note.—The thought disorder ratings are corrected for verbal productivity. SD = standard deviation; ICC = intraclass correlation coefficient.
[1] No one reliability was calculated for NEG. See text regarding negative thought disorder reliability (ICC).
*$p < 0.05$
**$p < 0.01$

Total scores for each thought disorder category were corrected for the amount of speech produced in each interview (i.e., single versus dual task). The rationale for the correction based on verbal productivity was that the more a subject speaks, the greater the opportunity to exhibit thought disorder. Thus, if the dual-task manipulation influenced the amount of speech produced by subjects, one could find differences in thought disorder between the single- and dual-task interviews that simply reflected changes in verbal productivity. However, we were interested in determining whether the working memory manipulation influenced the likelihood of producing particular categories of format thought disorder given the same amount of speech. Thus, the scores for each of the categories of formal thought disorder were corrected so that the final rating was the number of instances per 100 spoken words for all subtypes except tangential responses and non sequiturs (as these subtypes of thought disorder can be rated only once per question).

Negative thought disorder ratings. We hypothesized that decreased working memory capacity would produce *either* increased formal thought disorder or increased negative thought disorder. On the basis of prior research, we measured several components of speech thought to reflect negative thought disorder. These components were verbal productivity, syntactic complexity, poverty of speech, pausing, and blocking (Barch and Berenbaum 1997), all of which have different scales of measurement. Therefore, a total composite z score for negative thought disorder was calculated for each individual, for each of the two interviews, by converting each of the components of negative thought disorder to a z score, and summing the component z scores together. Alpha for this scale was 0.68.

Poverty of speech and blocking. Poverty of speech and blocking are thought disorder subtypes from the TLC. Poverty of speech was measured by counting the number of completely unanswered questions and unelaborated answers. The score for blocking was the total number of instances per interview. Interrater reliability for these TLC components of negative thought disorder, treating the raters as random effects and the mean of the raters as the unit of reliability, was 0.80 for the single-task and 0.89 for the dual-task interview (Shrout and Fleiss 1979).

Syntactic complexity. Syntactic complexity was rated by two advanced linguistics graduate students who coded the number of independent and dependent clauses in each participant's transcribed speech sample. Interrater reliability, measured using an intraclass correlation coefficient with the raters treated as random effects and the mean of the raters as the unit of reliability, was 0.98 for independent clauses in the single task and 0.97 in the dual task, and 0.98 for dependent clauses in the single task and 0.96 in the dual task. Syntactic complexity was then calculated by averaging the number of dependent clauses per T-unit. A T-unit is a single independent clause with all of its modifying subordinate clauses (Hunt 1965).

Verbal productivity and filled pauses. Verbal productivity was measured by counting the number of words per interview for each participant. Pauses were measured by counting the number of filled pauses (e.g., "um," "ah") in each interview. To correct for opportunity to produce pauses, based on the amount of speech produced, we divided the number of filled pauses by the number of words in each interview.

Data Analysis. Data from one of the four raters was missing for three subjects for the single-task fluency category, one subject for the dual-task fluency category, and two subjects for the dual-task DC category. Corrections were made in order to retain these participants in the analyses. The average rating for each subtype was calculated, based on the remaining three raters, and the average was used in place of the missing data for the fourth rater. The effect of the dual-task manipulation on language production was examined using paired t tests. However, four variables did not meet the assumption of a normal distribution, based on the Kolmogorov-Smirnov test for normality: single- and dual-task social convention; single-task discourse coherence; and dual-task content. Results for these variables were confirmed using nonparametric tests (Wilcoxon Matched-Pairs Signed-Ranks test and Spearman correlations). The results of the nonparametric tests were identical to the parametric tests except where explicitly mentioned.

Results

Correlations Among Thought Disorder Categories. We began by examining the correlations within the thought disorder measures. We first examined correlations among the scores that had *not* been corrected for verbal productivity. As shown in table 3, the pattern of correlations using these uncorrected scores was similar to the results of prior research (e.g., Andreasen 1979; Harvey and Pedley 1989; Harvey and Serper 1990). Specifically, all the formal thought disorder categories were positively intercorrelated, and all formal thought disorder categories were negatively correlated with negative thought disorder. However, it is possible that this pattern of correlations reflects, at least in part, a confound of verbal productivity, or the number of opportunities to produce the various subtypes of thought disorder. To assess this possibility, we next examined the correlations among our thought disorder measures using

the scores that had been corrected for verbal productivity. We had a priori predictions about some of the correlations among thought disorder (TD) measures corrected for verbal productivity (e.g., DC and NEG, DC and FLU), but not about others. Thus, we employed a modified Bonferroni correction, corrected for the number of correlations computed for each variable (5, leading to a corrected p value of 0.01). Interestingly, when verbal productivity was taken into account, the pattern of correlations was very different (table 4). Within the single-task interview, the only significant correlation was between SC and NEG thought disorder, and none of the dual-task TD measures were significantly correlated. Notably, contrary to predictions, FLU and DC were not significantly correlated.

Correlations Within Working Memory Measures. We next examined the zero-order correlations among the measures of working memory. Consistent with our predictions, Speaking Span was positively correlated with d-prime in both the single- ($r = 0.43$, $p < 0.01$) and dual-task ($r = 0.39$, $p < 0.01$) Category Monitoring task. D-primes on the single- and dual-task Category Monitoring task were also significantly positively correlated ($r = 0.52$, $p < 0.01$).

Influence of the Dual-task Manipulation on Language Production and Working Memory. A paired sample t test (table 4) indicated that d-prime on the Category Monitoring task was significantly worse in the dual- versus single-task condition. This result provides evidence that our dual-task paradigm was capable of reducing working memory capacity and inducing significant performance deficits. Paired sample t tests also indicated that, as predicted, the dual-task interview elicited significantly more NEG thought disorder than did the single-task condition. Also as predicted, disturbances in CON did not differ between single- and dual-task conditions. There was a significant difference in SC between the single and dual tasks. However, participants produced *fewer* SC disturbances during the dual-task interview, but this difference was not significant when checked with nonparametric measures. Contrary to our predictions, neither DC nor FLU increased significantly during the dual-task interview, although the means were in the predicted direction.

Table 3. Thought disorder correlations within single- and dual-task variables

	DC	FLU	CON	SC	NEG
DC	**0.45****	0.56**	0.36**	0.49**	–0.45**
FLU	0.51**	**0.62****	0.41**	0.80**	–0.61**
CON	0.53**	0.12	**0.22**	0.45**	–0.42**
SC	0.24*	0.47**	0.24*	**0.21**	–0.57**
NEG	–0.37**	–0.50**	–0.09	–0.32**	**0.47****

Note.—Correlations above the diagonal (indicated by bolded numbers) are for the single-task interview and correlations below the diagonal correlations are for the dual-task interview. Correlations on the diagonal are the correlations between the single- and dual-task interviews.

CON = Content; DC = Discourse Coherence; FLU = Fluency; NEG = Negative Thought Disorder; SC = Social Convention

*$p < 0.05$

**$p < 0.01$

Table 4. Thought disorder correlations within single- and dual-task variables—correcting for verbal productivity

	DC	FLU	CON	SC	NEG
DC	**0.60****	0.14	0.13	0.19	–0.02
FLU	0.24	**0.59****	–0.03	0.12	–0.003
CON	0.24	–0.02	**0.07**	–0.13	0.20
SC	0.28	0.06	0.02	**0.84****	–0.39**
NEG	–0.18	–0.09	0.29	–0.15	**0.46****

Note.—Correlations above the diagonal (indicated by bolded numbers) are for the single-task interview and correlations below the diagonal correlations are for the dual-task interview. Correlations on the diagonal are the correlations between the single- and dual-task interviews.

CON = Content; DC = Discourse Coherence; FLU = Fluency; NEG = Negative Thought Disorder; SC = Social Convention

**$p < 0.01$

Correlations Between Thought Disorder and Working Memory Measures. We predicted that the working memory measures would be correlated with DC, FLU, and NEG, but not with SC or CON. Consistent with this prediction, Speaking Span accuracy was negatively correlated with NEG for both the single- ($r = -0.36$, $p < 0.01$) and dual-task interviews ($r = -0.28$, $p < 0.05$). To determine whether Speaking Span performance was significantly more strongly correlated with NEG than with the other TD measures, we utilized methods for comparing correlated correlation coefficients suggested by Meng et al. (1992). For both the single-task ($z = -2.22$, $p < 0.05$) and dual-task interviews ($z = -1.99$, $p < 0.05$), Speaking Span accuracy was significantly more negatively correlated with NEG than with SC. For the single-task interview, the correlation between Speaking Span and NEG was not significantly different from the correlation between Speaking Span and CON. However, for the dual-task interview, there was a trend for Speaking Span performance to be significantly more negatively correlated with NEG than with SC ($z = -1.55$, $p = 0.06$). Contrary to our predictions, Speaking Span performance was not significantly correlated with DC or FLU in either interview.

Also as predicted, Category Monitoring performance was negatively correlated with DC for both the single- ($r = -0.35$, $p < 0.01$) and the dual-task interview ($r = -0.31$, $p < 0.05$). For the single-task interview, the correlation between Category Monitoring and DC was significantly greater than the correlation between Category Monitoring and SC ($z = -2.23$, $p < 0.01$). However, the correlation between Category Monitoring and single-task DC did not differ significantly from any other thought disorder categories. In the dual-task interview, there was a trend for Category Monitoring to be significantly more negatively correlated with DC than with SC ($z = -1.53$, $p = 0.06$). Contrary to our predictions, Category Monitoring performance was not significantly correlated with either NEG or FLU in either interview.

Individual Differences in Response to Working Memory Reduction. Our hypothesis was that NEG and some subtypes of formal thought disorder are alternative outcomes of decreased working memory capacity. Thus, we examined the relationships between changes in NEG from the single to dual task, and changes in DC from the single to dual task. Specifically, we calculated residualized change scores for both NEG and DC by regressing single-task performance on dual-task performance, calculating a predicted dual-task value, and subtracting this predicted score from the observed dual-task score. This allowed us to remove variance in dual-task scores predicted from single-task scores, letting us examine change not predicted by baseline performance (Llabre et al. 1991). The reliability of the residualized change score for NEG was 0.80.[1]

We calculated two residualized change scores for DC, once using the scores uncorrected for verbal productivity and once using scores corrected for verbal productivity. The reliability for the residualized change score for verbal productivity (uncorrected DC) was 0.73 and 0.42 for verbal productivity-corrected DC. As predicted, the verbal productivity-uncorrected DC change score was strongly negatively correlated with the NEG change score ($r = -0.49$, $p < 0.001$, 1-tailed). This indicates that individuals who showed the smallest increase in NEG from single to dual task tended to show the largest increases in DC from single to dual task. More interestingly, the verbal productivity (corrected DC) change score was also significantly negatively correlated with the NEG change score ($r = -0.26$, $p < 0.05$, 1–tailed). Again, this suggests that those individuals who showed the smallest increases in NEG from single to dual task tended to show the largest increases in DC from single to dual task (and vice versa), even when verbal productivity changes in the dual-task condition were taken into account.

Discussion

The results of this study supported some, but not all, of our initial hypotheses. First, as predicted, the dual-task manipulation reduced working memory capacity in our sample of patients with schizophrenia and led to an increase in negative thought disorder. Second, we found the predicted associations between individual differences in working memory performance and thought disorder, both negative thought disorder and discourse coherence. Third, as predicted, we found that those individuals who showed the largest increase in discourse coherence disturbances from single to dual task showed the smallest increases in negative thought disorder from single to dual task, even when verbal productivity reductions in the dual-task condition were taken into account. This latter finding in particular is consistent with our hypothesis that negative thought disorder and some subtypes of formal thought disorder are alternative manifestations of working memory disturbance. However, several other results were not consistent with our original hypothesis and require additional discussion. These results include the findings that (1) the dual-

[1]We did not have a single reliability coefficient for NEG since the reliability of each of the different components was calculated separately (e.g., TLC ratings versus syntactic complexity ratings). Thus, to estimate reliability for the residualized change score for NEG, we used the lowest reliability coefficient (TLC ratings) so that the estimated reliability for the change score likely represents a lower bound.

task manipulation did not cause a significant increase in either discourse coherence disturbances or fluency disturbances, although the means were in the predicted direction; (2) fluency was not significantly associated with working memory performance; and (3) discourse coherence and negative thought disorder were correlated with *different* working memory measures.

Before discussing the implications of our findings for understanding the relationship among formal thought disorder, negative thought disorder, and working memory, we should note that none of our predictions about fluency came to fruition. Disturbances in fluency and discourse coherence were not significantly correlated in either the single- or dual-task interview, fluency was not increased by the dual-task manipulation, and fluency did not show any of the predicted relationships with working memory. This result suggests that contrary to our original hypothesis, fluency is not influenced by working memory deficits. As described in the introduction, fluency disturbances include phenomena such as neologisms, word-approximations, and verbigeration. In prior work, we found that word approximations and neologisms were associated with poor performance on a task designed to assess grammatical-phonological encoding (Barch and Berenbaum 1996), components of language production that may not be as dependent on working memory function (Levelt 1989). Thus, fluency disturbances may be associated with deficits in putatively more "automatic" components of language production. Interestingly, it has been suggested that people with schizophrenia who have increased global thought disorder demonstrate increased semantic priming (Manschreck et al. 1988), especially at short stimulus onset asynchronies (Spitzer et al. 1993, 1994). Although the evidence for this suggestion is somewhat mixed (e.g., Spitzer et al. 1993, 1994; Barch et al. 1996), positive findings have been interpreted as potentially reflecting irregularities in automatic spreading activation in people with schizophrenia. In future research, it would be interesting to determine whether such increased semantic priming might be specifically related to fluency disturbances, as opposed to other components of positive thought disorder.

As predicted, the dual-task manipulation significantly increased the amount of negative thought disorder produced. This finding provides strong support for our hypothesis that working memory deficits contribute to negative thought disorder in schizophrenia. However, contrary to our prediction, the dual-task manipulation did not significantly increase the frequency of discourse coherence deficits. One interpretation of this result is that negative thought disorder is more associated with working memory function than are discourse coherence disturbances. However, the correlations between working memory performance and both negative thought disorder and discourse coherence were of approximately the same magnitude. Thus, it is somewhat surprising that a decrease in working memory capacity did not significantly increase discourse coherence disturbances.

One possible explanation for this finding may be related to our hypothesis that discourse coherence disturbances and negative thought disorder reflect alternative manifestations of coping with decreased working memory capacity. More specifically, it is possible that decreasing the amount and complexity of speech (i.e., increasing negative thought disorder) is a more effective and potentially more natural means of coping with increased working memory demands (Barch and Berenbaum 1994), even among individuals with schizophrenia. For example, if we defined an increase in thought disorder simply as a numerically higher score in the dual-task condition, then 70 percent of participants increased the degree of negative thought disorder produced, but only 50 percent increased the frequency of discourse coherence disturbances. Even if we define an increase more conservatively (i.e., an increase greater than one standard error of the mean), a greater percentage of people increased negative thought disorder (68%) than discourse coherence disturbances (48%). As such, it is possible that we did not find a significant increase in discourse coherence in the dual-task condition because the majority of patients instead increased negative thought disorder, potentially avoiding an increase in discourse coherence deficits. However, this is a post hoc explanation, and our current results clearly provide greater support for a link between working memory deficits and negative thought disorder than for a link between working memory deficits and discourse coherence disturbances. Nonetheless, future research could examine the prediction that if one can prevent patients from decreasing verbal productivity and complexity, one should find a significant increase in discourse coherence deficits when working memory capacity is reduced.

Some aspects of this pattern of performance may be specific to individuals with schizophrenia and other aspects may not be. Our previous research has demonstrated that healthy controls also reduce verbal productivity and syntactic complexity when asked to complete that same secondary task while producing speech (Barch and Berenbaum 1994). However, unlike patients with schizophrenia, healthy controls show absolutely no increase in discourse coherence and no negative correlations between changes in negative thought disorder and changes in discourse coherence. Thus, some aspects of these results are not specific to schizophrenia as compared to healthy controls, and some are. However, we would argue that even though healthy subjects also reduce verbal productivity and syntactic complexity in response to a reduction in working memory capacity,

this in no way necessarily precludes the possibility that reduced working memory capacity is a core process influencing thought disorder in schizophrenia.

An interesting and unexpected result was the finding that, although both discourse coherence and negative thought disorder were associated with working memory measures, they were associated with *different* working memory measures. Specifically, negative thought disorder was correlated with performance on the Speaking Span, and disturbances in discourse coherence were correlated with Category Monitoring performance. This result was somewhat surprising, especially since Speaking Span and Category Monitoring performance were themselves strongly correlated. It is possible that this pattern of correlations may be understood by looking more carefully at the task demands of the two working memory tasks. Although both tasks may require some type of general working memory resources, the Speaking Span task places specific demands on the ability to generate a message plan (e.g., generating a sentence for each word), while the Category Monitoring task requires maintenance of information (e.g., maintaining the target category). Interestingly, in prior work we found that negative thought disorder was associated with deficits in the ability to generate a message plan, whereas discourse coherence disturbances were associated with deficits in the ability to maintain a discourse plan (Barch and Berenbaum 1997). Such findings provide a potential mechanism for understanding how working memory dysfunction might lead to specific types of thought disorder in people with schizophrenia. It may be that general deficits in working memory function interact with disturbances in specific components of language production to produce particular subtypes of thought disorder. Specifically, negative thought disorder may be associated with difficulty generating a message plan and discourse coherence may be associated with difficulty maintaining a message, both of which have been suggested to require working memory resources (Levelt 1989). As such, this explanation suggests that working memory deficits alone may not be sufficient to lead to any type of language disturbance in schizophrenia. Instead, it is possible that a combination of working memory deficits and vulnerabilities in specific language production processes that are dependent on working memory is necessary in order to elicit particular types of language production deficits.

A related issue, raised by the results of our study, is whether our results reflect a specific effect of reducing working memory capacity per se, or a more general effect of reducing cognitive capacity. In other words, a critical question for future research will be to determine whether similar results are obtained when using a secondary task that does not demand working memory resources. To a certain extent, this will be difficult to do, as one could argue that the vast majority of tasks contain some working memory component, even if it is only the need to maintain the task instructions. However, a potentially useful secondary task for future studies would be something like a degraded CPT task, which is likely to be matched for task difficulty with the category monitoring task. Such a task clearly requires sustained attention, but likely has a minimal demand on working memory resources, except for task instructions. If using a degraded CPT task as the secondary task produced the same results that we obtained with the Category Monitoring task, it would suggest that a general reduction in cognitive capacity, rather than a specific reduction in working memory capacity, influences thought disorder.

An additional issue to be addressed in understanding language dysfunction in schizophrenia is the influence of antipsychotic medications on working memory deficits and language production. A criticism of the hypothesis that working memory deficits contribute to difficulties in language production in schizophrenia is the suggestion that formal thought disorder is responsive to antipsychotic medications but working memory is not (e.g., Goldberg and Weinberger 1995; Goldberg et al. 2000). However, the empirical data is somewhat mixed regarding the influence of antipsychotic medications on working memory function in schizophrenia. The majority of studies that have claimed not to find positive effects of antipsychotic medications on working memory have used tasks such as the Wisconsin Card Sorting Task (WCST) as their measure of working memory (e.g., Cleghorn et al. 1990; Verdoux et al. 1995). Although the WCST is very sensitive to cognitive dysfunction in schizophrenia, it is a complex task, simultaneously requiring many cognitive functions (e.g., set shifting, problem solving, mental flexibility, and attention) in addition to working memory. However, a number of other studies using tasks that may, at least in part, assess working memory (e.g., various versions of the CPT, Digit Symbol tests, Digit Span, verbal fluency) have found positive effects of antipsychotics on task performance (e.g., Goldberg and Weinberger 1995; Green et al. 1997; Schuepbach et al. 2002; Velligan et al. 2002). As such, whether the administration of antipsychotic medication improves working memory function in schizophrenia is still unclear. Future research utilizing cognitive tasks that are specific and validated measures of working memory function, as well as measures of multiple components of language production in schizophrenia (e.g., both discourse coherence and negative thought disorder measures), is needed.

References

Alpert, M.; Pouget, E.R.; Welkowitz, J.; and Cohen, J. Mapping schizophrenic negative symptoms onto measures of the patient's speech: Set correlational analysis. *Psychiatry Research,* 48:181–190, 1993.

Andreasen, N.C. Thought, language, and communication disorders: Diagnostic significance. *Archives of General Psychiatry,* 36:1325–1330, 1979.

Andreasen, N.C. The scale for assessment of thought, language, and communication (TLC). *Schizophrenia Bulletin,* 12(3):473–482, 1986.

Andreasen, N.C., and Olsen, S. Negative v positive schizophrenia. *Archives of General Psychiatry,* 39:789–794, 1982.

Baddeley, A.D. *Working Memory.* New York, NY: Oxford University Press, 1986.

Baldessarini, R.J. *Chemotherapy in Psychiatry*. Cambridge, MA: Harvard University Press, 1985.

Barch, D.M., and Berenbaum, H. The relationship between information processing and language production. *Journal of Abnormal Psychology*, 103:241–250, 1994.

Barch, D.M., and Berenbaum, H. Language production and thought disorder in schizophrenia. *Journal of Abnormal Psychology,* 105:81–88, 1996.

Barch, D.M., and Berenbaum, H. The effect of language production manipulations on negative thought disorder and discourse coherence disturbances in schizophrenia. *Psychiatry Research*, 71:115–127, 1997.

Barch, D.M.; Braver, T.S.; Nystrom, L.; Forman, S.D.; Noll, D.C.; and Cohen, J.D. Dissociating working memory from task difficulty in human prefrontal cortex. *Neuropsychologia,* 35:1373–1380, 1997.

Barch, D.M.; Cohen, J.D.; Servan-Schreiber, D.; Steingard, S.S.; Steinhauer, S.; and van Kammen, D. Semantic priming in schizophrenia: An examination of spreading activation using word pronunciation and multiple SOAs. *Journal of Abnormal Psychology,* 105:592–601, 1996.

Berenbaum, H., and Barch, D. The categorization of thought disorder. *Journal of Psycholinguistic Research*, 24:349–376, 1995.

Berenbaum, H.; Oltmanns, T.F.; and Gottesman, I.I. Formal thought disorder in schizophrenics and their twins. *Journal of Abnormal Psychology,* 94, 3–16, 1985.

Bleuler, E. *Dementia Praecox or the Group of Schizophrenias*. New York, NY: International Universities Press, 1950.

Cleghorn, J.M.; Kaplan, R.D.; Szechtman, B.; Szechtman, H.; and Brown, G.M.. Neuroleptic drug effects on cognitive function in schizophrenia. *Schizophrenia Research,* 3:211–219, 1990.

Cohen, J.D.; Barch, D.M.; Carter, C.S.; and Servan-Schreiber, D. Schizophrenic deficits in the processing of context: Converging evidence from three theoretically motivated cognitive tasks. *Journal of Abnormal Psychology,* 108:120–133, 1999.

Cohen, J.D.; MacWhinney, B.; Flatt, M.R.; and Provost, J. PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments and Computers,* 25(2):257–271, 1993.

Cuesta, M.J., and Peralta, V. Thought disorder in schizophrenia. Testing models through confirmatory factor analysis. *European Archives of Psychiatry and Clinical Neuroscience*, 249:55–61, 1999.

Daneman, M. Working memory as a predictor of verbal fluency. *Journal of Psycholinguistic Research,* 20:445–465, 1991.

Daneman, M., and Carpenter, P.A. Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior,* 19:450–466, 1980.

Daneman, M., and Green, I. Individual differences in comprehending and producing words in context. *Journal of Memory and Language,* 25:1–18, 1986.

Daneman, M., and Merikle, P.M. Working memory and language comprehension: A meta-analysis. *Psychonomic Bulletin and Review,* 3:422–433, 1996.

Davis, J.; Janicak, P.; Linden, R.; Moloney, J.; and Pavkovic, I. Neuroleptics and psychotic disorders. In: Cle, J.T., and Enna, S.J., eds. *Neuroleptics: Neurochemical, Behavioral, and Clinical Perspectives*. New York, NY: Raven Press, 1983. pp. 15–64.

Docherty, N.M.; Hawkins, K.A.; Hoffman, R.E.; Quinlan, D.M.; Rakfeldt, J.; and Sledge, W.H. Working memory, attention, and communication disturbances in schizophrenia. *Journal of Abnormal Psychology,* 105:212–219, 1996.

Francis, W.N., and Kucera, H. *Frequency Analysis of English Usage: Lexicon and Grammar.* Boston, MA: Houghton Mifflin, 1982.

Gold, J.M.; Carpenter, C.; Randolph, C.; Goldberg, T.E.; and Weinberger, D.R. Auditory working memory and Wisconsin Card Sorting Test performance in schizophrenia. *Archives of General Psychiatry,* 54:159–165, 1997.

Goldberg, T.E.; Dodge, M.; Aloia, M.; Egan, M.F.; and Weinberger, D.R. Effects of neuroleptic medications on speech disorganization in schizophrenia: Biasing associative networks toward meaning. *Psychological Medicine*, 30:1123–1130, 2000.

Goldberg, T.E.; Patterson, K.J.; Taqqu, Y.; and Wilder, K. Capacity limitations in short-term memory in schizophrenia. *Psychological Medicine,* 28:665–673, 1998.

Goldberg, T.E., and Weinberger, D.R. Thought disorder, working memory, and attention: Interrelationships and the effects of neuroleptic medications. *International Clinical Psychopharmacology,* 10:99–104, 1995.

Green, M.F.; Marshall, B.D.; Wirshing, W.C.; Ames, D.; Marder, S.R.; McGurk, S.; Kern, R.S.; and Mintz, J. Does Risperidone improve verbal working memory in treatment-resistant schizophrenia? *American Journal of Psychiatry*, 154:799–804, 1997.

Harvey, P.D., and Pedley, M. Auditory and visual distractibility in schizophrenia: Clinical and medication status correlations. *Schizophrenia Research*, 2:295–300, 1989.

Harvey, P.D., and Serper, M.R. Linguistic and cognitive failures in schizophrenia: A multivariate analysis. *The Journal of Nervous and Mental Disease*, 178:487–494, 1990.

Hoffman, R.E. Computer simulations of neural information processing and the schizophrenia-mania dichotomy. *Archives of General Psychiatry*, 44:178–188, 1987.

Hunt, K. *Grammar Structures Written at Three Grade Levels.* Research Report 3. Urbana, IL: NCTE, 1965.

Kay, S. *Positive and Negative Symptoms in Schizophrenia.* New York, NY: Brunner/Marzel, 1991.

Kraepelin, E. *Dementia Praecox and Paraphrenia.* (1919) Translated by R. Mary Barcaly. New York, NY: International Universities Press, Inc., 1950.

Llabre, M.M.; Spitzer, S.B.; Saab, P.G.; Ironson, G.H.; and Schneiderman, N. The reliability and specificity of delta versus residualized change as measures of cardiovascular reactivity to behavioural challenges. *Psychophysiology,* 28:701–711, 1991.

Levelt, W.J.M. *Speaking: From Intention to Articulation.* Cambridge, MA: MIT Press, 1989.

Liddle, P.F. Syndromes of chronic schizophrenia: A re-examination of the positive-negative dichotomy. *British Journal of Psychiatry*, 151:145–151, 1987.

Manschreck, T.; Maher, B.A.; Milavetz, J.J.; Ames, D.; Weisstein, C.C.; and Schneyer, M.L. Semantic priming in thought disordered schizophrenic patients. *Schizophrenic Research,* 1(1):61–66, 1988.

Meng, X.; Rosenthal, R.; and Rubin, D.B. Comparing correlated correlation coefficients. *Psychological Bulletin*, 111:172–175, 1992.

Nuechterlein, K.H. Vigilance in schizophrenia and related disorders. In: Steinhauer, S.R.; Gruzelier, J.H.; and Zubin, J., eds. *Handbook of Schizophrenia Vol. 5: Neuropsychology, Psychophysiology, and Information Processing.* Amsterdam, The Netherlands: Elsevier, pp. 397–433.

Nuechterlein, K.H.; Edell, W.S.; Norris, M.; and Dawson, M.E. Attentional vulnerability indicators, thought disorder and negative symptoms. *Schizophrenia Bulletin*, 12(3):408–426, 1986.

Peralta, V.; Cuesta, M.J.; and de Leon, J. Formal thought disorder in schizophrenia: A factor analytic study. *Comprehensive Psychiatry*, 33:105–110, 1992.

Rosvold, H.E.; Mirsky, A.F.; Sarason, I.; Bransome, E.D.; and Beck, L.H. A continuous performance test of brain damage. *Journal of Consulting Psychology*, 20:343–350, 1956.

Schuepbach, D.; Keshavan, M.S.; Kmiec, J.A.; and Sweeney, J.A. Negative symptom resolution and improvements in specific cognitive deficits after acute treatment in first-episode schizophrenia. *Schizophrenia Research*, 53:249–261, 2002.

Serper, M.R. Visual controlled information processing resources and formal thought disorder in schizophrenia and mania. *Schizophrenia Research,* 9:59–66, 1993.

Shrout, P.E., and Fleiss, J.L. Intraclass correlations: Uses in assessing rater reliability. *Psychological Bulletin,* 86:420–428, 1979.

Spitzer, M.; Braun, U.; and Maier, S. Associative semantic network dysfunction in thought-disordered schizophrenic patients: Direct evidence from indirect semantic priming. *Biological Psychiatry,* 34:864–877, 1993.

Spitzer, M.; Weisker, I.; Winter, M.; Maier, S.; Hermle, L.; and Maher, B.A. Semantic and phonological priming in schizophrenia. *Journal of Abnormal Psychology*, 103:485–494, 1994.

Spitzer, R.L.; Williams, J.B.W.; Gibbon, M.; and First, M.B. *Structured Clinical Interview for the DSM–III–R—patient edition (SCID-P), version 1.0.* Washington, DC: American Psychiatric Press, 1990.

Strauss, M.E. Relations of symptoms to cognitive deficits in schizophrenia. *Schizophrenia Bulletin,* 19(2):215–231, 1993.

Strauss, M.E.; Buchanan, R.W.; and Hale, J. Relations between attentional deficits and clinical symptoms in schizophrenic outpatients. *Psychiatry Research,* 47:205–213, 1993.

Velligan, D.I.; Newcomer, J.; Pultz, J.; Csernansky, J.; Hoff, A.L.; Mahurin, R.; and Miller, A.L. Does cognitive function improve with quetiapine in comparison to haloperidol? *Schizophrenia Research*, 53:239–248, 2002.

Verdoux, H.; Magnin, E.; and Bourgeois, M. 1995. Neuroleptic effects on neuropsychological test performance in schizophrenia. *Schizophrenia Research*, 14:133–139.

Wechsler, D. *Wechsler adult intelligence scale-Revised.* New York, NY: Psychological Corporation, 1981.