

Speech Symptoms in Schizophrenia and Relationships with Working Memory,  
Goal Maintenance, and Processing Speed

---

A Thesis  
presented to  
the Faculty of the Graduate School  
at the University of Missouri-Columbia

---

In Partial Fulfillment  
of the Requirements for the Degree  
Master of Arts

---

by  
Anne Merrill  
Dr. John Kerns, Advisor

MAY 2015

The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

SPEECH SYMPTOMS IN SCHIZOPHRENIA AND RELATIONSHIPS WITH  
WORKING MEMORY, GOAL MAINTENANCE, AND PROCESSING SPEED

presented by Anne Merrill,

a candidate for the degree of Master of Arts,

and hereby certify that, in their opinion, it is worthy of acceptance.

---

Professor John Kerns

---

Professor Nelson Cowan

---

Professor John Lauriello

### **Acknowledgments**

I would like to thank Professor John Kerns for his continuing support and guidance. I would also like to thank the members of my committee, Professor Nelson Cowan and Professor John Lauriello.

**Table of Contents**

Acknowledgments	ii
List of Tables	iv
Abstract	v
1. Introduction	1
2. Method	5
3. Results	15
4. Discussion	17
5. Bibliography	23
Tables	34

**Tables**

Table 1. Participant Demographic Information

Table 2. Task Performance and Group Differences

Table 3. Task Correlations in Participants with Schizophrenia

## Abstract

People with schizophrenia exhibit wide ranging cognitive deficits, including slower processing speed (i.e., speed of executing task components). Speech symptoms, such as disorganized speech and alogia, have been associated with cognitive control deficits, but the exact nature of their relationship to specific cognitive deficits is unclear. In the current study, people with schizophrenia ( $n = 51$ ) and non-psychiatric controls ( $n = 26$ ) completed speech interviews allowing for assessment of speech symptoms. Participants also completed two tasks strongly involving working memory and two tasks strongly involving goal maintenance. In addition, measures of processing speed for highly automatic prepotent responses and a measure of general poor task performance were also obtained. For disorganized speech, it was significantly associated with poor performance in all cognitive domains (all  $r$ 's  $> -.29$ ), with the largest association found with slower processing speed ( $r = -.46$ ). Further, disorganized speech was even associated with a non-cognitive control measure of poor general task performance (BY errors on the AX-CPT,  $r = -.43$ ). In contrast, alogia was not significantly related to any cognitive domain, with the largest association with goal maintenance tasks ( $r = -.24$ ). Overall, this study suggests that disorganized speech in schizophrenia, but not alogia, is associated with generalized cognitive deficits.

## **Speech Symptoms in Schizophrenia and Relationships with Working Memory, Goal Maintenance, and Processing Speed**

People with schizophrenia exhibit wide ranging cognitive deficits in most cognitive domains, such as working memory, prepotent inhibition, and slower processing speed (Nuechterlein et al., 2004). Previous schizophrenia research has examined whether cognitive deficits are related to speech symptoms in schizophrenia (Cohen, Barch, Carter, & Servan-Schreiber, 1999; Docherty, 2005; Kerns, 2007), including both disorganized and negative speech symptoms. Disorganized speech symptoms, including measures of communication impairment (Docherty, 1996; Docherty, DeRosa, & Andreasen, 1996), are arguably the schizophrenia symptom that has been most consistently associated with cognitive deficits (e.g., Dominguez, Viechtbauer, Simons, van Os, Krabbendam, 2009; Kerns & Berenbaum, 2002; Tandon, Nasrallah, & Keshavan, 2009). Negative speech symptoms such as alogia, or decreased amount of speech, have also occasionally been associated with cognitive deficits (e.g., Becker, Cicero, Cowan, & Kerns, 2012). However, the exact nature of the associations between disorganized and negative speech symptoms and cognitive deficits is still unclear. The current research examined the extent to which communication impairment and alogia were associated with poor cognitive control, increased processing speed, or generalized poor task performance.

Disorganized speech refers to speech that is difficult to understand or poorly organized (e.g., frequent jumping to unrelated ideas; Andreasen et al., 1979; McGrath, 1991). Communication impairment as defined by Docherty (2005) and measured by the Communication Disturbances Index (CDI; Docherty et al., 1996), refers to frequent instances of significant speech unclarity. This conceptualization of disorganized speech is related to more traditional constructs of disorganized speech such as formal thought disorder (Docherty & Gordinier, 1999)

and measures such as the Thought, Language, and Communication (TLC) scale (Docherty et al., 1996). However, in measuring disorganized speech, communication impairment focuses on the communication failures in speech, rather than the underlying thought disorder (Docherty, 2005). Disorganized speech as rated by the CDI can be assessed very sensitively (Kerns & Berenbaum, 2003) and reliably (Docherty et al., 1996) and has been found to be elevated in first-degree relatives of people with schizophrenia (Docherty, Gordinier, Hall, & Dombrowski, 2004). Furthermore, there is evidence that the disorganization symptoms of schizophrenia are the most heritable of schizophrenia symptom factors (Rietkerk et al., 2008) and that they can predict both onset of schizophrenia (Berenbaum, Oltmanns, & Gottesman, 1985; Gooding et al., 2012) as well as poor outcome in the disorder (Sigauo et al., 2014; Ventura, Helleman, Thames, Koellnew, & Nuechterlein, 2009). As previously mentioned, disorganized speech symptoms such as communication impairment have also been consistently associated with poor cognitive task performance (Docherty, 2005; Kerns & Berenbaum, 2003).

Alogia, or poverty of speech, refers to decreased verbal production and there is consistent evidence that alogia and disorganized speech are distinct symptoms, with alogia loading on a negative symptom factor (e.g., Andreasen, 1979b; Berenbaum et al, 1985; Harvey et al., 1992; Liddle, 1987). In a recent meta-analysis, Cohen, Mitchell, and Elvevag (2014) reviewed studies utilizing objective measures of natural speech and found overall decreased speech production in schizophrenia with a large effect size ( $d = -.80$ ). Increased alogia has also been found in patients who have high rates of familial schizophrenia, suggesting possible relationship between alogia and genetic risk for the disorder (Arajarvi et al., 2006). Similar to disorganized speech, there is previous evidence that alogia is associated with poor cognitive task performance (Berenbaum, Kerns, Vernon, & Gomez, 2008; Kerns, 2007).

However, the specific cognitive correlates of disorganized speech and alogia are still unclear. For instance, previous research has consistently found that disorganized speech is associated with poor cognitive control task performance (i.e., executive functioning; Kerns & Berenbaum, 2002). Similarly, there is also evidence that alogia might be associated with poor cognitive control (Becker et al., 2012; Berenbaum et al., 2008). However, cognitive control is a broad construct and is made up of multiple components. Two potentially important components of cognitive control are working memory and goal maintenance. Working memory has been defined as the temporary storage of a small amount of information for active processing (Cowan, 2005) and has been found to be strongly correlated with other aspects of complex cognition (Conway, Kane, & Engle, 2003; Engle & Kane, 2004; Engle, Kane, & Tuholski, 1999). Goal maintenance is the ability to maintain important task critical information, such as rules, goals, or instructions (Rougier, Noelle, Braver, Cohen & O'Reilly, 2005). Goal maintenance is thought to be important for complex cognition as it is thought to provide a top-down biasing signal that allows for processing of information in accordance with current goals (Braver, Gray, & Burgess, 2007). Hence, it is possible that communication impairment or alogia might be associated with either poor working memory or poor goal maintenance.

A recent schizophrenia study examined whether either communication impairment or alogia was associated with impairments in working memory or goal maintenance (Becker et al., 2012). Communication impairment was significantly associated with poor goal maintenance but not with poor working memory ( $r = -.14$ ). In contrast, alogia was significantly associated with both poor working memory and poor goal maintenance. Hence, this previous study suggested that communication impairment might be specifically associated with poor goal maintenance whereas alogia might be associated with poor complex cognition in general.

However, the Becker et al. study did have some important limitations. One limitation is that it only included one measure each of working memory and goal maintenance. Other research has found that disorganized speech is associated with other working memory tasks (e.g., Berenbaum et al., 2008; Docherty, 1996). Further, that study did not examine the AX-CPT goal maintenance task, which is arguably the most well-validated measure of goal maintenance (Cohen et al., 1999). In the current study, I examined whether communication impairment and alogia would be associated with poor working memory or goal maintenance using two well-validated behavioral tasks assessing each construct.

Another limitation of the previous Becker et al. study is that alogia was assessed using live clinical ratings (i.e., symptom ratings made by a clinical interviewer) and not with a detailed quantitative assessment of actual speech produced. Live clinical ratings could be influenced by global impressions of patients (e.g., that someone has problems completing cognitive tasks; Cohen & Elvevag, 2014). The Becker et al. study involved a non-structured interview in which people who did not say much were continually prompted to speak more, which precluded the use of actual amount of speech to rate alogia. In the current study, participants were given structured interviews (i.e., the same questions were given to every participant) without any additional prompting. Hence, in the current study, ratings of alogia were based on the actual amount of speech each person produced.

Another limitation of some previous disorganized speech research such as the Becker et al. study is that it has often only focused on measures of cognitive control task performance. However, it is possible that communication impairment or alogia might also be associated with non-cognitive control impairments. In particular, there is some previous evidence that communication impairment is also associated with deficits in processing speed (Docherty, 2005;

Docherty, Strauss, Dinzeo, & St-Hilaire, 2006). Processing speed refers to the execution speed of the multiple components of a task, with evidence for a general speed factor involved in both simple and complex tasks (Salthouse, 1996; Salthouse, 2011). Processing speed is also a well-established deficit in schizophrenia (Dickinson, Ramsey, & Gold, 2007). Previous research has found that slower responding on a basic processing speed task, the Trail Making Test A (Reitan & Davidson, 1974), is related to communication impairment in schizophrenia (Docherty, 2005; Docherty et al., 2006). In the present study, I examined whether processing speed assessed on tasks and conditions not involving cognitive control demands (i.e., those involving making simple and automatic responses) would be associated with speech symptoms.

In addition to processing speed, I also examined whether speech symptoms were associated with a general measure of poor task performance. On the AX-CPT, performance on BY trials is thought to provide a measure of general task performance unrelated to cognitive control (Cohen et al., 1999; MacDonald, 2008). Hence, I also examined whether speech symptoms in schizophrenia would be related to errors on BY trials.

Overall, the current research examined whether the schizophrenia speech symptoms communication impairment or alogia were associated with cognitive deficits. In particular, I examined whether they were related to two aspects of cognitive control, working memory and goal maintenance. I also examined whether they were related to slower processing speed or to a measure of general poor task performance.

## **Method**

### **Participants**

Fifty-one people with schizophrenia and 26 healthy controls participated in this study. The schizophrenia group was comprised of non-acute inpatients with a wide range of functioning

recruited from a long-term state psychiatric hospital (with a largely forensic population). Participants resided on units in which the average length of stay is approximately 8 years. All eligible participants met Diagnostic and Statistical Manual of Mental Disorders (4<sup>th</sup> ed.; DSM-IV; American Psychiatric Association, 1994) criteria for schizophrenia ( $n = 33$ ) or schizoaffective disorder ( $n = 18$ ) based on the Structured Clinical Interview for the DSM-IV (SCID; First, Spitzer, Gibbon, & Williams, 1998). All but three participants in the schizophrenia group were taking antipsychotic medication at the time of participation. All patients scored over 19 on the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975). Control participants were recruited through community advertisements in central Missouri. Exclusion criteria for controls were no history of psychosis and no current Axis I disorder based on the SCID. General exclusionary criteria for both groups included diagnosis of a substance disorder within the past 6 months, diagnosis of intellectual disability, a history of any neurological event or disease (e.g., loss of consciousness for more than 10 minutes, stroke) or being a non-native English speaker. As can be seen in Table 1, the groups did not differ in age, gender, or parental education, all  $p > .20$ . As expected, the control group had completed significantly more years of education than the schizophrenia group,  $t = 8.2$ ,  $p < .001$ . The groups did differ in ethnicity,  $\chi^2 = 6.30$ ,  $p = .01$ , but there was no evidence that differences in ethnicity accounted for any group differences presented below. This study was approved by the Institutional Review Board of the University of Missouri, the state of Missouri Department of Mental Health, and Fulton State Hospital.

## Measures

**Working memory.** Participants completed two different measures of working memory: a reading digit span task (Barrouillet, Bernardin, & Camos, 2004) and a visual array task (adapted

from Luck and Vogel, 1997). In the reading digit span task, participants saw a series of letters and numbers (e.g., T 3 N 8). Each letter or number was displayed for 1,200 milliseconds (ms) with a 300 ms delay between items. Participants were instructed to remember the letters that they saw and to read the numbers that they saw aloud. At the end of each series, participants were required to recall the letters from that trial. Participants completed twelve trials (each trial being one series of letters and numbers). Series increased in length from two to five letters and numbers, with three trials completed at each series length. As in previous research (Barrouillet et al., 2004), a span score was calculated based on the number of correctly recalled series. A series was counted as correct if each letter was recalled in the correct order. Each correctly recalled series counted as  $1/3$  and were summed to provide the overall span score. Therefore, if a participant correctly recalled all three series at the two-item level and made errors on all larger series, their span score would be  $1/3 + 1/3 + 1/3 = 1$ . The reading digit span task was designed to be similar to traditional complex working memory span tasks that include both a storage and a processing component (e.g., operation span; Turner & Engle, 1989). However the processing component on the reading digit span task (simply reading numbers aloud) is much less complex than in other traditional complex span tasks (e.g., performing arithmetic or sentence reading). Given the simplicity of the processing component on the reading digit span task, this task might be especially well-suited for use with groups like schizophrenia who might be expected to have deficits on the processing components of other complex working memory span tasks. Critically, performance on the reading digit span task predicts performance on more traditional complex working memory span tasks (Barrouillet, Lepine, & Camos, 2008) while also predicting academic achievement at least as well (Lepine, Bernardin, & Barrouillet, 2005). Therefore, the

reading digit span is a valid measure of working memory capacity that has a more limited contribution from ancillary cognitive abilities.

For the visual array task (Luck & Vogel, 1997), after pressing a button to start the trial, participants observed an array of 4-8 solid colored squares spread out in various locations on a computer screen for 500 ms. The colored squares were comprised of a random combination of the colors red, blue, violet, green, yellow, black, and white. After a 500 ms delay, during which a blank grey screen was displayed, participants were presented with a second array of colored squares. The second array displayed a circle around one of the squares, with the circled square either staying the same color or changing in color from the first screen, with all of the other squares always staying the same color. The participant pressed “z” if the color of the circled square remained the same as in the previous screen and pressed “/” if the color of the circled square had changed from the previous screen. The second array remained on the screen until the participant made a response. Participants completed 6 practice trials and 72 test trials. The test trials included 24 trials each with 4, 6, or 8 squares per array. In previous research with healthy controls (e.g., Luck & Vogel, 1997), the visual array task has often included a secondary low verbal working memory load task to prevent verbal rehearsal in an attempt to specifically assess visual working memory storage limit. However, the presence of a secondary verbal working memory task could make the visual array task too difficult for people with schizophrenia to complete. Furthermore, performance in controls does not differ with the addition of the low load verbal working memory load (Morey & Cowan, 2005). Therefore, the present study used a version of the visual array that did not include a secondary verbal working memory task. The visual array was scored using Cowan’s K, an estimate of the capacity of visual memory. The formula for Cowan’s K is as follows:  $(\text{hits} + \text{correct rejections} - 1) \times \text{number of items in array}$

(Cowan, 2000). The visual array is thought to be a good measure of working memory storage limit because it is less conducive to rehearsal and grouping than verbal tasks (Saults & Cowan, 2007). The visual array has been used as a measure of working memory storage extensively in healthy individuals (e.g., Luck & Vogel, 1997; Vogel, Woodman, & Luck, 2001) and has also been used in previous research with schizophrenia (Gold, Wilk, McMahon, Buchanan, & Luck, 2003). In the current study, six participants with schizophrenia and 1 control did not complete the visual array task, due either to participant refusal or the task being inadvertently omitted.

Previous research has found that complex span tasks such as the reading digit span are highly correlated with working memory storage tasks such as the visual array task (e.g., Daneman & Carpenter, 1980). In the current research, as expected they were also correlated in people with schizophrenia, Spearman's rho ( $r_s$ ) = .42,  $p = .01$ . Hence, in examining correlations with language symptoms, I created a composite working memory variable by averaging standardized scores, with larger values indicating better working memory. If a participant was missing a score from one of the two working memory tasks, I used their one available working memory task score as their overall working memory score.

**Goal maintenance.** Participants completed two different measures of goal maintenance: the AX-CPT (Continuous Performance Task; Servan-Schreiber, Cohen, & Steingard, 1996) and the Preparation for Overcoming a Prepotent Response Task (POP; Barber & Carter, 2005). On the AX-CPT (Braver et al., 2001), participants saw letters presented one at a time at the center of the computer screen. Participants were instructed that the letter "X" was the target, but only when it followed the letter "A." Participants evaluated each letter as a target or non-target, pressing "1" for targets and "0" for non-targets. Each letter was presented for a duration of 300 ms with a delay between cue and probe onset of 6,100 ms. After the onset of the probe, there was

a 2,800 ms response window, followed by an additional inter-trial interval of 1,000 ms. Note that both the cue-probe delay (which included the response window for the cue) and the length of the probe response window were modified from Braver et al.'s (4,900 ms and 1,300 ms, respectively) to provide people with schizophrenia longer response windows. There are four trial types on this task: A-X trials, A-Y trials (where Y is any non-X probe, e.g., A followed by R), B-X trials (where B is any non-A cue; e.g., L followed by X), and B-Y trials. Participants completed 10 practice trials and 180 test trials. The trial frequencies were as follows: 70% A-X, 10% A-Y, 10% B-X, 10% B-Y. Given that 70% of trials were A-X trials, this means that people develop a prepotent response to respond to X as a target. People with poor goal maintenance make more errors on B-X trials because they are more likely to make a prepotent response error and incorrectly respond to the X as a target on these trials.

To ensure that participants were completing the task to a minimum standard of accuracy, participants were excluded who had accuracy less than 0.70 on either AX or BY trials (i.e., the easiest of the 4 trial types). In addition, as the BX trials are the most difficult and are of particular importance for assessing goal maintenance, participants who responded to fewer than 6 BX trials or those with a BX accuracy of 0% were also excluded (under the assumption that BX accuracy of 0% indicates clearly not performing the task as intended). 7 participants with schizophrenia were excluded from final analyses based on these performance exclusions. Trials with reaction times less than 200 ms were excluded from accuracy analyses. A large amount of behavioral, brain imaging, and computational modeling research supports the AX-CPT as a measure of goal maintenance (e.g., Barch et al., 2009; Cohen et al., 1999; MacDonald et al., 2005). Following previous research (Barch, Carter, MacDonald, Braver, & Cohen, 2003; Chung, Mathews, & Barch, 2011; Cohen et al., 1999; Servan-Schreiber et al., 1996), the dependent

variable for the AX-CPT was  $d'$ -context, measured using the AX condition hit rate and the BX condition false alarm rate to provide an index more specifically reflective of goal maintenance. In addition, consistent with previous literature (Cohen et al., 1999; MacDonald, 2008), accuracy on BY trials was calculated to assess general task performance presumably unrelated to goal maintenance (note associations with BY trial performance were similar whether or not we excluded participants with BY accuracy  $< 0.70$ ). Of the total sample, one participant with schizophrenia and 7 controls did not complete the AX-CPT.

On the POP goal maintenance task (Becker et al., 2012), participants saw either a red or green square (the cue) for 200 ms. Immediately following this screen, participants observed an arrow (the probe) pointing to either the left or the right that remained until a response was made. If the color of the cue was green, participants made a prepotent response and responded in the direction of the arrow probe, pressing “1” for left and “0” for right. However, if the color of the cue was red, then participants needed to respond in the direction opposite of the arrow probe (e.g., if the arrow pointed left, then they needed to respond right). Hence, this task is thought to involve goal maintenance, as participants need to retain and use cue information in order to correctly overcome the prepotent response tendency to respond in the direction of the arrow. On this task, participants first simply responded to the direction of the arrow (without first seeing a color cue) for 40 trials. Then they were informed about the color cues and completed 8 practice trials, followed by 120 test trials. On this task, probes were displayed until the participant responded. The trials were evenly split between red and green cues and right and left probes. The dependent variable was the *POP interference score*, which was accuracy for red trials minus accuracy for green trials, with poorer goal maintenance resulting in more errors on red trials than on green trials. Trials with reaction times (RTs) less than 200 ms were excluded from accuracy

analyses. Participants were excluded with accuracy below 60% on the easiest trial type, green cue trials that had been preceded by another green cue trial (note that chance performance on this task is 50%). Four participants with schizophrenia were excluded for poor performance and an additional two participants with schizophrenia did not complete this task.

I created a goal maintenance composite score by averaging standardized scores from the AX-CPT  $d'$ -context and the POP interference scores, with larger values representing better goal maintenance task performance. These two scores were correlated in patients  $r_s = .55, p < .001$ . If a participant was missing a score from one of the two tasks, I used their one available goal maintenance task score as their overall goal maintenance score.

**Processing speed.** Processing speed was measured by examining reaction time for simple, prepotent response trials on both the AX-CPT and the POP. On the AX-CPT, the measure of processing speed was RT on AX trials, which occur on 70% of trials and therefore are thought to involve a relatively automatic and highly prepotent response. From the POP task, the processing speed variable was RT for the initial set of 40 trials in which participants only saw arrows pointing left and right and simply responded in the direction of the arrow, responding as quickly and accurately as possible. Hence these initial 40 arrow trials involve simply making relatively automatic and highly prepotent responses. For both tasks, RTs only included trials in which the participants responded accurately, and RTs less than 200 ms were excluded from all analyses. To eliminate long duration RT outliers, I excluded any trial on which RT was greater than 3.5 SDs above the participant's individual mean.

I created a processing speed composite score by averaging standardized processing speed scores from the AX-CPT AX trials and the POP arrow only trials, with larger values indicating faster speed. These two scores were correlated in patients  $r_s = .57, p < .001$ . As with working

memory and goal maintenance, if a participant was missing reaction time from one of the two tasks, I used their one available task score as their overall measure of processing speed.

**Speech symptoms.** To reliably rate the speech symptoms communication impairment and alogia, participants completed up to two 5-20 minute structured interviews that were audiotaped and transcribed. Forty-seven people with schizophrenia completed interview one and 44 completed interview two, with all but 3 completing at least one interview. The first interview asked about general information and interests with questions such as, “Can you describe where you live now?” and “What kinds of movies do you like?” The second interview asked about specific memories with questions such as, “Tell me a specific memory about a time you were with your family.”

Communication impairment was rated using the Communication Disturbances Index (CDI; Docherty, 1996; Docherty, et al., 1996), which rates the number of speech unclaritys, with a speech unclarity defined as any passage of speech 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 & Martin, 1979). More recently, the CDI has also frequently been used to measure disorganized speech in patients with schizophrenia (e.g., Docherty, 2005; Kerns & Berenbaum, 2003). The CDI is associated with previously established measures of positive formal thought disorder (Docherty & Gordinier, 1999; Docherty et al., 1996). Moreover, the CDI is thought to focus on communication failures in speech, rather than the underlying thought disorder (Docherty, 2005). In the current study, three trained raters reached consensus on all CDI ratings. As in previous research (Docherty et al., 1996), CDI scores were corrected for overall amount of speech, such that CDI scores are reported as number of unclaritys per 100

words of speech. For alogia, as in previous research (Berenbaum et al., 2008; Kerns, 2007), the measure of alogia was the amount of words produced in the structured interviews, with higher levels of alogia reflected in a fewer number of words produced.

As two language interviews were collected and rated, I created composite scores for both communication disturbances and alogia by averaging standardized scores for the two interviews. Interview 1 and interview 2 were highly correlated for both communication disturbances ( $r_s = .70, p < .001$ ) and alogia ( $r_s = .71, p < .001$ ).

**Positive symptoms.** Experienced and advanced graduate students administered all diagnostic and clinical interviews. To measure positive symptoms, interviewers rated delusions and hallucinations using the Scale for the Assessment of Positive Symptoms (SAPS; Andreasen, 1984). A composite positive or reality distortion variable was created by summing the global delusions and global hallucinations items.

### **Procedure and data analyses**

Participants completed all cognitive measures on a computer as part of a larger cognitive battery. The participants completed the tasks in this study in the following order: AX-CPT, reading digit span task, visual array, and POP. The clinical assessments were interspersed among the cognitive tasks. Participants with schizophrenia completed the assessment battery over two or three sessions, approximately a week apart (with the two speech interviews occurring in different sessions), whereas most control participants were able to complete the entire battery in a single session lasting approximately 3 hours.

In analyzing correlations between tasks, I used non-parametric Spearman rho correlations ( $r_s$ ) to minimize the chance that outliers could overly influence the results. Reliability and discriminating power were calculated for all tasks. I calculated split-half reliability for the

dependent variable from each task. To ensure that the correlations obtained from the splits were representative of the overall level of task reliability, split-half reliability was calculated from 10 different randomly determined splits and the reliability estimates were averaged together. As an estimate of discriminating power, I used the between-groups Cohen's *d* effect size between people with schizophrenia and controls.

## Results

**Between-group differences in cognitive performance.** As can be seen in Table 2, as expected, participants with schizophrenia performed significantly worse than controls on all of the cognitive tasks. Between-group effect sizes ranged from moderate to very large, with numerically the largest effect sizes for the working memory tasks. Furthermore, reliability for all tasks was excellent except for BY accuracy, which is limited by the relatively small number of BY trials and the POP Interference score, which as a difference score was understandably reduced (Lord, 1963).

**Correlations between cognitive domains in schizophrenia.** Next, I examined to what extent the three cognitive domains (working memory, goal maintenance, processing speed) were significantly correlated in people with schizophrenia. Overall, the three cognitive domains were significantly positively correlated: working memory was correlated with goal maintenance,  $r_s = .66, p < .001$ , and with processing speed,  $r_s = .43, p = .002$ ; goal maintenance and processing speed were correlated  $r_s = .41, p = .003$ . Furthermore, all cognitive domains were also significantly correlated with fewer BY errors on the AX-CPT: for working memory,  $r_s = .63, p < .001$ ; for goal maintenance,  $r_s = .60, p < .001$ ; for processing speed,  $r_s = .35, p = .022$ .

**Correlations between language symptoms and cognitive task performance in schizophrenia.** As can be seen in Table 3, communication impairment was significantly

associated with poorer performance for all three cognitive domains. Specifically, CDI scores were associated with poorer working memory task performance (for individual working tasks, CDI was correlated at trend levels with both reading digit span task and the visual array,  $r_s = -.24, p = .097$ ;  $r_s = -.30, p = .052$ , respectively). Similarly, CDI scores were associated with poorer goal maintenance (for individual goal maintenance tasks, CDI correlated with AX-CPT,  $r_s = -.39, p = .016$ ; with POP Interference,  $r_s = -.33, p = .029$ ). Finally, CDI scores were also associated with increased processing speed (CDI with AX trials RT,  $r_s = -.34, p = .031$ ; for POP arrow only,  $r_s = -.54, p < .001$ ).

In addition to the significant correlations with the three cognitive domains, communication impairment was also significantly associated with poorer BY performance,  $r_s = -.43, p = .006$ . Hence, overall communication impairment was associated with poor cognitive task performance in general, with if anything the largest associations being found on the simplest cognitive tasks. Given the association between communication impairment and BY performance, I next examined whether this association was only due to some patients performing especially poorly on BY trials. Overall, in both controls and patients, BY performance was excellent, with all of the controls and 60% of the patients demonstrating 100% accuracy on these trials. As an exploratory analysis, patients with schizophrenia were split into two groups with one group comprised of those with perfect performance (i.e., 100% accuracy on BY trials) and a second group comprised of those who made at least one error (accuracy in this group ranged from 71% to 94%). As expected given the correlation presented above, the group of people with schizophrenia with BY errors had significantly higher levels of communication impairment compared to the group of people with schizophrenia with perfect BY performance ( $t = -3.21, p = .003$ ). Importantly, this difference held when the group with BY errors was restricted to those

with BY accuracy  $\geq 80\%$  or even  $\geq 90\%$ . Hence, the association between communication impairment and BY errors did not seem to only be due to some people with schizophrenia who had especially poor BY condition performance, suggesting a broader association between communication impairment and poor task performance.

In contrast to the results for communication impairment, as can be seen in Table 3, alogia was not significantly associated with any of the cognitive constructs (with the largest non-significant correlation being with poorer goal maintenance). All correlations between alogia and individual task variables were  $r_s > -.24$ , except for the correlation between alogia and AX trials RT, which was  $r_s = -.36, p = .02$ . In addition, the size of the correlation between processing speed and CDI was significantly larger than the correlation between processing speed and alogia,  $Z = -2.01, p = .02$  (Meng, Rosenthal, & Rubin, 1992).

As reaction time may be affected by participant's age, we tested for an association between age and response speed. In people with schizophrenia, age and response speed were not significantly correlated ( $p \geq .70$ ), and statistically partialling variance shared with age did not affect associations with CDI scores.

**Correlations with positive symptoms.** Delusions and hallucinations from the SAPS were not significantly correlated with working memory, goal maintenance, processing speed, or with BY errors (all  $r_s < .18$ ). There were also no significant correlations between the SAPS and either communication impairment or alogia (all  $r_s < .05$ ).

## Discussion

The current study found evidence that communication impairment in schizophrenia is related to both cognitive control and non-cognitive control deficits. Therefore, the current study suggests that disorganization symptoms in schizophrenia might be related to the broad level of

cognitive dysfunction generally observed in this disorder. In contrast, the current study found little evidence that alogia was related to either cognitive control or non-cognitive control deficits. Hence, the current study suggests that if alogia is related to cognitive dysfunction that it could be associated with a relatively circumscribed set of impaired cognitive mechanisms.

In the current study, communication impairment in schizophrenia was associated with poor task performance in general. As predicted, communication impairment was associated with poor performance in both cognitive control domains, working memory and goal maintenance. However, communication impairment was also associated with slower processing speed on relatively automatic tasks and conditions involving the execution of highly prepotent responses. Further, communication impairment was also associated with a measure of general poor task performance, increased BY errors on the AX-CPT. In fact, in this study the largest correlations numerically with communication impairment were with the simpler tasks and conditions (e.g., speed of responding to arrow only trials) rather than with the more complicated and cognitively complex tasks (e.g., the reading digit span task). Overall, the current results suggest that the association between communication impairment and poor cognitive task performance could be fairly general and extend beyond poor cognitive control.

The current results for processing speed are also consistent with some previous communication impairment research. For instance, performance on the Trail Making Task condition A is typically thought to be a measure of processing speed, whereas Trails B is typically thought to involve cognitive control. However, communication impairment has been associated with slower performance on both Trails A and Trails B (Docherty, 2005; Docherty, et al., 2006). Hence, the current study provides further evidence that disorganized speech in schizophrenia is associated with slower processing speed. The current study is also consistent

with research on other populations known to have both increased disorganization and slower processing speed. In particular, both people who have had closed head injuries as well as elderly adults exhibit increased levels of disorganized behavior and speech (e.g., Gold et al., 1988; Hinchliffe, Murdoch, & Theodoros, 2001; Levin & Grossman, 1978). In addition, both closed head injuries and older age are associated with slower processing speed (e.g., Incoccia, Formisano, Muscato, Reali, & Zoccolotti, 2004; Salthouse, 1996). Hence, both in people with schizophrenia and in other populations there is an association between disorganization and slower processing speed. This suggests that processing speed and problems in the efficient and timely execution of information processing could play an important role in disorganized speech in schizophrenia. In addition, in the current study, the strong associations between disorganized speech and processing speed is not easily accounted for by task discriminating power (Chapman & Chapman, 1973), as the processing speed measures tended to have the least amount of discriminating power (estimated from between-groups effect sizes). Future research could continue to examine whether disorganization is associated with slower processing speed using a broader range of processing speed tasks than used in the current study.

The current study also provides additional evidence that disorganization symptoms are potentially the schizophrenia symptom most associated with cognitive deficits. In the current study, we found that communication impairment was associated with poor cognition broadly. As a disorder, schizophrenia is also associated with a broad range of cognitive deficits and fairly general cognitive dysfunction (Dickinson, Iannone, Wilk, & Gold, 2004; Dickinson, Ragland, Gold, & Gur, 2008; Reichenberg, 2010). Furthermore, schizophrenia is also associated with a broad level of neural dysfunction as well. For example, a recent large sample brain imaging study reported a broad decrease in gray matter across the brain in people with schizophrenia or

with schizoaffective disorder (Ivleva et al., 2013). Further, extensive white matter deficits have also been found in schizophrenia (e.g., Roalf et al., 2014) that might also be expected to contribute to poor cognitive coordination on a wide range of cognitive tasks, including processing speed tasks. Hence, the current study suggests that disorganization symptoms in schizophrenia might be associated with the relatively generalized cognitive and neural dysfunction present in this disorder.

In contrast to disorganization, other schizophrenia symptom factors do not seem as clearly related to cognitive deficits. Consistent with this, in the current study neither positive symptoms nor alogia tended to be associated with deficits on the cognitive tasks completed in this study. This is consistent with other evidence that positive symptoms are not related to poor cognitive functioning in general (e.g., Barch, Carter, MacDonald, Braver, & Cohen, 2003; Dominguez et al., 2009). Similarly, there is other evidence that negative symptoms in general may not be strongly associated (e.g., Dominguez et al., 2009), if at all associated (Gur et al., 2006; Kring, Gur, Blanchard, Horan, & Reise, 2013), with generalized cognitive deficits. Hence, in contrast to positive and negative symptoms, the current study has found additional evidence that disorganized symptoms are the symptom factor in schizophrenia that is most associated with general cognitive dysfunction.

Given the evidence in this study that communication impairment was related to evidence of fairly broad cognitive dysfunction, this does raise the question of whether there is any evidence of disorganization symptoms *not* being associated with cognitive dysfunction. One possible type of cognitive task that does not appear to be strongly if at all associated with disorganized speech is fluency tasks (e.g., producing as many words as possible that begin with the letter 's'). Multiple studies have reported that disorganization symptoms are not significantly

associated with decreased output on fluency tasks, such as verbal fluency (e.g., Berenbaum et al., 2008; Docherty et al., 1996). One possible explanation for the lack of association between disorganization and fluency task performance may be that simple processing speed does not make a large contribution to fluency. Although there is literature documenting a relationship between processing speed as measured on more complex tasks and fluency, there may be less shared variance between fluency and processing speed for simple prepotent response. Hence, the lack of association between disorganized speech and fluency tasks might provide some evidence that the wide ranging associations between cognitive deficits and disorganized speech could be largely related to slower processing speed. Another possibility is that some other cognitive deficits related to disorganized speech, such as a deficit in typical build-up of interference from previously produced items on a fluency task (Rosen & Engle, 1997), might paradoxically help fluency performance in people with disorganized speech. Overall, it is possible that research comparing relationships between processing speed, fluency task performance, and disorganized speech in schizophrenia might help further understand the nature of cognitive deficits related to disorganization.

In contrast to communication impairment, there was limited evidence for alogia to be related to cognitive deficits in this study. In previous research, the relationship between alogia and cognitive control has been somewhat inconsistent (Becker et al., 2012; Berenbaum et al., 2008; Kerns, 2007). Potentially use of less valid clinical ratings rather than direct measures of actual amount of speech produced could account for some of the inconsistencies (Becker et al., 2012). In addition, the current results are similar to previous cognitive control and alogia research in which alogia was measured using actual word counts. For instance, previous research has found that alogia was not associated with a composite measure of working memory (Kerns,

2007), or with a composite cognitive control measure that included both working memory capacity (Reading Span task) and goal maintenance (AX-CPT d' context; Berenbaum et al., 2008). Hence, overall, it does not appear that alogia when measured using objective and reliable word counts is strongly associated with poor cognitive control. Also, based on the current research, it does not appear that alogia may be as broadly associated with poor cognition as is communication impairment.

Although alogia was not clearly associated with poor cognition in the current study, there is other evidence that alogia might be associated with some aspects of poor cognition. Intriguingly, arguably the cognitive task deficit most associated with alogia is poor performance on fluency tasks (Berenbaum et al., 2008; Joyce et al., 1996; Stolar, Berenbaum, Banich, & Barch, 1994). This is striking given that, as mentioned previously, disorganization symptoms do not seem to be related to decreased fluency task performance. It is also striking that alogia is associated with poor performance on both verbal and non-verbal fluency tasks (Berenbaum et al., 2008; Stolar et al., 1994), suggesting that alogia is not simply associated with a deficit in verbal productivity. Therefore, future research examining the nature of the relationship between alogia and fluency task performance might be important in understanding the nature of cognitive deficits associated with alogia.

## References

- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4<sup>th</sup> ed.). Washington, DC.
- Andreasen, N. C. (1979a). Thought, language, and communication disorders: I. Clinical assessment, definition of terms, and evaluation of their reliability. *Archives of General Psychiatry*, *36*, 1315–1321. doi:10.1001/archpsyc.1979.01780120045006
- Andreasen, N. C. (1979b). Thought, language, and communication disorders: II. Diagnostic significance. *Archives of General Psychiatry*, *36*, 1325–1330.  
doi:10.1001/archpsyc.1979.01780120055007
- Andreasen, N.C. (1984). *Scale for the Assessment of Positive Symptoms (SAPS)*. Iowa City, IA, University of Iowa.
- Arajärvi, R., Verilo, T., Haukka, J., Suvisaari, J., Suokas, J., Juvonen, H., ... Lonnqvist, J. (2006). Affective flattening and alogia associate with the familial form of schizophrenia. *Psychiatry Research*, *141*, 161-172. doi:10.1016/j.psychres.2005.08.008
- Barber, A. D., & Carter, C. S. (2005). Cognitive control involved in overcoming prepotent response tendencies and switching between tasks. *Cerebral Cortex*, *15*, 899-912.  
doi:10.1093/cercor/bhh189
- Barch, D. M., Berman, M. G., Engle, R., Hurdelbrink Jones, J., Jonides, J., MacDonald III, A.... & Sponheim, S. R. (2009). CNTRICS final task selection: Working memory. *Schizophrenia Bulletin*, *35*(1), 136-152. doi:10.1093/schbul/sbn153
- Barch, D. M., Carter, C. S., MacDonald, A. W., Braver, T. S., & Cohen, J. D. (2003). Context-processing deficits in schizophrenia: Diagnostic specificity, 4-week course, and relationships to clinical symptoms. *Journal of Abnormal Psychology*, *112*(1), 132-143.  
doi:10.1037/0021-843X.112.1.132

- Barrouillet, P., Bernardin, S., & Camos, V. (2004). Time constraints and resource sharing in adults' working memory spans. *Journal of Experimental Psychology*, *133*(1), 83-100. doi:10.1037/0096-3445.133.1.83
- Barrouillet, P., Lepine, R., & Camos, V. (2008). Is the influence of working memory capacity on high-level cognition mediated by complexity or resource-dependent elementary processes? *Psychonomic Bulletin & Review*, *15*(3), 528-534. doi:10.3758/PBR.15.3.528
- Becker, T. M., Cicero, D. C., Cowan, N., & Kerns, J. (2012). Cognitive control components and speech symptoms in people with schizophrenia. *Psychiatry Research*, *196*, 20-26. doi:10.1016/j.psychres.2011.10.003
- Berenbaum, H., Kerns, J. G., Vernon, L. L., & Gomez, J. J. (2008). Cognitive correlates of schizophrenic signs and symptoms: I. verbal communication disturbances. *Psychiatry Research*, *159*, 163-166. doi:10.1016/j.psychres.2007.08.016
- Berenbaum, H., Oltmanns, T. F., & Gottesman, I. I. (1985). Formal thought disorder in schizophrenics and their twins. *Journal of Abnormal Psychology*, *94*(1), 3-16. doi:10.1037/0021-843X.94.1.3
- Braver, T. S., Barch, D. M., Keys, B. A., Carter, C. S., Cohen, J. D., Kaye, J. A., ... Reed, B. R. (2001). Context processing in older adults: Evidence for a theory relating cognitive control to neurobiology in healthy aging. *Journal of Experimental Psychology: General*, *130*, 746-763. doi:10.1037/0096-3445.130.4.746
- Braver, T. S., Gray, J. R., & Burgess, G. C. (2007). Explaining the many varieties of working memory variation: dual mechanisms of cognitive control. In: Conway, A.R.A., Jarrold, C., Kane, M.J., Miyake, A., Towse, J.N. (Eds.), *Variation in Working Memory*. Oxford Press, New York, pp. 76-106.

- Chapman, L. J., & Chapman, J. P. (1973). *Problems in the measurement of cognitive deficit. Psychological Bulletin, 79*(6), 380-385. doi: 10.1037/h0034541
- Chung, J. S., Mathews, J. R., & Barch, D. M. (2011). The effect of context processing on different aspects of social cognition in schizophrenia. *Schizophrenia Bulletin, 37*(5), 1048-1056. doi:10.1093/schbul/sbq012
- Cohen, A. S., & Elvevag, B. (2014). Automated computerized analysis of speech in psychiatric disorders. *Current Opinion in Psychiatry, 27*(3), 203-209. doi:10.1097/YCO.0000000000000056
- Cohen, A. S., Mitchell, K. R., & Elvevag, B. (2014). What do we really know about blunted vocal affect and alogia? A meta-analysis of objective assessments. *Schizophrenia Research, 159*, 533-538. doi:10.1016/j.schres.2014.09.013
- Cohen, J. D., Barch, D. M., Carter, C., & Servan-Schreiber, D. (1999). Context-processing deficits in schizophrenia: Converging evidence from three theoretically motivated cognitive tasks. *Journal of Abnormal Psychology, 108*(1), 120-133. doi:10.1037/0021-843X.108.1.120
- Conway, A. R. A., Kane, M. J., & Engle, R. W. (2003). Working memory capacity and its relation to general intelligence. *Trends in Cognitive Sciences, 7*(12), 547-552. doi:10.1016/j.tics.2003.10.005
- Cowan, N. (2000). The magic number 4 in short-term memory: A reconsideration of mental storage capacity. *The Behavioral and Brain Sciences, 24*, 87-185. doi:10.1017/S0140525X01003922
- Cowan, N. (2005). *Working Memory Capacity*. Hove, East Sussex, UK: Psychology Press.

- Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, *19*, 450-466.  
doi:10.1016/S0022-5371(80)90312-6
- Dickinson, D., Iannone, V. N., Wilk, C. M., & Gold, J. M. (2004). General and specific cognitive deficits in schizophrenia. *Biological Psychiatry*, *55*, 826-833.  
doi:10.1016/j.biopsych.2003.12.010
- Dickinson, D., Ragland, J. D., Gold, J. M., & Gur, R. C. (2008). General and specific cognitive deficits in schizophrenia: Goliath defeats David? *Biological Psychiatry*, *64*, 823-827.  
doi:10.1016/j.biopsych.2008.04.005
- Dickinson, D., Ramsey, M. E., & Gold, J. M. (2007). Overlooking the obvious: A meta-analysis comparison of digit symbol coding tasks and other cognitive measures in schizophrenia. *Archives of General Psychiatry*, *64*, 532-542. doi:10.1001/archpsyc.64.5.532
- Docherty, N. M. (1996). *Manual for the Communication Disturbances Index (CDI)*. Kent, OH: Kent State University, Department of Psychology.
- Docherty, N. M. (2005). Cognitive impairments and disordered speech in schizophrenia: Thought disorder, disorganization, and communication failure perspectives. *Journal of Abnormal Psychology*, *114*, 269-278. doi:10.1037/0021-843X.114.2.269
- Docherty, N. M., DeRosa, M., & Andreasen, N. C. (1996). Communication disturbances in schizophrenia and mania. *Archives of General Psychiatry*, *53*, 358-364.  
doi:10.1001/archpsyc.1996.01830040094014
- Docherty, N. M., Hawkins, K. A., Hoffman, R. E., Quinlan, D. M., Rakfeldt, J., & Sledge, W. H. (1996). Working memory, attention, and communication disturbances in schizophrenia. *Journal of Abnormal Psychology*, *105*(2), 212-219. doi:10.1037/0021-843X.105.2.212

- Docherty, N. M. & Gordinier, S. W. (1999). Immediate memory, attention, and communication disturbances in schizophrenia patients and their relatives. *Psychological Medicine*, 29(1), 189-197. doi:10.1017/S0033291798007843
- Docherty, N. M., Gordinier, S.W., Hall, M. J., & Dombrowski, M. E. (2004). Referential communication disturbances in the speech of nonschizophrenic siblings of schizophrenia patients. *Journal of Abnormal Psychology*, 113(3), 399-405. doi:10.1037/0021-843X.113.3.399
- Docherty, N. M., Strauss, M. E., Dinzeo, T. J., & St-Hilaire, A. (2006). The cognitive origins of specific types of schizophrenic speech disturbances. *American Journal of Psychiatry*, 163, 2111-2118. doi:10.1176/appi.ajp.163.12.2111
- Dominguez, M. G., Viechtbauer, W., Simons, C. J. P., van Os, J., & Krabbendam, L. (2009). Are psychotic psychopathology and neurocognition orthogonal? A systematic review of their associations. *Psychological Bulletin*, 135(1), 157-171. doi:10.1037/a0014415
- Engle, R.W., & Kane, M.J. (2004). Executive attention, working memory capacity, and a two-factor theory of cognitive control. In The psychology of learning and motivation, vol 44. B. Ross, ed. 145-199. New York: Elsevier.
- Engle, R. W., Kane, M. J., & Tuholski, S. W. (1999). Individual differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence, and functions of the prefrontal cortex. In A. Miyake & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 102-134). New York: Cambridge University Press.
- First, M. B., Spitzer, R. L., Gibbon, M., & Williams, J. B. (1998). Structured Clinical Interview for DSM-IV Axis Disorders. New York: New York State Psychiatric Institute.

- Folstein, M. F., Folstein, S. E., & McHugh, P.R. (1975). Mini-mental state. A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12*, 189-198. doi:10.1016/0022-3956(75)90026-6
- Gold, D., Andres, D., Arbuckle, T., & Schwartzman, A. (1988). Measurement and correlates of verbosity in elderly people. *Journal of Gerontology: Psychological Sciences, 43*, 27– 33.
- Gold, J. M., Wilk, C. M., McMahon, R. P., Buchanan, R. W., & Luck, S. J. (2003). Working memory for visual features and conjunctures in schizophrenia. *Journal of Abnormal Psychology, 112*(1), 61-71. doi:10.1037/0021-843X.112.1.61
- Gooding, D. C., Coleman, M. J., Roberts, S. A., Shenton, M. E., Levy, D. L., & Erlenmeyer-Kimling, L. (2012). Thought disorders in offspring of schizophrenic parents: Findings from the New York high-risk project. *Schizophrenia Bulletin, 38*(2), 263-271. doi: 10.1093/schbul/sbq061
- Gur, R. E., Kohler, C. G., Raglund, J. D., Siegel, S. J., Lesko, K., Bilker, W. B., & Gur, R. C. (2006). Flat affect in schizophrenia: Relation to emotion processing and neurocognitive measures. *Schizophrenia Bulletin, 32*, 2, 279-287. doi:10.1093/schbul/sbj041
- Harvey, P. D., Lenzenweger, M. F., Keefe, R. S., Pogge, D. L., Serper, M. R., & Mohs, R. C. (1992). Empirical assessment of the factorial structure of clinical symptoms in schizophrenic patients: Formal thought disorder. *Psychiatry Research, 44*, 141-151. doi:10.1159/000285058
- Hinchliffe, F.J., Murdoch, B. E., Theodoros, G. Linguistic deficits in adults subsequent to traumatic brain injury. In: Murdoch BE, Theodoros DG, editors. *Traumatic brain injury: Associated speech, language and swallowing disorders*. San Diego, CA: Singular Publishing Group; 2001. pp 199–222.

- Incoccia, C., Formisano, R., Muscato, P., Reali, G., & Zoccolotti, P. (2004). Reaction and movement times in individuals with chronic traumatic brain injury with good motor recovery. *Cortex, 40*, 111-115.
- Ivleva, E. I., Bidesi, A. S., Keshavan, M. S., Pearlson, G. D., Meda, S. A., Dodig, D., ... Tamminga, C. A. (2013). Gray matter volume as an intermediate phenotype for psychosis: Bipolar-Schizophrenia Network on Intermediate Phenotypes (B-SNIP). *American Journal of Psychiatry, 170*(11), 1285-1296.  
doi:10.1176/appi.ajp.2013.13010126
- Joyce, E. M., Collinson, S. L., & Crichton, P. (1996). Verbal fluency in schizophrenia: Relationship with executive function, semantic memory, and clinical alogia. *Psychological Medicine, 26*, 39-49.
- Kerns, J. G. (2007). Verbal communication impairments and cognitive control components in people with schizophrenia. *Journal of Abnormal Psychology, 116*(2), 279-289.  
doi:10.1037/0021-843X.116.2.279
- Kerns, J. G., & Berenbaum, H. (2002). Cognitive impairments associated with formal thought disorder in people with schizophrenia. *Journal of Abnormal Psychology, 111*(2), 211-224. doi:10.1037//0021-843X.111.2.211
- Kerns, J. G., & Berenbaum, H. (2003). The relationship between formal thought disorder and executive functioning component processes. *Journal of Abnormal Psychology 112*, 339-352. doi:10.1037/0021-843X.112.3.339
- Kring, A. M., Gur, R. E., Blanchard, J. J., Horan, W. P., & Reise, S. P. (2013). The clinical assessment interview for negative symptoms (CAINS): Final development and validation. *American Journal of Psychiatry, 170*(2), 165-172. doi:10.1176/appi.ajp.2012.12010109.

- Lepine, R., Bernardin, S., & Barrouillet, P. (2005). Attention switching and working memory spans. *European Journal of Cognitive Psychology, 17*(3), 329-345.  
doi:10.1080/09541440440000014
- Levine, H. S., & Grossman, R. G. (1978). Behavioral sequelae of closed head injury. *Archives of Neurology, 35*, 720-727.
- Liddle, P. F. (1987). The symptoms of chronic schizophrenia. A re-examination of the positive-negative dichotomy. *British Journal of Psychiatry, 151*, 145-151.  
doi:10.1192/bjp.151.2.145
- Lord, 1963. Lord, F. M. (1963). Elementary Models for Measuring Change, in C. W. Harris, ed., *Problems in Measuring Change*, Madison: University of Wisconsin Press, 22-38.
- Luck, S. J., & Vogel, E. K. (1997). The capacity of visual working memory for features and conjunctions. *Nature, 390*, 279-281. doi:10.1038/36846
- MacDonald III, A. W. (2008). Building a clinically relevant cognitive task: Case study of the AX paradigm. *Schizophrenia Bulletin, 34*(4), 619-628. doi:10.1093/schbul/sbn038
- MacDonald III, A. W., Carter, C. S., Kerns, J. G., Ursu, S., Barch, D. M., Holmes, A. J.,...Cohen, J. D. (2005). Specificity of prefrontal dysfunction and context processing deficits to schizophrenia and never-medicated patients with first-episode psychosis. *American Journal of Psychiatry, 162*, 475-484. doi:10.1176/appi.ajp.162.3.475
- McGrath, J. (1991). Ordering thoughts on thought disorder. *British Journal of Psychiatry, 158*, 307-316. doi:10.1192/bjp.158.3.307
- Meng, X., Rosenthal, R., & Rubin, D. B. (1992). Comparing correlated correlation coefficients. *Psychological Bulletin, 111*, 172-175. doi:10.1037/0033-2909.111.1.172

- Morey, C. C. & Cowan, N. (2005). When do visual and verbal memories conflict? The importance of working-memory load and retrieval. *Journal of Experimental Psychology*, 31(4), 703-713. doi:10.1037/0278-7393.31.4.703
- Nuechterlein, K. H., Barch, D. M., Gold, J. M., Goldberg, T. E., Green, M. F., & Heaton, R. K. (2004). Identification of inseparable cognitive factors in schizophrenia. *Schizophrenia Research*, 72, 29-39. doi: 10.1016/j.schres.2004.09.007
- Reichenberg, A. A. (2010). The assessment of neuropsychological functioning in schizophrenia. *Dialogues in Clinical Neuroscience*, 12(3), 383-392.
- Reitan, R. M., & Davidson, L. A. 1974. *Clinical Neuropsychology: Current status and applications*. New York, Hemisphere.
- Rietkerk, T., Boks, M. P. M., Sommer, I. E., Liddle, P. F., Ophoff, R. A., & Kahn, R. S. (2008). The genetics of symptom dimensions of schizophrenia: Review and meta-analysis. *Schizophrenia Research*, 102, 197-205. doi:10.1016/j.schres.2008.01.023
- Roalf, D. R., Gur, R. E., Verma, R., Parker, W. A., Quarmley, M., Gur, R. C. (2014). White matter microstructure in schizophrenia: Associations to neurocognition and clinical symptomatology. *Schizophrenia Research*, S0920-9964. doi:10.1016/j.schres.2014.09.026
- Rochester, S. R., & Martin, J. R., 1979. *Crazy Talk: A Study of the Discourse of Schizophrenic Speakers*. Plenum Press, New York.
- Rosen, V. M., & Engle, R. W. (1997). The role of working memory capacity in retrieval. *Journal of Experimental Psychology: General*, 126, 211-227.

- Rougier, N. P., Noelle, D. C., Braver, T. S., Cohen, J. D., & O'Reilly, R. C. (2005). Prefrontal cortex and flexible cognitive control: Rules without symbols. *Proceedings of the National Academy of Sciences, 102*, 7338-7343. doi:10.1073/pnas.0502455102
- Salthouse, T. A. (1996). General and specific speed mediation of adult age differences in memory. *Journal of Gerontology: Psychological Sciences, 51B*(1), 30-42. doi:10.1093/geronb/51B.1.P30
- Salthouse, T. A. (2011). What cognitive abilities are involved in trail-making performance? *Intelligence, 39*, 4, 222-232. doi:10.1016/j.intell.2011.03.001
- Saults, J. S., & Cowan, N. (2007). A central capacity limit to the simultaneous storage of visual and auditory arrays in working memory. *Journal of Experimental Psychology: General, 136*, 663-684. doi:10.1037/0096-3445.136.4.663
- Servan-Schreiber, D., Cohen, J. D., & Steingard, S. (1996). Schizophrenic deficits in the processing of context. A test of a theoretical model. *Archives of General Psychiatry, 53*(12), 1105-1112. doi:10.1001/archpsyc.1996.01830120037008
- Sigaudo, M., Crivello, B., Castagna, F., Giugiaro, M., Mingrone, C., Montemagni, C., ... Rocca, P. (2014). Quality of life in stable schizophrenia: The relative contributions of disorganization and cognitive dysfunction. *Schizophrenia Research, 153*, 196-203. doi:10.1016/j.schres.2014.01.013
- Stolar, N., Berenbaum, H., Banich, M. T., & Barch, D. (1994). Neuropsychological correlates of alogia and affective flattening in schizophrenia. *Biological Psychiatry, 35*, 164-172. doi:10.1016/0006-3223(94)91148-7

- Tandon, R., Nasrallah, H. A., & Keshavan, M. S. (2009). Schizophrenia, “just the facts” 4: Clinical features and conceptualization. *Schizophrenia Research*, 110(1-3), 1-23.  
doi:10.1016/j.schres.2009.03.005
- Turner, M. L., & Engle, R. W. (1989). Is working memory capacity task dependent? *Journal of memory and language*, 28, 127-154. doi:10.1016/0749-596X(89)90040-5
- Ventura, J., Helleman, G., Thames, A., Koellnew, V., & Nuechterlein, K. (2009). Symptoms as mediators of the relationship between neurocognition and functional outcome in schizophrenia: A meta-analysis. *Schizophrenia Research*, 113, 189-199.  
doi:10.1016/j.schres.2009.03.035
- Vogel, E. K., Woodman, G. F., & Luck, S. J. (2001). Storage of features, conjunctions, and objects in visual working memory. *Journal of Experimental Psychology: Human Perception and Performance*, 27, 92–114. doi:10.1037//0096-1523.27.1.92

Table 1

## Participant Demographic Information

Variable	Schizophrenia	Controls
Gender (% male)	75	88
Race/ethnicity (% Caucasian)	61	88
Mean (SD) age in years	40.2 (11.4)	42.5 (10.4)
Mean (SD) years education	11.3 (2.0)**	15.7 (2.6)
Mean (SD) years parental education	12.3 (2.3)	12.9 (2.5)
Mean (SD) Mini-Mental State Examination (Max score of 30)	26.3 (3.2)	
CDI		
Interview 1	3.6 (2.0)	
Interview 2	3.6 (3.3)	
Alogia (word count)		
Interview 1	692.7 (560.3)	
Interview 2	853.6 (737.7)	

\*\*  $p < .01$

Table 2

## Task Performance and Group Differences

Variable	Schizophrenia	Controls	Discriminating Power	Reliability
	M (SD)	M (SD)		
Working Memory				
Reading Digit Span	1.30 (1.00)	2.96 (.91)	1.74**	.94
Visual Array: K	1.79 (1.43)	3.33 (.52)	1.44**	.81
Goal Maintenance				
AX-CPT: d'-context	-.50 (1.56)	1.14 (.66)	1.37**	.90
POP: Interference	-.07 (.13)	0.00 (.02)	0.70*	.49
Processing speed				
AX-CPT: AX RT	777.05 (268.45)	555.29 (102.04)	1.09**	.97
POP: Arrow RT	630.36 (469.79)	416.26 (43.06)	.64*	.96
General Task Performance				
BY accuracy	.95 (.08)	1.00 (.00)	.92**	.45

\*  $p < .05$ \*\*  $p < .01$

Note:  $K$  = visual working memory capacity score; discriminating power = between-groups effect size  $d$

Table 3  
Task Correlations in Participants with Schizophrenia

Variables	CDI	Alogia
Working Memory	-.29*	-.09
Goal Maintenance	-.34*	-.24
Processing speed	-.46**	-.11
General Task Performance	-.43**	.01

\*  $p < .05$

\*\*  $p < .01$

Note: General Task Performance is accuracy for BY trials on the AX-CPT.