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Cognitive control components and speech symptoms in people with schizophrenia

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Previous schizophrenia research suggests poor cognitive control is associated with schizophrenia speech symptoms. However, cognitive control is a broad construct. Two important cognitive control components are poor goal maintenance and poor verbal working memory storage. In the current research, people with schizophrenia ($n = 45$) performed three cognitive tasks that varied in their goal maintenance and verbal working memory storage demands. Speech symptoms were assessed using clinical rating scales, ratings of disorganized speech from typed transcripts, and self-reported disorganization. Overall, alogia was associated with both goal maintenance and verbal working memory tasks. Objectively rated disorganized speech was associated with poor goal maintenance and with a task that included both goal maintenance and verbal working memory storage demands. In contrast, self-reported disorganization was unrelated to either amount of objectively rated disorganized speech or to cognitive control task performance, instead being associated with negative mood symptoms. Overall, our results suggest that alogia is associated with both poor goal maintenance and poor verbal working memory storage and that disorganized speech is associated with poor goal maintenance. In addition, patients' own assessment of their disorganization is related to negative mood, but perhaps not to objective disorganized speech or to cognitive control task performance.

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1. Introduction

An important goal of current schizophrenia research is to identify relationships between treatment-refractory symptoms and deficits in particular cognitive and neural mechanisms (Carter and Barch, 2007). Negative and disorganized speech symptoms can be enduring (Bowie et al., 2005) and predict poorer long-term outcomes (Liddle, 1994; Walker, 1995; Fuller et al., 2003). In addition, previous research has consistently found that negative and disorganized speech symptoms are distinct (Andreasen, 1979; Harvey et al., 1992). Negative speech symptoms, or alogia, refer to a paucity of speech amount and speech content (Andreasen, 1979, 1982). Disorganized speech symptoms refer to speech that is difficult to understand or is poorly organized (e.g., jumping from idea to idea). There are at least two ways of assessing and conceptualizing disorganized speech symptoms. One way is in terms of communication impairment, or an increased number of unclear utterances in speech (Docherty et al., 1996). Another way is in terms of formal thought disorder, or the occurrence of specific types of speech symptoms (e.g., instances of derailment or of word approximations; Andreasen, 1979). Although communication impairment and formal thought disorder are somewhat related (Docherty et al., 1996), there is also evidence that they can be somewhat distinct constructs (Docherty, 2005). Communication impairment can be measured very sensitively (Kerns and Berenbaum, 2003) and reliably (Docherty et al., 1996) and has been consistently associated with cognitive deficits (Docherty et al., 2004).

The current schizophrenia research examined whether negative and disorganized speech symptoms would be associated with distinct cognitive control components. Cognitive control refers to processes involved in carrying out goal-directed behavior in the face of conflict (Rougier et al., 2005). People with schizophrenia exhibit large deficits on cognitive or executive control tasks and these deficits have been associated with treatment-refractory symptoms (Barch and Smith, 2008; Kerns et al., 2008). However, cognitive control is a broad construct involving multiple components. Understanding how symptoms are related to specific cognitive control mechanisms could help us both understand what might cause these symptoms as well as how we might be able to treat these symptoms (Carter and Barch, 2007). Two cognitive mechanisms that are often involved in cognitive control tasks are (a) goal maintenance (Braver et al., 2007); and (b) verbal working memory storage (Cowan, 2005).

Goal maintenance, or context processing, is a potentially central component of cognitive control and refers to the representation and maintenance of important task critical information, such as rules, goals, instructions, or intentions (Cohen and Servan-Schreiber, 1992; Cohen et al., 1996; Kane and Engle, 2003; Braver et al., 2007). Maintenance of important goal information in the prefrontal cortex (PFC) is thought to bias activity in other brain regions responsible for task execution (Miller and Cohen, 2001). One goal maintenance

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task that has been associated with self-reported disorganization symptoms in college students is the Preparation for Overcoming a Prepotent Response (POP) task (Kerns, 2006). In this study, for the first time, we examined associations between performance on the POP task and schizophrenia symptoms.

In addition to goal maintenance, a second cognitive component often involved in cognitive control tasks is working memory storage capacity, which refers to the amount of information that can be maintained in active memory (Cowan, 2005). When factors such as chunking of information and use of rehearsal are eliminated, a consistent finding is that people can maintain about three or four items in working memory (e.g., Cowan, 2001; Owen, 2004), which is associated with posterior brain regions such as the parietal cortex (e.g., Chein et al., 2003). Importantly, most models of cognitive control and of working memory suggest that goal maintenance and working memory storage are distinct cognitive components (Baddeley, 2000; Cowan, 2005; Braver et al., 2007). One measure of verbal working memory storage capacity is the Running Memory Span task. In this study, for the first time, we examined associations between schizophrenia symptoms and performance on this task.

Although these two cognitive control mechanisms, goal maintenance and working memory storage, are thought to be distinct, they are often involved in the same complex working memory tasks that involve both a strong processing and a strong storage demand. For example, one complex working memory task is the N-Back (e.g., the 2-back task; Cohen et al., 1997), on which participants see a series of letters and decide if each letter is the same or different from the letter that was *n* items back. This task involves working memory to maintain the last *n* (e.g., 2) letters and also involves goal maintenance to update and maintain the target letters in the face of distraction from other recently presented letters (Miller et al., 1996). In the current research, to examine associations between symptoms and cognitive control components, participants completed three tasks that varied by the extent to which they involved either goal maintenance demands (the POP task), verbal working memory storage demands (the Running Memory Span task), or both types of cognitive demands (the N-Back task).

It was expected that if a symptom was correlated with both poor goal maintenance and poor working memory storage capacity, then the symptom would be correlated with both the POP and the Running Memory Span tasks. In addition, it was also expected that the symptom would have an even larger association with the N-Back task because that task involves both types of cognitive control demands. However, this does assume that there is not a floor effect in N-Back task performance that could result in a symptom exhibiting the same size association with the N-Back as with the tasks involving only one component. In contrast, if a symptom was correlated with only one of these two cognitive control components, then it was expected that it would only be associated with either the POP or the Running Memory Span. In addition, it was expected that the symptom would also be correlated with the N-Back, but the correlation with the N-Back was not expected to be differentially larger than the correlation between the symptom and the other cognitive control task with which it was also associated.

Previous schizophrenia research has found evidence that both alogia and disorganized speech are associated with cognitive control deficits (e.g., attentional or reality monitoring deficits; Harvey and Serper, 1990; Docherty and Gordinier, 1999; Kerns and Berenbaum, 2002; Melinder and Barch, 2003). For example, some studies have reported evidence of associations between disorganized symptoms and poor performance on goal maintenance tasks (Cohen et al., 1999; Berenbaum et al., 2008). Poor goal maintenance could contribute to disorganized speech because problems maintaining a speech goal could result in poorly organized and poorly monitored speech (Kerns and Berenbaum, 2003). However, these previous studies either did not specifically report results for a task designed to specifically measure goal maintenance or they did not report results specifically for disorganized speech symptoms. In addition, two studies have found that poor performance on the N-Back complex working memory task is associated with disorganized speech (Kerns and Berenbaum, 2003; Kerns, 2007). However, to our knowledge, no previous study has examined associations between disorganized speech with both goal maintenance and complex working memory tasks in the same study. In addition, to our knowledge, no previous study has examined the association between disorganized speech and performance on a working memory storage capacity task that minimizes processes such as chunking and rehearsal. At the same time, some previous studies have found that alogia is also associated with poor performance on cognitive control tasks (Melinder and Barch, 2003; Berenbaum et al., 2008) whereas at least one study has not (Kerns, 2007). Poor goal maintenance could contribute to alogia because problems maintaining a speech goal could decrease a person's ability to produce any speech (Barch and Berenbaum, 1997). At the same time, poor verbal working memory capacity and decreased amount of information maintained in working memory during speech could decrease the complexity and scope of one's verbal output (Romani and Martin, 1999). We further examined associations between cognitive control and schizophrenia speech symptoms by using tasks that systematically varied in their cognitive control component demands.

2. Method

2.1. Participants

Participants were 45 native English speakers who met *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; DSM-IV; American Psychiatric Association, 1994) criteria for schizophrenia-spectrum disorders (schizophrenia, $n=29$; schizoaffective disorder, $n=16$). Participants were either inpatients ($n=34$ non-acute inpatients with a wide range of functioning) at a state psychiatric hospital (with a largely forensic population) or outpatients ($n=11$) living in central Missouri. Outpatients were recruited by flyers that were distributed to case managers at a local outpatient treatment facility, with case managers mentioning the study to participants. Interested participants then contacted us about the study. Participant demographic information is presented in Table 1. Diagnoses were based on the psychotic, mood, and substance use disorders sections of the Structured Clinical Interview for the DSM-IV (SCID; First et al., 1998) administered by clinical psychology graduate students and a review of clinical records. Participants were excluded from the current study if they met criteria for a current substance-use diagnosis, had undergone drug detoxification in at least the past 6 months, or had a known cognitive or neurological disorder. All participants were taking antipsychotic medication at the time of their participation, with 29% also taking mood stabilizers, 36% antidepressants, and 13% anticholinergics.

2.2. Measures

2.2.1. Clinical Symptom Ratings

Negative and positive schizophrenia symptoms were measured using the Scale for the Assessment of Negative Symptoms (SANS; Andreasen, 1982) and the Brief Psychiatric Rating Scale (BPRS; Overall and Gorham, 1962). Alogia was measured using the global

Table 1
Demographic and clinical data for schizophrenia participants ($n=45$).

Variable	*M*	S.D.	Range
Gender (% male)	77.8%		
Race/ethnicity (% African-American)	22.2%		
Age (years)	44.1	9.7	23–62
Education (years)	11.2	2.0	6–16
Symptoms			
Disorganized speech (CDI: ratings/100 words)	2.6	1.5	0.8–7.5
Alogia (SANS: possible 0–5)	1.2	1.2	0–4
Flat affect (SANS: possible 0–5)	1.5	0.9	0–3.7
Avolition (SANS: possible 0–5)	2.2	1.6	0–5
Anhedonia (SANS: possible 0–5)	1.8	1.6	0–5
Delusions (BPRS: possible 1–7)	3.9	1.6	1–7
Hallucinations (BPRS: possible 1–7)	2.7	2.0	1–7
BPRS total	44.1	9.4	27–69

Note: CDI = Communication Disturbances Index, SANS = Scale for the Assessment of Negative Symptoms, BPRS = Brief Psychiatric Rating Scale.

rating from the SANS. Interrater reliability for alogia was 0.88. To assess current level of negative mood symptoms, we created a negative mood symptom measure based on past-week clinical ratings of four BPRS symptoms: anxiety, depression, guilt, and hostility. Interrater reliability for negative mood was 0.99.

2.2.2. Disorganized speech

Each participant completed a 15–30 min semi-structured interview, which was audiotaped and transcribed. The interview consisted of being asked to provide up to 19 memories (i.e., "Tell me a specific memory about a time you were …"). The first memory was used for practice. After that, there were six neutral memories (e.g., a time you were at a restaurant; traveling), then six negative memories (e.g., lonely; angry), and finally six positive memories (e.g., happy, pleasantly surprised). Participants were encouraged to speak for approximately 1 min for each memory. If participants did not say much for a particular memory, they were encouraged to say more, and if necessary, participants were prompted with questions to encourage more speech about that memory. Importantly, by having people answer open-ended questions, some of which involved emotional content, it was expected, based on previous research, that the current interview would elicit a high enough mean level and enough variance in disorganized speech ratings to be able to successfully examine associations with cognitive task performance (Johnston and Holzman, 1979; Docherty et al., 1998; Docherty, 2005).

To measure disorganized speech, four research assistants rated the typed transcripts using the Communication Disturbances Index (CDI; Docherty, 1996; Docherty et al., 1996). The CDI provides a measure of communication impairment (Docherty, 2005) and rates the number of speech unclarities, with an unclarity being any speech passage in which the meaning is sufficiently unclear to impair the overall meaning of the speech passage. The CDI was developed as an extension of a previous measure of unclear referents in speech that has been used frequently in previous schizophrenia research (Rochester and Martin, 1979), and the CDI has been used frequently in schizophrenia research as a measure of disordered speech (Kerns and Berenbaum, 2003; Docherty, 2005). It is associated with older measures of disorganized speech such as the Thought, Language, and Communication (TLC) scale (Docherty et al., 1996). Importantly, the CDI is a more sensitive measure of speech disorder than the TLC, potentially making it useful for research examining associations between disorganized speech and cognitive task performance.

Interrater reliability for the total CDI score, measured using an intraclass correlation (Shrout and Fleiss, 1979), treating the raters as random effects and the mean of the four raters as the unit of reliability, was 0.91. Following Docherty and colleagues (Docherty et al., 1996; Docherty, 2005), raw CDI scores were corrected for total amount of speech; hence, reported CDI scores in Table 1 are the number of speech unclarities per 100 words of speech. The mean CDI score in the present study is very similar to mean schizophrenia CDI scores in studies using similar speech interviews (e.g., Docherty et al., 1998). The audiotapes for three inpatient participants were too poor in quality to be able to accurately rate disorganized speech from the typed transcripts. For these three participants, we substituted their global formal thought disorder rating from the Scale for the Assessment of Positive Symptoms (SAPS; Andreasen, 1984) as our best estimate of their level of speech disorganization. We did this by first calculating standardized z-scores for both CDI and SAPS FTD ratings. Excluding these three participants would have resulted in virtually identical results (e.g., largest change in correlation with the three excluded would have been an increase in size of correlation with POP by 0.02).

2.2.3. Self-reported disorganization

The Cognitive Slippage Scale (CSS) is a 35-item, true-false self-report measure (Miers and Raulin, 1987) that contains items related to one's reporting of speech deficits and confused thinking (e.g., "I can usually think through things clearly." "My thinking often gets "cloudy" for no apparent reason." "I often find myself saying something that comes out completely backwards." "My thoughts often jump from topic to topic without any logical connection."). Three participants did not complete this measure. Alpha in the current study was 0.91.

2.2.4. Cognitive control tasks

Participants completed three different tasks. One task, the Preparation to Overcome a Prepotent Response (POP) task, is thought to involve a high level of goal maintenance demands but a low level of verbal working memory storage demands. On the POP task, participants saw a cue, either a green or a red square (each presented half of the time), for 200 ms. Then they saw a probe arrow pointing to the left or right for up to 3.5 s or until a response was made. If the cue was green, participants were instructed to make the prepotent response and respond with a button press with their right or left index finger in the direction of the arrow. If the cue was red, participants needed to overcome the prepotent response and respond in the direction opposite of the arrow. Participants completed four blocks of 32 trials each. The dependent variable was how much slower and less accurate participants were for red cue trials than for green cue trials. A variety of behavioral, neuroimaging, and patient research has supported the involvement of goal maintenance on the POP task (e.g., Barber and Carter, 2005; Snitz et al., 2005; MacDonald et al., 2006). For instance, POP task performance has been associated with other goal maintenance tasks such as the Stroop (Kerns, 2006), with non-prepotent cues being found to activate the left dorsolateral PFC (e.g., Barber and Carter, 2005). Chance accuracy on this task is 50%. If participants are at chance performance for green trials, this makes a comparison between red and green trials meaningless. Hence, we excluded seven participants (five inpatients) with accuracy on green trials not exceeding 60%. Importantly, the participants who completed each of the three cognitive tasks were equivalent on their level of cognitive performance and symptom severity. Hence, differences in correlations between various cognitive tasks and symptoms cannot be easily accounted for by differences in the samples.

For the POP task, comparing red and green trials, participants were both slower and less accurate for red than for green trials [green cue mean reaction time (RT) = 986.7, S.D. = 380.7; red cue RT = 1058.3, S.D. = 446.4; RT red–green difference = 71.7, S.D. = 149.4; green cue mean error proportion = 0.14, S.D. = 0.1; red cue mean error proportion = 0.23, S.D. = 0.2; mean error proportion red–green difference = 0.09, S.D. = 0.2]. A composite score was created by taking the average of the z-scores for participants' RTs and error rates.

A second task, the Running Memory Span task, was thought to involve a high level of verbal working memory storage demands but a low level of goal maintenance demands. On this task (Pollack et al., 1959; Cowan et al., 2005), participants heard a series of digits, with one digit presented every 250 ms. The digits were presented too rapidly to be successfully chunked, updated, or rehearsed. After hearing between 12 and 20 digits, participants were asked to recall the last four digits from the end of the list. Overall, participants heard 20 lists of digits. The dependent variable was accuracy rate corrected for guessing (i.e., the average of the guessing-rate for the four digits to be recalled), mean = 0.59, S.D. = 0.23. Previous research has consistently found that the rapid presentation rate of this task requires participants to maintain information in working memory using a passive, low effort strategy and minimizes the use of updating, chunking, or rehearsal (e.g., Elosúa and Ruiz, 2008). In addition, seven people with schizophrenia (five inpatients) declined to complete the task.

The third task, the N-Back task, is thought to involve a high level of both goal maintenance and verbal working memory storage demands. On the N-Back task (Cohen et al., 1997), participants saw a series of single letters presented one at a time in the center of a computer screen. For every letter, participants decided if it was the same or different from the letter presented two letters previously. Each letter was preceded by a fixation cross for 500 ms. Each letter then appeared for 2 s and was followed by a blank screen for 2.5 s. Participants completed four blocks of 20 trials each. On half of the trials, the current letter was different from the letter presented two letters previously (i.e., negative trials). On half of these negative trials, the current letter was the same as the letter presented either one or three letters previously (i.e., recent negative trials). The inclusion of recent negative trials ensures that participants actually had to maintain items in working memory to do the task rather than being able to rely on a more passive recognition strategy to perform the task (Gray et al., 2003). The dependent variable for the N-Back task was accuracy rate corrected for guessing (i.e., hit rate minus the false alarm or guessing rate; Johnson et al., 1996). In this study, given that we were interested in correlations between symptoms and cognitive performance only within people with schizophrenia, we did not include a non-schizophrenia comparison group (Kerns and Berenbaum, 2003). However, note that in the current research, people with schizophrenia appeared to exhibit the expected large deficits in N-Back task performance when compared to performance by a non-psychiatric control group of comparable age and parental education (Kerns, 2007). In the present study, N-Back accuracy rate corrected for guessing was mean = 0.39, S.D. = 0.26. In addition, 10 people with schizophrenia (six inpatients) declined to complete the N-back task.

2.3. Procedure and data analysis

The University of Missouri Institutional Review Board and the Missouri Department of Mental Health reviewed the study design, and all participants provided written informed consent after the nature of the procedures had been fully explained. Participants completed the study in the following order: disorganized speech interview, POP, SCID, N-Back, Cognitive Slippage Scale, and Running Memory Span. In analyzing correlations between tasks and symptoms, to minimize the chance that outliers could overly influence results, we used non-parametric Spearman rho correlations. Furthermore, to demonstrate the comparability of the participants included in the analyses, we found that inpatients and outpatients were comparable (i.e., not significantly different) on age, education, cognitive performance, disorganized speech, positive symptoms, and negative symptoms. As mentioned earlier, we expected that differential associations between symptoms and either one or both cognitive control components would result in larger or smaller associations with cognitive tasks. To examine whether symptoms were differentially associated with cognitive tasks, we compared the size of different symptom by task correlations.

3. Results

3.1. Cognitive task performance

As can be seen in Table 2, performance on the POP task was strongly correlated with performance on the N-Back task. This was expected given that both tasks are thought to involve goal maintenance. At the same time, the Running Memory Span task was strongly correlated with the N-Back task. This was expected given that both tasks are thought to involve working memory storage capacity.

Table 2
Correlations among cognitive tasks and symptoms in people with schizophrenia.

	POP task	Running Memory	N-back	Alogia	Disorganized speech
POP task	–				
Running Memory	0.21	–			
N-back	0.60**	0.61**	–		
Alogia	−0.32†	−0.41*	−0.69**	–	
Disorganized speech	−0.40*	−0.14	−0.34*	0.32*	–

Note: POP = Preparation to Overcome a Prepotent Response.
† $p = 0.061$.
* $p < 0.05$.
** $p < 0.01$.

However, the POP and the Running Memory Span tasks were not significantly correlated. This was expected as these tasks were thought to involve different cognitive control components.

3.2. Symptoms and cognitive control task performance

As can be seen in Table 2, alogia tended to be associated with performance on all three cognitive control tasks, being most strongly associated with performance on the N-Back task, being significantly associated with the Running Memory Span, and being associated at a trend level with performance on the POP. This pattern of results suggests that alogia is associated with both poor goal maintenance and with poor verbal working memory storage capacity. If so, it would be expected that the association between the alogia and the N-Back would be stronger than the association between alogia with either the POP or the Running Memory Span because the N-Back involves both goal maintenance and working memory storage. Consistent with this, alogia was significantly more strongly associated with performance on the N-Back than it was with either the POP, $Z = 2.49$, $p < 0.01$ or the Running Memory Span tasks, $Z = 2.05$, $p < 0.05$ (Meng et al., 1992).

For objectively rated disorganized speech, as can be seen in Table 2, it was significantly associated with performance on both tasks that involved a high level of goal maintenance demands, the POP and the N-Back tasks. However, in contrast to alogia, FTD was not significantly more associated with performance on the N-Back than with performance on the POP, $Z = 0.39$, $p = 0.35$, if anything being slightly more associated with performance on the POP. In addition, comparing alogia and disorganized speech, performance on the N-Back was significantly more strongly correlated with alogia than with disorganized speech, $Z = 2.15$, $p < 0.05$. Also in contrast to alogia, disorganized speech was not significantly associated with performance on the Running Memory Span task. In addition, there was a trend for performance on the Running Memory Span task to be more strongly correlated with alogia than with disorganized speech, $Z = 1.39$, $p = 0.08$. There was also a trend for disorganized speech to be (a) more strongly correlated with performance on the POP task than with performance on the Running Memory Span, $Z = 1.23$, $p = 0.109$, and (b) more strongly correlated with performance on the N-Back than with performance on the Running Memory Span, $Z = 1.35$, $p = 0.09$.

In addition, all significant correlations between symptoms and cognitive task performance remained significant when examining only those people with a diagnosis of schizophrenia. At the same time, inpatient versus outpatient status did not account for the associations between symptoms and cognitive task performance.

3.3. Correlations with self-reported disorganization

Next we examined correlations with self-reports of speech and cognitive disorganization. Self-reported disorganization was not significantly correlated with objectively rated disorganization using the CDI. In fact, if anything, the correlation was in the opposite direction, rho = −0.16. In addition, self-reported disorganization was not significantly correlated with objective cognitive control task performance (POP rho = −0.05, Running Memory rho = −0.19, N-Back rho = 0.07). In contrast, self-reported disorganization was strongly associated with current negative mood symptoms, rho = 0.48, $p < 0.01$.

4. Discussion

There were several novel and potentially important results in the current research that to our knowledge have not been previously reported. For example, to our knowledge, this is the first schizophrenia study that has examined the relationship between symptoms with either the POP goal maintenance task or the Running Memory Span verbal working memory storage task. Performance on the goal maintenance POP task was correlated with both alogia (at a trend level) and disorganized speech. Performance on the verbal working memory storage Running Memory Span task was correlated with alogia. In addition, for the first time, it was found that both alogia and disorganized speech are associated with the N-Back task that includes both goal maintenance and verbal working memory storage, with the association between the N-Back and alogia being significantly larger than the association with disorganized speech. Also, for the first time, we have assessed self-reported disorganization symptoms in schizophrenia and found that these symptoms are not correlated with either objectively rated disorganized speech or cognitive control task performance. This suggests that patients are not very accurate at gauging their own level of disorganization. Instead, self-reported disorganization was associated with current negative mood symptoms.

In this study, alogia seemed to be associated with both poor goal maintenance and poor verbal working memory. For instance, alogia was associated at a trend level with the POP task that seems to only involve goal maintenance demands. Alogia was also associated with the Running Memory Span task that seems to only involve verbal working memory storage demands. Furthermore, alogia was very strongly associated with performance on the N-Back complex working memory task that seems to involve both goal maintenance and verbal working memory storage demands. In fact, the associations between alogia and the N-Back was significantly larger than the associations between alogia and either the POP task or the Running Memory Span. This pattern of correlations suggests that the increasing cognitive control demands on the N-Back task which involved both goal maintenance and verbal working memory storage demands resulted in an even larger association with alogia.

In contrast to alogia, the overall pattern of the associations between disorganized speech and cognitive control tasks was very different. Disorganized speech was only significantly associated with performance on the tasks involving goal maintenance, the POP and the N-Back, and was not associated with the task that only involved working memory storage, the Running Memory Span. In addition, there were trends for the correlations between disorganized speech and the POP and between disorganized speech and the N-Back to be significantly larger than the correlation between disorganized speech and the Running Memory Span. Furthermore, there were also differences in the size of the associations for alogia and disorganized speech. The N-Back was significantly more strongly associated with alogia than with disorganized speech. In addition, there was a trend for the Running Memory Span to be significantly more associated with alogia than it was with disorganized speech. In contrast to alogia, there was no difference in the size of the associations of disorganized speech with the POP versus with the N-Back. Overall, in the present study, alogia seemed to be associated with both poor goal maintenance and poor verbal working memory storage. For disorganized speech in the current research, it seems reasonable to conclude that it was associated with poor goal maintenance. However, at the very least, one would be reluctant to conclude based on our results that disorganized speech was associated with verbal working memory storage capacity. However one might interpret these results, we think these novel results provide important new information about the relationship between speech symptoms and cognitive control in schizophrenia.

The association between disorganized speech and poor goal maintenance suggests that disorganized speech symptoms in schizophrenia could be related to problems maintaining goals to guide ongoing behavior. This is consistent with previous language production research which has found that goal-relevant and contextually appropriate speech relies in part on maintaining speech goals (Dell et al., 1997; Kerns et al., 2004). Hence, perhaps part of the reason that people with schizophrenia produce speech that is difficult to understand or that strays off topic is because of difficulty maintaining a speech topic to coordinate ongoing speech (Holzman, 1978; McGrath, 1991; Cohen et al., 1992).

The current results suggest that alogia is not only related to problems in maintaining speech goals but is also related to problems in working memory capacity. This suggests that people with alogia in part might have problems initiating speech and have problems producing a lot of speech because of problems maintaining enough information in working memory to talk about. This also suggests that the alogia symptom of blocking, where people lose track of their train of thought, could also be related to problems both in maintaining goals and in maintaining speech-relevant information in working memory. Our results for alogia also seem consistent with some previous alogia research. For example, alogia has been associated with poor verbal fluency (Stolar et al., 1994), and previous research has found that verbal fluency is associated with complex working memory tasks involving both goal maintenance and working memory storage (Rosen and Engle, 1997). In addition, alogia itself has also been associated with performance on a complex verbal working memory task (Melinder and Barch, 2003).

The current results also seem consistent with some previous speculation about the relationship between cognitive control and these speech symptoms. For example, Barch and Berenbaum (1997) speculated that both alogia and disorganized speech shared some common cognitive control correlates. However, they also speculated that there had to be some differences between the two symptoms, because with alogia people decrease speech output whereas with disorganized speech amount of speech may be intact but what is produced is disorganized. Consistent with this, our results suggest that alogia and disorganized speech might share some cognitive deficits but differ on other cognitive deficits, as alogia was associated with both poor goal maintenance and poor verbal working memory storage.

The current results are also consistent with another hypothesis made by Barch and Berenbaum (1997) who suggested that disorganized speech in schizophrenia might also reflect poor monitoring. In the present study, we assessed patients' own beliefs about their speech and cognitive disorganization. We found that their own beliefs were unrelated to either their objectively rated speech disorganization or to their objective level of cognitive performance. This suggests that some people with schizophrenia might have very disorganized speech and yet be unaware of it. Hence, as predicted by Barch and Berenbaum (1997), disorganized speech in schizophrenia might reflect poor monitoring of actual speech performance. The current results are also consistent with other research that has found that people with schizophrenia are poor at evaluating their own cognitive difficulties (Medalia et al., 2008). At the same time, we also found some evidence that when patients are evaluating their own cognitive performance, they might be especially influenced by their current negative mood related symptoms, consistent with at least one previous study (Bowie et al., 2007). Thus, the current results suggest that patients' perceptions of their cognitive problems might reflect their sense of how much their negative mood and stress levels are influencing their thinking.

Based on the present results, one issue for future research would be to further examine associations between speech symptoms in schizophrenia and types of working memory tasks. For example, in previous research, we have found that alogia was not associated with performance on the Sternberg probe recognition working memory task (Kerns, 2007), but in the current research, alogia was associated with performance on the Running Memory Span task. However, the Sternberg task involves presenting people with several items and then involves a delay period during which people can chunk and rehearse information. In contrast, the Running Memory Span prevents people from using chunking or rehearsal. This suggests that tasks that specifically assess working memory storage capacity and minimize other processes that can aid retention of information will be more strongly associated with alogia. Another issue for future research would be to examine the role that interference resolution might play in the association between working memory storage and alogia. Previous research has found evidence that alogia is associated with poor interference resolution (Kerns, 2007). Interference resolution (i.e., ability to mitigate proactive interference in working memory) also appears to be an important contributor to working memory performance (Barch and Smith, 2008).

Future research could also use functional brain imaging to further examine the cognitive and neural mechanisms involved in schizophrenia speech symptoms. For example, previous research has consistently found that goal maintenance demands activate the DLPFC (e.g., MacDonald et al., 2005). In contrast, working memory storage capacity appears to activate a specific parietal lobe region (Cowan et al., 2011). Hence, based on our results, we might expect that alogia would be associated with decreased activation in the parietal region associated with working memory storage.

Another issue for future research would be to examine whether alogia is associated with poor coordination of cognitive demands. We found a stronger association between alogia with the N-Back than with the other cognitive tasks. However, it is possible that the N-Back includes not just multiple cognitive components but that it also involves a unique coordination of cognitive abilities. Hence, although we have interpreted the stronger correlation between alogia and the N-Back as an indicator that alogia is associated with both poor goal maintenance and poor working memory storage, it is also possible that alogia is associated with poor coordination of cognitive abilities (Harvey et al., 2006). One issue for future research would be to examine whether alogia might be specifically associated with poor coordination of cognitive abilities or perhaps with overall poor task performance.

Another issue for future research would be to see whether improvements in cognitive control components reduce schizophrenia speech symptoms. The association between speech symptoms and poor goal maintenance suggests that treatments that influence goal maintenance and perhaps the functioning of the PFC might reduce the level of speech symptoms. For example, perhaps adjunctive medications that increase activity in the PFC, such as drugs influencing GABA (Lewis et al., 2008), could decrease alogia and disorganized speech.

There are some limitations in the current research. First, some of the associations between symptoms and cognitive task performance were only moderate in size (according to conventional definition of moderate effect size, i.e., Cohen's $d \geq 0.5$ or correlation ≥ 0.24; although some associations do correspond to the conventional definition of a large effect size, i.e., Cohen's $d \geq 0.80$ or correlation ≥ 0.37). In addition, although we had a decent sample size, we potentially did not have sufficient power to detect some differences in the size of correlations. At the same time, not all participants were able to complete all cognitive tasks. Finally, it could be argued that the same cognitive constructs have been examined in previous schizophrenia research; although, we do think the current study does make some novel empirical contributions and our study is arguably the first to examine associations between verbal working memory capacity and communication impairments.

Overall, the results of this study suggest that alogia is associated with both poor goal maintenance and poor verbal working memory storage. At the same time, we found further evidence that disorganized speech is associated with poor goal maintenance. In contrast, there was evidence that patients' own assessment of their disorganization is related to negative mood, but perhaps not to objective disorganized speech or to cognitive control task performance.

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