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Evidence that communication impairment in schizophrenia is associated with generalized poor task performance

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ABSTRACT

People with schizophrenia exhibit wide-ranging cognitive deficits, including slower processing speed and decreased cognitive control. Disorganized speech symptoms, such as communication impairment, have been associated with poor cognitive control task performance (e.g., goal maintenance and working memory). Whether communication impairment is associated with poorer performance on a broader range of non-cognitive control measures is unclear. In the current study, people with schizophrenia (n =51) and non-psychiatric controls (n =26) completed speech interviews allowing for reliable quantitative assessment of communication impairment. Participants also completed multiple goal maintenance and working memory tasks. In addition, we also examined (a) simple measures of processing speed involving highly automatic prepotent responses and (b) a non-cognitive control measure of general task performance. Schizophrenia communication impairment was significantly associated with poor performance in all cognitive domains, with the largest association found with processing speed (r_s =−0.52). Further, communication impairment was also associated with the non-cognitive control measure of poor general task performance (r_s =−0.43). In contrast, alogia, a negative speech symptom, and positive symptoms were less if at all related to cognitive task performance. Overall, this study suggests that communication impairment in schizophrenia may be associated with relatively generalized poor cognitive task performance.

1. Introduction

People with schizophrenia exhibit wide ranging deficits in most cognitive domains, such as goal maintenance, working memory, and processing speed (e.g., Nuechterlein et al., 2004). One focus of schizophrenia research has been whether cognitive deficits are related to specific symptoms of schizophrenia (Dominguez et al., 2009). A schizophrenia symptom consistently associated with poor cognitive task performance is disorganized speech (e.g., Kerns and Berenbaum, 2002; Dominguez et al., 2009; Tandon et al., 2009). In particular, disorganized speech symptoms, such as communication impairment (i.e., communication impairment is defined as communication failures in speech, that is, a phrase or passage of speech in which the meaning is sufficiently unclear to impair the overall meaning of the speech passage; Docherty, 2005), have been consistently associated with poor performance on cognitive control tasks (e.g., Docherty et al., 1996b; Kerns and Berenbaum, 2002), which are tasks that require goal directed behavior in the face of conflict (Rougier et al., 2005). However, whether disorganized speech is associated with poorer performance on a broader range of tasks that do not require cognitive control (i.e., non-cognitive control tasks, such as processing speed on an automatic task) is unclear. The current research examined whether communication impairment in schizophrenia was specifically associated with poor cognitive control task performance or associated with a pattern of general poor task performance[1] that was not restricted to cognitive control tasks.

Disorganized speech refers to speech that is difficult to understand or poorly organized (e.g., frequent jumping to unrelated ideas;

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[1] "General poor task performance," alternatively referred to as "the generalized deficit," is the tendency for those with schizophrenia to perform poorly across a broad range of cognitive tasks, regardless of the specific cognitive abilities required by the task (for more on the generalized deficit, see Dickinson et al. (2008)).

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Andreasen, 1979; McGrath, 1991). One conceptualization of disorganized speech is communication impairment, which refers to frequent instances of significant speech unclarity (Docherty, 2005) and is typically measured by the Communication Disturbances Index (CDI; Docherty et al., 1996a). The CDI rates speech based on the occurrence of language that fails to communicate the intended message through unclear references or grammatical disturbances.[2] Communication impairment is related to more traditional constructs of disorganized speech, such as formal thought disorder (Docherty and Gordinier, 1999) and measures such as the Thought, Language, and Communication (TLC) scale (Docherty et al., 1996a). However, in measuring disorganized speech, communication impairment focuses on the communication failures in speech, rather than the underlying thought disorder (Docherty, 2005). Communication impairment can be assessed very sensitively (Kerns and Berenbaum, 2003) and reliably (Docherty et al., 1996a) and has been found to be elevated in first-degree relatives of people with schizophrenia (Docherty et al., 2004).

Furthermore, as previously mentioned, communication impairment and other disorganized speech measures have been consistently associated with poor cognitive control task performance, including measures of goal maintenance and working memory (e.g., Docherty et al., 1996b; Cohen et al., 1999). Goal maintenance is the ability to maintain important task critical information, such as rules, goals, or instructions (Rougier et al., 2005). In a meta-analytic review, cognitive control (executive functioning) task performance was strongly associated with disorganized speech symptoms (Kerns and Berenbaum, 2002). More recently, communication impairment has consistently been associated with both poor goal maintenance and poor working memory task performance (e.g., Kerns and Berenbaum, 2003; Docherty, 2005; Becker et al., 2012; Docherty, 2012). However, despite the strong evidence for a relationship between disorganized speech and cognitive control, previous research has not examined cognitive control using the AX-CPT, which is arguably the most well-validated measure of cognitive control (Cohen et al., 1999). Therefore, one goal of the present study is to further examine the relationship between communication impairment and cognitive control by using the AX-CPT as the measure of cognitive control.

Extending beyond cognitive control, it is not clear whether disorganized speech measures are also associated with broader non-cognitive control task performance. For instance, processing speed is a well-established deficit in schizophrenia (Dickinson et al., 2007) and there is some previous evidence that communication impairment is also associated with deficits in processing speed (Docherty, 2005; Docherty et al., 2006). Hence, the current research examined whether communication impairment in schizophrenia was associated only with complex cognitive control measures such as working memory and goal maintenance tasks or whether communication impairment would also be associated with simpler non-cognitive control measures, such as slower processing speed and general poor task performance. In contrast to the complex cognitive control measures, we examined whether communication disturbances would be related to processing speed for responses that required minimal attention and cognitive processing due to previous associations between stimulus and response (i.e., prepotent responses). Similarly, general poor task performance was measured with a non-cognitive control condition of the AX-CPT task (i.e., BY errors). Following Docherty (2012), we also examined whether cognitive control measures (i.e., "more complex cognitive measures" in Docherty) were still statistically associated with communication impairment after accounting for non-cognitive control measures (i.e., "less complex cognitive measures" in Docherty).

Finally, although disorganization is the symptom most associated with cognition, negative speech symptoms such as alogia, or decreased amount of speech, have also been associated with cognitive deficits (e.g., Becker et al., 2012). Therefore, we also examined the relationships between cognitive performance and both negative and positive symptoms.

2. Method

2.1. Participants

Fifty-one people with schizophrenia and 26 healthy controls participated in this study. The schizophrenia group was comprised of non-acute inpatients recruited from a long-term state psychiatric hospital with a largely forensic population, and with participants residing on units in which the average length of stay was approximately 8 years. Given that prolonged hospitalization in this sample was often not contingent on current symptomatology or functional disability, there was a wide range of functioning within the group of people with schizophrenia. For instance, for hallucinatory behavior on the BPRS, 34% had scores of 4 or above and for unusual thought content 51% had scores of 5 or above. As far as general cognitive functioning, on the Mini-Mental State Examination (MMSE; Folstein et al., 1975), patients scored between 19 and 30 (i.e., the max score), with 3 people having scores less than 21% and 80% having MMSE scores above 24. This wide variation and lack of truncated range for both symptoms and cognitive functioning is arguably ideal for assessing the relationships between symptoms and cognitive performance (e.g., difficult to assess relationships in a relatively low symptom and/or minimal cognitive deficit group; there is limited generalizability of understanding relationship between cognition and symptoms in schizophrenia if only assessing people with low levels of both cognitive deficits and symptoms). All eligible participants met Diagnostic and Statistical Manual of Mental Disorders (4th 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 et al., 1998). All but three participants in the schizophrenia group were taking antipsychotic medication at the time of participation: 9% taking typical antipsychotics, 53% atypical, and 38% combination of typical and atypical. We collected specific antipsychotic dosage information from 35 of the patients with schizophrenia and converted dose to chlorpromazine equivalents (due to limited access to medical records, specific dosage information was not available for the other 16 patients). For those 35 patients with known medication dose, there was no relationship between chlorpromazine equivalents and CDI scores or other symptoms (all $p > 0.32$). Given the absence of associations with symptoms makes it, if anything, arguably less likely that antipsychotic effects can account for any of the associations between task performance and symptoms (for limitations of this approach, see Blanchard and Neale (1992)). 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 min) 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 $p > 0.20$. The groups did differ in ethnicity, $\chi^2 = 6.30$, $p = 0.01$, but there was no evidence that differences in ethnicity accounted for any group differences presented in the results (i.e., when sample was restricted to one ethnicity or when ethnicity was included as a covariate, all results remained the same). 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.

[2] One such example is confused references, which, according to Docherty et al. (1996a), "are unclear because they could refer to one of at least two clear-cut alternative referents, and the correct choice is not obvious" (p. 359). For example, "He stabbed the dude and I kicked him. I thought he punched him. I thought he was on the ground just acting like he was hurt" (p. 359, Docherty et al., 1996a).

Table 1
Participant Demographic Information.

Variable	Schizophrenia	Controls
Gender (% male)	75	88
Race/ethnicity (% Caucasian)	61	88
Mean (SD) age (years)	40.2 (11.4)	42.5 (10.4)
Mean (SD) education (years)	11.3 (2.0)**	15.7 (2.6)
Mean (SD) parental education (years)	12.3 (2.3)	12.9 (2.5)
Mean (SD) MMSE (max = 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)	
BPRS		
Hallucinations	2.5 (1.9; range 1–7)	
Unusual Thought Content	4.3 (1.6; range 1–7)	

Note: MMSE = Mini-Mental State Examination; CDI = Communication Disturbances Index.
** $p < 0.01$.

2.2. Measures

2.2.1. Speech symptoms

To reliably rate speech symptoms, participants completed up to two 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?” The second interview asked about specific memories with questions such as, “Tell me a specific memory about a time you were with your family.” Participants were told that there were no right or wrong answers and that they could speak for as little or as much as they wanted.

Communication impairment was rated using the Communication Disturbances Index (CDI; Docherty, 1996; Docherty et al., 1996a), which rates the number of speech unclarities, 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. In the current study, to maximize rater reliability, three trained raters reached consensus on all CDI ratings. As in previous research (Docherty et al., 1996b), CDI scores were corrected for overall amount of speech, such that CDI scores are reported as number of unclarities per 100 words of speech.

In addition to the CDI, we also examined the negative speech symptom alogia, which following previous research (Kerns, 2007; Berenbaum et al., 2008) was measured as the number of words produced in the structured interviews, with higher levels of alogia reflected in a fewer number of words produced. Critically, by not standardizing the interviews to be of a certain length, we are able to sensitively measure alogia because our alogia measure should largely reflect people's individual ability and willingness to speak.

2.2.2. Positive symptoms

Experienced and advanced graduate students administered all diagnostic and clinical interviews. To measure positive symptoms, interviewers rated delusions and hallucinations (interrater reliability > 0.90) using the Brief Psychiatric Rating Scale (BPRS; Overall and Gorham, 1962, 1988) A composite score was computed by summing the unusual thought content and hallucinations items.

2.2.3. Goal maintenance

Participants completed two different goal maintenance measures: the AX-CPT (Continuous Performance Task; Servan-Schreiber et al., 1996) and the Preparation for Overcoming a Prepotent Response Task (POP; Barber and Carter, 2005). The AX-CPT is a well-validated goal maintenance task and has been used extensively in previous schizophrenia research (e.g., Cohen et al., 1999; Barch et al., 2003), although its relationship to disorganized speech has been rarely examined. The AX-CPT has been used to study attention in individuals with schizophrenia and other types of brain injury since the 1950s (Kornetsky and Mirsky, 1966; Rosvold et al., 1956). On the AX-CPT, 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. 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. The trial frequencies were as follows: 70% A-X, 10% A-Y, 10% B-X, 10% B-Y (for details about task timing, see Braver et al. (2001); note current version differed by increasing response window to allow people with schizophrenia more time to respond). Following previous research (e.g., Barch et al., 2003), the dependent variable for the AX-CPT was d′-context, measured using the hit rate in the AX condition (i.e., prepotent response trials that do not involve inhibition) and the false alarm rate in the BX condition (i.e., prepotent inhibition trials overcoming tendency to respond to X as a target). One participant with schizophrenia and 7 controls did not complete the AX-CPT. To ensure that participants completed the task to a reasonable 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). Seven participants with schizophrenia were excluded from final analyses based on these performance exclusions.

In addition, consistent with previous literature (Cohen et al., 1999; MacDonald, 2008), accuracy on BY trials was calculated to assess general task performance presumably independent from goal maintenance. In the current sample BY accuracy was moderately to strongly correlated with all other cognitive measures (r_s from 0.24 to 0.63), supporting the theory that BY captures general task performance. As an alternative measure of general cognition, we also considered utilizing scores from the MMSE, which shows similar correlations with CDI (r_s =−0.32). However as a task measure, BY accuracy was the primary measure of general task performance.

The Preparation for Overcoming a Prepotent Response Task (POP task; Barber and Carter, 2005) is a well-validated measure of goal maintenance used in multiple previous schizophrenia studies (e.g., Snitz et al., 2005; for current version, see Becker et al. (2012)). On this task, people see either a red or green square (the cue) and then see an arrow pointing to either the left or the right (the probe). If the cue is green, participants make a prepotent response and respond in the direction of the arrow. If the cue is red, participants need to inhibit the prepotent response and instead respond in the direction opposite of the arrow probe (e.g., if the arrow points left, then respond right). The dependent variable was the *POP interference score*, which was accuracy for red trials minus accuracy for green trials. 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. As expected, AX-CPT d′-context and POP interference scores were significantly correlated in patients, Spearman's rho (r_s) =0.55, $p < 0.001$.

Hence, we computed a composite goal maintenance variable by averaging standardized scores, with larger values indicating better goal maintenance. If a participant was missing a score from one of the two tasks, we used their one available goal maintenance task score as their overall goal maintenance score.

2.2.4. Working memory

Participants completed two different working memory tasks: the reading digit span task (RDST; Barrouillet et al., 2004) and the visual array comparison task (Luck and Vogel, 1997). The RDST is comparable to other complex working memory capacity tasks (i.e., involving a short-term storage component and a simultaneous processing component; e.g., O-Span), with comparable evidence of validity. However, critically the processing component on the RDST (simply reading numbers aloud) is much less complex than in other traditional complex span tasks (e.g., performing arithmetic). Hence, the RDST might be especially well-suited for people with schizophrenia who likely have deficits on the processing components of other complex working memory span tasks. To our knowledge, the RDST has not previously been examined in schizophrenia. The span score for this task reflects the number of correctly recalled series (for more details on the current RDST, see Barrouillet et al. (2004) Experiment 5; note current version was adapted for a cognitively impaired population by lengthening stimulus display and with the longest series containing 5, rather than 7, letters).

The visual array comparison task (VAT; Luck and Vogel, 1997) measures the total amount of information that can be maintained in visual working memory and has been used successfully in previous schizophrenia research (e.g., Gold et al., 2003), although to our knowledge its relationship to disorganized speech symptoms has not been examined. The VAT was scored using Cowan's K, an estimate of the capacity of visual memory (Cowan, 2000; for more VAT details, see Luck and Vogel (1997); note that current version differed by omitting the verbal rehearsal dual task because previous research has found that the dual task with the VAT does not appear necessary in controls, Morey and Cowan, 2005, and hence its inclusion could make the VAT unnecessarily difficult for people with schizophrenia). In the current study, six participants with schizophrenia and 1 control did not complete the visual array due either to participant refusal or the task being inadvertently omitted. As expected, performance on the two working memory tasks were significantly correlated in people with schizophrenia, r_s =0.42, p=0.01, and hence just as for goal maintenance, a composite working memory variable was computed.

2.2.5. Processing speed

Processing speed has been defined by Salthouse (1996, 2011) as the speed of completing each task component. To measure processing speed with as little of a contribution from cognitive control as possible, we measured processing speed by examining reaction time for simple, prepotent response trials on both the AX-CPT and for a simple Arrow Task. On the AX-CPT, the measure of processing speed was RT on AX trials, which comprise 70% of all trials and therefore are thought to involve a relatively automatic and highly prepotent response (Cohen et al., 1999). On the Arrow Task, completed just prior to the POP task, participants saw an arrow pointing left and right and simply responded in the direction of the arrow as quickly and accurately as possible. Hence the 40 Arrow Task trials involved simply making relatively automatic and highly prepotent responses. For both tasks, RTs were only included for correct trials and RTs < 200 ms were excluded. To eliminate long duration RT outliers, we excluded any trial on which RT was greater than 3.5 SDs above the participant's individual mean. One additional participant was excluded whose mean RT was 6 SDs above the sample mean. As expected, performance on the two processing speed scores were highly correlated in people with schizophrenia, r_s =0.57, $p < 0.001$. Hence, we created a processing speed composite variable.

2.3. 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 comparison, simple Arrow Task, 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 h.

In analyzing correlations, we used non-parametric Spearman rho correlations to minimize the chance that outliers could overly influence the results (de Winter et al., 2016). As described above, there was missing data from each of the tasks. To explore the possible influence of missing data on the results, all analyses presented below were also analyzed restricted to the sample with complete data and the patterns of results did not change. Reliability and discriminating power were calculated for all tasks. For reliability, we 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, we used the between-groups Cohen's d effect size between people with schizophrenia and controls.

3. Results

3.1. 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, d, ranged from moderate to large). Further, reliability for all tasks was excellent except for BY accuracy, which might be limited by the lack of variability in performance, and the POP Interference score, which as a difference score was

Table 2
Between Group Differences on Task Performance.

Variable	Schizophrenia	Controls	Effect size: d	Task reliability
Goal Maintenance				
AX-CPT: d′-context	−0.50 (1.56)	1.14 (0.66)	1.37**	0.90
POP: Interference	−0.07 (0.13)	0.00 (0.02)	0.70*	0.49
Working Memory				
Reading Digit Span	1.30 (1.00)	2.96 (0.91)	1.74**	0.94
Visual Array: K	1.79 (1.43)	3.33 (0.52)	1.44**	0.81
Processing Speed				
AX-CPT: AX RT	777.05 (268.45)	555.29 (102.04)	1.09**	0.97
POP: Arrow RT	567.97 (196.45)	416.26 (43.06)	1.07**	0.96
General Task Performance				
BY accuracy	0.95 (0.08)	1.00 (0.00)	0.92**	0.45

Note: AX-CPT = AX version of the Continuous Performance Task, POP = Preparation for Overcoming a Prepotent Response Task; K = visual working memory capacity score; BY accuracy = BY trials from the AX-CPT.
* $p < 0.05$.
** $p < 0.01$.

Table 3
Correlations between Cognitive Domains and Individual Cognitive Tasks with Symptoms in People with Schizophrenia.

Variables	CDI	Alogia	Delusions/Hallucinations
Goal Maintenance Composite	−0.37**	−0.28t	0.08
AX-CPT	−0.38*	−0.24	0.13
POP	−0.33*	−0.16	−0.08
Working Memory Composite	−0.29*	−0.09	0.06
Reading Digit Span	−0.24t	−0.04	0.01
Visual Array	−0.30t	−0.10	0.11
Processing Speed Composite	−0.52**	−0.15	0.13
AX Speed	−0.34*	−0.36*	0.23
Arrow Task	−0.54**	0.10	0.08
General Task Performance	−0.43**	0.01	0.02

Note: AX-CPT = AX version of the Continuous Performance Task, POP = Preparation for Overcoming a Prepotent Response Task; General Task Performance assessed with accuracy for BY trials on the AX-CPT.
t $p < 0.10$.
* $p < 0.05$.
** $p < 0.01$.

understandably reduced (Lord, 1963).

3.2. Correlations between communication impairment and cognitive task performance in schizophrenia

As can be seen in Table 3, higher CDI scores were significantly associated with poorer performance for all four cognitive domains. Further, there was at least a trend for CDI scores to be associated with all individual cognitive tasks (all $p < 0.097$). 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/measures (processing speed/simple Arrow Task; general poor task performance/BY condition errors).

3.3. Correlations between other symptoms and cognitive task performance in schizophrenia

In contrast to the results for communication impairment, as can be seen in Table 3, alogia was not significantly associated with any of the scores for the four cognitive constructs (with the largest non-significant correlation being with poorer goal maintenance). Alogia also tended to be unassociated with individual cognitive tasks, except for the correlation between alogia and AX trials RT. In addition, delusions/hallucinations were not significantly correlated with any measure. Further, the size of the correlation between the composite score for processing speed and CDI was significantly larger than both the correlation between processing speed and alogia, $Z = -2.01$, $p = 0.02$ and the correlation between processing speed and delusions/hallucinations, $Z = -3.17$, $p < 0.01$ (Meng et al., 1992).

3.4. Hierarchical regression analysis

Thus far we have reported that communication impairment is associated with evidence of widespread cognitive impairment. Next, following Docherty (2012), we examined whether cognitive control tasks (i.e., goal maintenance and working memory) are statistically associated with communication impairment after accounting for non-cognitive control tasks (i.e., processing speed and general poor task performance). To do this, given substantial skewness in some of the scores, we log transformed the goal maintenance, processing speed, and general task performance measures (note results were very similar with non-transformed scores). Given missing values in BY data, to include all participants, we also computed a composite score for processing speed and general task performance (therefore this composite score equaled the average of the two scores or just the processing speed score; note results were very similar if we did not create a composite variable). As can be seen in Table 4, working memory and goal maintenance did not explain any unique variance in CDI scores beyond processing speed and general task performance.

Table 4
Hierarchical regression analyses predicting CDI scores from task performance.

Predictor	β	R^2	R^2 Change
Step 1		0.26	0.26**
Processing Speed and General Task Performance Composite Score	−0.51**		
Step 2		0.28	0.02
Working Memory	0.19		
Goal Maintenance	−0.14		

Note: Results do not change when working memory and goal maintenance are entered in individual steps in the model.
** $p < 0.01$.

4. Discussion

The current study found evidence that communication impairment in schizophrenia is related to both poor cognitive control and poor non-cognitive control task performance. 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. As expected, communication impairment was associated with poor performance in both cognitive control domains, goal maintenance, and working memory. However, communication impairment was also associated with slower processing speed on a relatively automatic task (Arrow Task) and in a condition involving the execution of highly prepotent responses (AX condition of AX-CPT). Further, communication impairment was also associated with a measure of general poor task performance. In fact, the largest correlations numerically with communication impairment were with the simplest tasks and conditions (e.g., Arrow Task) 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 extends beyond poor cognitive control and could be fairly general.

The current results for processing speed are also consistent with some previous communication impairment research. For instance, Docherty (2005, Docherty et al., 2006) has found communication impairment to be associated with slower performance of processing speed tasks that do involve cognitive control (i.e., Trails Making Task B) and those that do not involve cognitive control (i.e., Trails Making A). 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 traumatic brain/closed head injuries as well as elderly adults exhibit increased levels of disorganized behavior and speech (e.g., Levin and Grossman, 1978; Gold et al., 1988; Hinchliffe et al., 2001). In addition, both traumatic brain injuries and older age are associated with slower processing speed (e.g., Salthouse, 1996; Incoccia et al., 2004). Hence, both in people with schizophrenia and in other populations there is an association between disorganization and slower processing speed.

In addition to slower processing speed, communication impairment was also associated with a non-cognitive control measure of poorer general task performance, increased errors on BY trials of the AX-CPT. The BY condition is thought to be a measure of general poor task performance because in this condition both the cue letter and the probe letter are associated with a "non-target" response and there is no prepotent response to overcome. It should be noted that people with schizophrenia did generally perform well on the BY trials (average accuracy =95%). However, people with schizophrenia were more likely to make errors in this condition than controls (e.g., control accuracy =100%), with this tendency for errors associated with increased communication impairment. Previous schizophrenia research has noted a tendency for poorer performance on many of the easiest tasks and conditions in schizophrenia, which has been termed the "irreducible error rate" (Gold et al., 2003). The current study suggests that at least on a speeded response task that the tendency to perform relatively poorly on even the easiest tasks and conditions is associated with communication impairment.

Moreover, our results show that the more complex cognitive measures (i.e., cognitive control measures) were not statistically associated with communication impairment beyond the variance accounted for by the less complex cognitive measures (i.e., non-cognitive control measures). This finding, along with the correlation patterns seen in this data, suggests that a single general cognitive factor contributes to variance in communication impairment. These results differ from those reported by Docherty (2012), who found that each increasing complex cognitive measure accounted for unique variance in CDI scores. The results of the current study may differ from Docherty's because the studies used different cognitive measures. It may be that the measures of processing speed and generalized poor task performance in the current study better account for the variation in communication impairment found in individuals with schizophrenia. Alternatively, Docherty's measures of more complex cognitive processes, especially conceptual sequencing, might better tap into critical complex cognitive processes associated with communication impairment. This suggests that future research should explore the relationship between the types of non-cognitive control measures used in the current research with conceptual sequencing and examine their respective contributions to communication impairment.

Hence, overall, the current study suggests that processing speed and problems in the efficient and timely execution of information processing could play an important role in communication impairment in schizophrenia. In addition, in the current study, the strong associations between communication impairment and both processing speed and general poor task performance may not be easily accounted for by task discriminating power (Chapman and Chapman, 1973). When discriminating power is estimated from between-groups effect sizes, the processing speed measures tended to have the least amount of discriminating power. When discriminating power is estimated from true-score variance for two similarly scaled task measures, goal maintenance measure of POP Interference and the generalized task deficit measure of BY accuracy, the goal maintenance measure has the greater amount of true-score variance. Yet, if anything, the generalized task measure tends to be more associated with communication impairment (for more on discriminating power, Kang and MacDonald, 2010). Future research could continue to examine whether communication impairment is associated with slower processing speed using additional processing speed and general poor task performance measures. Moreover, additional research should continue to explore the role of processing speed in cognitive rehabilitation for schizophrenia. As simple processing speed is related to variance shared between disorganized speech symptoms and complex cognitive measures, it may be that interventions targeting processing speed lead to improvements in disorganization symptoms and perhaps to other cognitive and functional domains. This is consistent with recent research demonstrating that processing speed is a mediator for improvements in functioning following a cognitive rehabilitation program (Rispaud et al., 2016).

This study does have some limitations. One important limitation is that while this study assessed multiple areas of cognition, in addition to including a measure of general task performance, it does not provide evidence that all areas of cognition are related to communication impairment. For example, this study did not measure verbal fluency and others have failed to find a relationship between verbal fluency and communication impairment (Docherty et al., 1996b; Berenbaum, 2008). However, in the current study, we found that communication impairment was associated with poor cognition broadly. A second limitation is that our study included a healthy control group rather than a psychiatric control group and therefore does not provide evidence for specificity of these impairments to schizophrenia. A third limitation is that the tasks were presented in a set order rather than counterbalanced across participants. Additionally, many patients with schizophrenia were unable to complete the study in one sitting and required two sessions while most controls were able to complete the entire study in one session. A final limitation may come from using RT from the AX condition of the AX-CPT as a processing speed variable. The AX-CPT as a whole involves multiple conditions requiring multiple cognitive abilities and we cannot rule out that the overall complexity of the AX-CPT could have an effect on the AX condition RT measure. However, we note that these concerns do not apply to the much simpler Arrow Task that was also used as a measure of processing speed.

Despite theses limitations, our findings are consistent with previous research that points to the important role communication impairment, or disorganization, broadly plays in schizophrenia, as it is related to the development of schizophrenia (Berenbaum et al., 1985; Gooding et al., 2012), as well as poor outcome in the disorder (Ventura et al., 2009; Sigaudo et al., 2014). As a disorder, schizophrenia is also associated with a broad range of cognitive deficits and fairly general cognitive dysfunction (Dickinson et al., 2004, 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., 2015) 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.

The current study also provides additional evidence that disorganization symptoms are potentially the schizophrenia symptom most associated with cognitive deficits. 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 delusions/hallucinations nor alogia tended to be consistently if at all associated with deficits on the cognitive tasks completed in this study. This is consistent with other evidence that positive symptoms are often not related to poor cognitive functioning in general (e.g., Barch et al., 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 et al., 2013), with generalized cognitive deficits. In previous research that has found a relationship between alogia and cognition, alogia has typically been assessed with clinical ratings, rather than word count (e.g., Becker et al., 2012; although see Berenbaum et al. (2008) for an exception). 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 could be most associated with general cognitive dysfunction.

Future research should continue to explore factors that may underlie the relationship between general poor task performance and communication impairment. It may be that this relationship is driven by decreased motivation or effort, or alternatively by frequent lapses in attention. Although we did not directly assess effort, overall we do not think our pattern of results is likely due to decreased effort. We posit that if the association between communication impairment and poor general task performance reflected decreased effort, then decreased effort should also influence another speech measure, alogia (with decreased effort affecting how much people say in response to the prompts). However, we did not find a relationship between alogia and general task performance, which makes it less likely that effort is responsible for the relationship between poor task performance and disorganization. Overall, this study provides evidence that communication impairment in schizophrenia may be associated with relatively generalized poor cognitive task performance.

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