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Title: Latent semantic variables' relationship with formal thought disorder and adaptive behavior in older inpatients with schizophrenia

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Abstract

Introduction: Formal thought disorder is a hallmark feature of schizophrenia in which disorganized thoughts manifest as disordered speech. A dysfunctional semantic system and a disruption in executive functioning have been proposed as possible mechanisms for formal thought disorder and verbal fluency impairment. Traditional rating scales and neuropsychological test scores might not be sensitive enough to distinguish among types of semantic impairments. This has lead to the proposed used of a natural language processing technique, Latent Semantic Analysis (LSA), which offers improved semantic sensitivity.

Method: In this study, LSA, a computational, vector-based text analysis technique to examine the contribution of vector length, an LSA measure related to word unusualness and cosines between word vectors, an LSA measure of semantic coherence to semantic and phonological fluency, disconnectedness of speech, and adaptive functioning in 165 older inpatients with schizophrenia.

Results: In stepwise regressions word unusualness was significantly associated with semantic fluency and phonological fluency, disconnectedness in speech, and impaired functioning, even after considering the contribution of pre-morbid cognition, positive and negative symptoms, and demographic variables.

Conclusions: These findings support the utility of LSA in examining the contribution of coherence to thought disorder and the its relationship with daily functioning. Deficits in verbal fluency may be an expression of underlying disorganization in thought processes.

Keywords: schizophrenia, verbal fluency, thought disorder, cognitive functioning, adaptive functioning

1. Introduction

Formal thought disorder refers to a disorganization of thought that manifests in communication abnormalities. Disordered speech has long been recognized as one of the core features of schizophrenia (Bleuler, 1911; Kraepelin, 1919) occurring in 20-50% of patients with schizophrenia (Andreasen and Black, 2005; Breier and Berg, 2003). These symptoms are stable across the course of the disorder, are not simply a measurement artifact arising from psychotic symptoms (Harvey, Docherty, Serper, Rasmussen, 1990), and have been identified as predictors of poor functional outcome (Bowie and Harvey, 2008; Keefe et al., 1987).

Disordered speech may manifest in various forms, often classified as either "positive" or "negative" thought disorder. Positive thought disorder is characterized by disorganized or disconnected speech, such as loose associations between concepts evident in the switching of topics disjointedly, providing tangential responses, using nonsense words, or circumstantial speech patterns. Negative thought disorder is characterized by a reduction in the amount of elaboration, or overall verbal output. Typically, these subtypes are referred to as disconnected speech and verbal underproductivity, respectively. These subtypes are distinct from one another (Andreasen, 1979a; Harvey et al., 1992), from positive and negative symptoms in recent-onset, neuroleptic-naïve (John et al., 2003) and chronically ill (White et al., 1997) samples, and are differentially associated with social functioning competencies and behaviors (Bowie et al., 2011). Disordered speech is typically rated using instruments such as the Scale for the Assessment of Thought, Language, and Communication (TLC; Andreasen, 1979a, 1979b), allowing for a clinical rating of a disordered thought

phenomenon that manifests in conversational speech.

Various pathogenic neurocognitive mechanisms have been proposed to underlie disconnected speech wherein the two most prominent approaches are variants of executive dysfunction and impaired processing of semantic information and memory (Kerns and Berenbaum, 2002; Barrera et al., 2005; Stirling et al., 2006). Executive functioning is proposed to play a role in maintaining a topic of conversation, planning upcoming speech, and inhibition of inappropriate or unrelated discourse. Alternatively, disruption of semantic processing and memory may be due to a loss of stored information or impaired retrieval (Rapp and Caramazza, 1993),manifesting in difficulties retrieving correct words resulting in diffluent and nonsensical speech.There is currently no clear cognitive mechanism, though it stands to reason that it may involve a combination of semantic information processing and executive functioning (Kerns and Berenbaum, 2002; Doughty et al., 2009).

One promising area utilizing disordered speech in understanding the role of thought disorder and cognition in schizophrenia is that of verbal fluency, specifically measures of semantic and phonological fluency. During these tasks participants are given a specific production rule, such as generating words that belong to a specific category for semantic fluency or words that begin with a specific letter for phonological fluency in a predetermined amount of time (Benton, 1968; Lezak, 1995). Verbal fluency tasks have been shown to be a sensitive indicator of general brain dysfunction (Lezak, 1995) and are thought to include semantic processing skills including controlled retrieval, semantic memory, and context processing (Docherty et al., 2011). Further, they are considered to place comparable demands on executive processing because of the requirements of

efficient organization, self-monitoring of previous responses, and inhibition of inappropriate responses (Crawford and Henry, 2005; Ruff et al., 1997).

Previous research demonstrates that symptoms, and demographic characteristics such as level of education, premorbid ability, and chronological age (Crawford et al., 1992; Benton et al., 1994; Spreen and Strauss, 1998) play a role in the severity of thought disorder and verbal fluency deficits. Similar to other tests of cognitive functioning, performance on verbal fluency tasks is related to the presence of negative symptoms, but not positive symptoms (Howanitz et al., 2000; Kerns et al., 1999). Indeed, patients with more severe negative symptoms generate fewer words overall (Allen et al., 1993).In older samples, patients who have a more chronic course of illness demonstrate more impairments than younger patients (Harvey et al., 1997)and there is a pattern of longitudinal worsening in verbal productivity that is predicted by concurrent cognitive worsening (Bowie et al., 2005).

Disconnected speech has been found to be associated with production of fewer contextually-accurate semantic word clusters in a semantic fluency task (Kerns et al., 1999) and worse performance on a phonological fluency task (Aloia, 1998). Recently, Docherty et al (2011) found that that there may be differential patterns of performance on verbal fluency tasks for individuals with alogia (i.e., underproductive speech) and formal thought disorder (i.e., disconnected speech). Specifically, disconnected speech was related to the proportion of semantically related words uttered in a phonological fluency task (Docherty et al., 2011). In studies comparing healthy older adults to younger adults, elderly participants generate fewer total words and fewer category switches on a semantic fluency task, and larger cluster sizes (i.e., greater number of semantically related words in

a semantic cluster prior to shifting to a new semantic cluster) on a phonological fluency task (Troyer et al., 1997).

Examinations of factors associated with social and adaptive functioning in schizophrenia repeatedly reveal cognition as the most robust predictor (Green, 1996; Harvey et al., 1998). Specifically concerning verbal fluency, previous studies have found performance on verbal fluency tasks (measured by total number of words) to be correlated with impairments in functioning in individuals with schizophrenia (Green et al., 2000), a finding which holds even after accounting for negative symptoms (Jaeger et al., 2003), and is evident in geriatric patients (Bowie et al., 2004). Moreover, verbal fluency has been shown to be an important predictor of daily problem solving skills both in a testing setting (Keefe et al., 2006; Revheim et al., 2006) and in a real-world context (Rempfer et al., 2003).

While it is evident that performance on verbal fluency tasks is associated with severity of disconnected speech, it remains unclear how unique components of incoherent discourse specifically result in poor performance in these tasks, and the functional impact of underlying dysfunctional semantic and executive systems. A promising recent development for the evaluation of discourse in schizophrenia utilizes the ability of Latent Semantic Analysis (LSA; Landauer et al., 1998) to provide automated measures of semantic relatedness. LSA is a statistical, cognitive modeling and computational tool that quantifies the semantic relatedness of words and groupings of words in a high-dimensional semantic space. In this semantic space, individual words are represented as vectors and the cosine between word vectors provides a measure of the semantic similarity between words, providing a measure of coherence (Elvevåg et al., 2007; Foltz et al., 1998). Average coherence refers to the average of all cosine values between each

word and the word that immediately follows that word (e.g., the average of the cosine between words A and B, B and C, C and D etc, where A is the first and D is the last word uttered in a sequence). The vector length of any individual word provides a measure of the information value of a word (i.e., a word's unusualness). Vector length is an index of unusualness in the sense that low frequency words convey more information value (and hence have a higher vector length). LSA offers an automated, finer grained method to evaluate discourse organization than is often available from other more subjective or observational measures of thought disorder (McKenna and Oh, 2005). Applying LSA to the set of words spoken during a verbal fluency task allows for a more nuanced approach to evaluating fluency that is sensitive to the specific relationships between words uttered rather than simply being a metric that is contingent upon the total number of words produced as is the case with typical tests of verbal fluency. Further, given that speech disconnectedness is a clinical measure of an inaccessible phenomenon (i.e., the content and organization of thoughts), LSA affords an opportunity to explicitly evaluate underlying cohesiveness of thoughts.

In light of the exploratory nature of LSA, this study serves to provide an overview of the psychometric properties of latent semantic variables and the nature of their relationships to thought disorder and functioning. As such, we examined the contribution of two LSA derived constructs, namely word unusualness and coherence to semantic fluency, as well as phonological fluency, clinically rated disconnected speech, and real-world adaptive functioning. We hypothesized that average word unusualness and average coherence would be associated with semantic and phonological fluency, disconnected speech during interpersonal conversation, and adaptive functioning on an inpatient ward,

even when accounting for the contribution of premorbid cognition, positive and negative symptoms, and demographic variables (level of education and age).

2. Methods

2.1. Participants

Participants in this study were part of a longitudinal study of chronic schizophrenia described in detail elsewhere (Bowie, et al., 2004; Davidson, et al., 1995).All participants were residing in a state psychiatric inpatient facility or ina restricted nursing home setting. Institutional Review Boards at Pilgrim Psychiatric Center and the Mount Sinai School of Medicine approved a waiver of signed informed consent in lieu of the participants' verbal assent witnessed by a staff member. A structured consensus procedure was employed to establish a diagnosis of schizophrenia (see Harvey et al., 1998 for additional details).

2.2. Measures

2.2.1.*Positive and Negative Symptoms*

Severity of clinical symptoms was assessed with the Positive and Negative Syndrome Scale (PANSS; Kay, 1991). Following a structured interview, seven positive symptoms, seven negative symptoms, and sixteen general aspects of psychopathology were rated on a 7-point Likert scale. We used the total scores on the positive and negative domains from the empirically derived 5-factor model of the PANSS (White et al., 1997). Inter-rater reliability of these ratings in the present sample was previously found to be acceptably high (Davidson et al., 1995), with intra-class correlations (ICC; $n = 30$) attained during training procedures of ranging from .86 to 1.00 (all p's $< .001$).

2.2.2. *Premorbid cognition*

The Wide-Range Achievement Test-Revised (WRAT-R; Jastak, 1984) was administered in order to obtain an estimate of premorbid functioning. The WRAT word recognition reading subtest was administered as a measure of putative premorbid cognition. This component requires participants to read a standardized list of words out loud to the tester. The dependent measure is the total score (i.e., total number of words correctly pronounced).

2.2.3. *Formal Thought Disorder*

Thought disorder was rated with the Scale for Assessment of Thought, Language, and Communication (TLC; Andreasen, 1979a, 1979b). TLC ratings were based on 5 to 10 minutes of unscripted conversations conducted prior to other assessments. The TLC provides definitions and rating criteria for 18 subtypes of communication abnormalities. Ratings are made on a Likert scalesranging from 0 (absent) to 3 (severe) or 0 (absent) to 4 (extreme). For the purposes of these analyses, we examined the disconnected speech subtype, previously identified with confirmatory factor analysis (Harvey et al., 1992) as there is a relative paucity of speech production in negative thought disorder (i.e., underproductive factor) whereas individuals with disconnected speech would demonstrate an inability to stay on topic.Disconnected speech is the mean of the following TLC items: Derailment, Tangentiality, Loss of Goal, Circumstantiality, and Incoherence. This scale has been found to have acceptable reliability (ICC=.86).

2.2.4.*Semantic (category) and phonological (letter) fluency tasks*

In the semantic fluency task participants were required to name as many different animals as possible in the span of 90 secs. For the phonological fluency task participants reported as many words starting with a F, A, and S for one minute each (Spreen and

Strauss, 1998). The dependent variable for both tasks was the total number of correct responses. Latent semantic analyses were applied to only the semantic fluency task.

2.2.5. *Adaptive functioning*

The Clinical Dementia Rating Scale (CDRS; Berg, 1988) is devised to evaluate the severity of dementia. It was used in this project due to the severity of cognitive and functional impairments in older, chronically institutionalized schizophrenia patients. The CDRS includes domains of functioning including judgment and problem solving, community affairs, ward life, and personal care. Each domain is rated on a 5, 6, or 7-point scale (0 = absent; 0.5 = questionable; 1 = mild; 2 = moderate; 3 = severe; 4 = profound; 5 = terminal), wherein scoring is completed by a clinician following a chart review and a semi-structured interview with the patient. The CDRS also includes an overall rating of dementia severity by the clinician. Previous reports suggest that the interrater reliability of the CDRS is acceptable (Berg, 1988; Berg et al., 1988) and that scores are consistently associated with performance-based assessments of cognitive functioning in this population (Harvey et al., 1999).

2.3. Data Analysis

2.3.1. *Latent Semantic Analysis (LSA)*

LSA is a statistical, cognitive modeling tool and computational technique for matching discourse content (Elvevåg et al., 2007; Landauer, et al., 1998). It is based on the premise that words used in similar contexts tend to have more similar meaning than words used in different contexts, and derives a measure of the similarity of words to each other based on an analysis of their contextual usage across large text corpora. This approach has been successfully used to quantify incoherent or aberrant speech in schizophrenia (Elvevåg et al., 2007). Elvevåg et al. demonstrated the applicability of this

methodology to measure incoherent discourse in a manner that bypasses problems associated with subjective ratings of frequency and severity of communication abnormalities, a common limitation among research on formal thought disorder. Their findings demonstrate that LSA is a sensitive measure capable of reliably analyzing communication abnormalities in schizophrenia.

The initial step before applying LSA is to transcribe the audio recordings into a text format, such that each response serves as its own "passage". Next, LSA acquires a representation of semantic relationships among words (or any passage of text) by an automated analysis of millions of words of natural discourse. This analysis involves deriving the relationships among word and passage meanings using singular value decomposition (a matrix algebra technique similar to factor analysis). In this view of the text, the meaning of a word is contingent upon all the contexts in which it appears. LSA is highly sensitive to underlying relationships among words such that text vectors that share semantic content by containing terms with similar meanings may be rated highly similar (cosine between the text vectors near 1.0) regardless of the differences in the literal words used. For instance the vector representing: "Doctors operate on patients" has a cosine of 0.81 with the vector representing "Physicians do surgery". Conceptually, both sentences express similar meaning despite using different words to convey the message. Thus, LSA is not simply a measure of semantic-relatedness based on contiguity frequencies and co-occurrence contingencies, but rather a measure capable of inferring *latent* relationships between words in a given text passage (Elvevåg et al., 2007; Landauer, et al., 1998). The present research used an LSA-semantic space from the TASA corpus containing 44,486 unique documents by 98,646 unique terms with 300 dimensions (see http://lsa.colorado.edu) in order to calculate the average vector length

(word unusualness) of each response and the average cosine coherence between each response and the next.

To the extent that fluency tasks are a proxy measure of fluent discourse (and underlying organization), the LSA theory-driven coherence measures are sensitive assays of subtle differences in words produced in verbal fluency tasks. Participants' responses from the semantic fluency task were transcribed and LSA was subsequently applied to each participant's answers. For each word uttered in the semantic fluency task its vector length was computed and for every pair of sequential words the cosine between the vectors for those words was computed. The average for the first set generated the average vector length (word unusualness measure) and the average of the cosines generated the average cosine (coherence measure) for each participant. In order to adjust for the relationship between coherence and total words uttered in the semantic fluency task, total number of words for the semantic fluency task was regressed onto the average cosine value. Applying LSA to verbal fluency tasks proffer the following advantages: (1) LSA is not specifically contingent upon the number of words uttered, thus there is little impact on the reliability of these data in light of the limited words that can be produced in the span of 90 seconds, (2) LSA is sensitive to underlying semantic relatedness of words spoken during a task wherein the goal is to generate words belonging to a specific category (i.e., animals). Thus, the application of LSA to a verbal fluency task with constricted rules for output may especially sensitive to underlying suboptimal semantic organization structures in individuals with schizophrenia as the task dictates the degree to which participants can deviate from semantically related verbal output.

3. Results

3.1 *Descriptive Characteristics and Correlations*

165 native English speaking geriatric schizophrenia patients (29.6% males; 80% Caucasian, 16% Black, 4% not reported) residing in long-stay institutional settings (restricted living adult homes; n=27) or state psychiatric facilities (n=138) were included in these analyses. They were recruited as part of a longitudinal study of cognition and functioning in geriatric schizophrenia. See Table 1for descriptive statistics, Table 2 for test performance scores, and Table 3 for percentage of sample expressing TLC subtypes subsumed under disconnected speech. The correlation between LSA variables, average cosine and average vector length, was r (165) = .32, p< .001. Further, average vector length, negative symptoms, and age share the strongest relationships with performance on the verbal fluency tasks and with adaptive functioning as measured by the CDRS. Please see Tables 4 and 5 depicting correlation coefficients between symptom, demographic, speech, and adaptive functioning variables.

Table 1. Here

Table 2. Here

Table 3. Here

Table 4. Here

Table 5. Here

3.2. Regressions

Hierarchical stepwise regressions were conducted to examine predictors or factors associated with dependent variables. We were interested in examining the contribution of LSA derived variables in explaining variance in dependent variables after accounting for typical related factors. Thus, premorbid cognition, demographic variables (age and

education), and symptom variables (positive and negative symptoms) were forced into Block 1, followed by average vector length (word unusualness) and cosine (coherence) in Block 2. Regression models are presented in Table 6 below.

Table 6. Here

Higher number of correct responses on the semantic fluency task was significantly predicted associated with by older age at evaluation, $F(1, 131) = 21.88$, $p<.001$, $R^2\Delta = .14$, negative symptoms, $F(2, 130) = 13.99$, $p< .001$, $R^2\Delta = .03$, premorbid cognition, $F(3,129) = 10.87$, $p< .001$, $R^2\Delta = 03$, and average vector length, $F(4, 128) = 11.27$, $p< .001$, $R^2\Delta = 06$.

Better performance on the phonological fluency task was significantly associated with older age at evaluation, $F(1,138) = 23.88$ $p< .001$, $R^2\Delta = .15$, premorbid cognition, $F(2,137) = 19.36$, $p< .001$, $R^2\Delta = .07$., and positive symptoms, $F(3,136) = 14.98$ $p< .001$, $R^2\Delta = .03$.

Higher disconnectedness during natural speech (i.e., more severe clinically rated positive thought disorder on the TLC) was significantly associated with positive symptoms, $F(1,141) = 19.72$, $p< .001$, $R^2\Delta = .12$, negative symptoms, $F(2, 140) = 12.58$, $p< .001$, $R^2\Delta = .03$, and average vector length, $F(3,139) = 11.23$, $p< .001$, $R^2\Delta = .04$.

Greater impairment in judgment and problem solving on the CDRS were associated with negative symptoms, $F(1,141) = 29.57$, $p< .001$, $R^2\Delta = .17$, and older age at evaluation, $F(2,140) = 22.06$, $p< .001$, $R^2\Delta = .07$.

Severity of deficits in community affairs on the CDRS were associated with negative symptoms, $F(1,141) = 29.42$, $p< .001$, $R^2\Delta = .17$, older age at evaluation,

$F(2,140) = 20.14$, $p < .001$, $R^2\Delta = .05$, average vector length, $F(3,139) = 16.27$, $p < .001$, $R^2\Delta = .04$, and cosine (coherence), $F(4,138) = 14.16$, $p < .001$, $R^2\Delta = 03$.

More severe impairment in ward life and hobbies on the CDRS was associated with negative symptoms, $F(1,141) = 58.03$, $p < .001$, $R^2\Delta = .29$, and average vector length, $F(2,140) = 32.08$, $p < .001$, $R^2\Delta = .02$.

Higher impairment in personal care on the CDRS was associated with negative symptoms, $F(1,141) = 19.60$, $p < .001$, $R^2\Delta = .12$, older age at evaluation, $F(2,140) = 14.99$, $p < .001$, $R^2\Delta = .09$, and average vector length, $F(3,139) = 14.03$, $p < .001$, $R^2\Delta = .03$.

4. Discussion

Formal thought disorder is a pervasive symptom of schizophrenia (Bleuler, 1911; Kraepelin, 1919); it is associated with impairment in functional outcome (Bowie and Harvey, 2008) and is experienced by a large majority of individuals with schizophrenia (Andreasen and Black, 2005; Brier and Berg, 1999). Yet, there is little understanding of the discrete components of disorganized thought and how these are specifically related to functional outcome. The goal of the present study was to evaluate the relationship between discrete components of discourse to disconnected speech, semantic fluency, phonological fluency, and adaptive functioning in geriatric schizophrenia.The larger implications speak to the degree to which computational techniques may prove to be effective tools in the study of thought disorder and how variables derived from LSA coalesce with evidence to date on the role of disordered prose as it relates to adaptive functioning. Findings suggest that measures of latent semantic structure of speech differentially associated with disorganized speech, performance on verbal fluency tasks,

and adaptive functioning over and above demographic, clinical, and premorbid cognition variables.

Coherence was not related to performance on either verbal fluency tasks, but semantic fluency was associated with average vector length. Furthermore, both verbal fluency tasks shared a significant negative correlation with average vector length. This may suggest that individuals who demonstrate difficulties in retrieval of words related to a specific demand (e.g., verbal fluency task) fail to generate "usual" verbal responses thereby hindering their performance in quickly generating many "correct" or "high frequency" words on verbal fluency tasks. Semantic fluency was also associated with older age at evaluation, negative symptoms, premorbid cognition, and average vector length, whereas phonological fluency was only related to age at testing, premorbid cognition, and positive symptoms. Previous research has found that negative symptoms are related to verbal fluency (Kerns et al., 1999; O'Leary et al., 2000), while a recent meta-analysis suggests that negative symptoms are more strongly correlated with phonological fluency than semantic fluency (Henry and Crawford, 2005). Given the similar magnitude of the correlations between verbal fluency tasks and negative symptoms, it is likely this discrepancy emerged as a function of sample size rather than differential relationships among the verbal fluency tasks and negative symptoms.

Only word unusualness emerged as a significant factor related to disconnected speech, after considering premorbid cognition and demographic variables. Positive symptoms, negative symptoms, and word unusualness were associated with disconnected speech. Positive symptoms included items that overlap with thought disorder, and previous reports support this relationship (Bowie et al., 2004). The finding of vector length (word unusualness) as related factor is in line with a study by Baskak et al (2008)

that found unusual word use to be associated with the severity of formal thought disorder. A previous study by Kuperberg et al (1998) found that individuals with positive thought disorder experienced more intrusions, as it may be the case that individuals with more severe positive thought disorder may generate more semantically unrelated words (Docherty et al., 2011). Thus, we had predicted that coherence (specifically, lower coherence) would be associated with of disconnected speech. While coherence did not emerge as a significant factor related to disconnected speech, the negative correlation between the two suggests that individuals who produce more disconnected speech demonstrated lower coherence on the verbal fluency task. Furthermore, positive thought disorder is inversely correlated with activity in the Wernicke area, a region implicated in the production of coherent speech (Kircher et al., 2001). These findings are consistent with previous evidence suggesting that there is a relationship between aspects of verbal fluency performance and thought disorder (Kerns et al., 1999). A possible explanation for this relationship is the overlapping neural areas responsible for performance on verbal fluency tasks and thought disorder, wherein both are strongly associated with temporal and frontal lobe regions (Artiges et al., 2000; Curtis et al., 1998; Petty et al., 1995).

It has been proposed that verbal fluency tests provide a reliable means of finding out whether and how well people organize their thinking (Estes, 1974), thus, it stands to reason that specific features of latent disorganization may be expressed in disorganized behavior and inability to execute functional behavior. In the present study, adaptive functioning behaviors were associated with negative symptoms, age, average word unusualness, and coherence. Negative symptoms frequently play a large role in functional disability and poor overall outcome (Perlick et al., 1992; Velligan et al., 1997) and adaptive functioning impairments in older people with schizophrenia in both inpatients

(McGurk et al., 2000) and outpatients (Leifker et al., 2009). Furthermore, these findings coalesce with previous reports that performance deficits in verbal fluency have functional importance as they are related to negative symptoms, lower number of social contacts (Hanuszkiewicz et al., 2009), worse performance on daily problem solving tasks (Rempfer et al., 2003), and poorer social-adaptive functioning in hospitalized geriatric schizophrenia patients (Bowie et al., 2004).Concerning the LSA variables, cosine was only associated with community behaviors, yet coherence was related to worse functioning. We speculate that this is because the LSA measure of coherence in this study was confounded by the fact that as individuals generated more words on the semantic fluency tasks (from which the LSA variables were derived) they produced more clusters (i.e., categories) of words, which inadvertently reduced their average coherence. Thus, we suggest that word unusualness (i.e., average vector length) emerges as having a stronger association with functioning because it is related to a generation of less frequently used verbal responses under certain conditions. In this regard, we suggest that uttering infrequently utilized words (which may be due to difficulties retrieving "usual words" or simply being "creative" in words generated during the task) may actually detract from overall task performance. One interpretation is that these results may speak to a possible general disorganization of semantic networks in retrieval of high frequency words and appears to be related to difficulties in execution of functional behavior.

This study has several limitations that should be taken into consideration, some of which may hinder these results from being generalized to other samples. Firstly, this study documents the performance of older, chronically ill patients, thus these findings may not readily translate to younger or more acutely ill individuals. It should be noted that cognition and functioning were reported to have the same global correlations in

acutely ill and institutionalized older patients (Harvey et al., 1998). However, this age-range is also a unique strength of the current study as previous literature demonstrates that there are age-based differences in performance on verbal fluency tasks (Bowie et al., 2005; Harvey, et al., 1997; Troyer et al., 1997) highlighting the importance of considering differential predictors of performance across the lifespan. A comprehensive assessment of cognitive functioning was not employed in this study, thereby precluding the possibility of comprehensively evaluating the contribution of underlying neurocognitive mechanisms that contribute to the pathogenesis of disorganized discourse. We have published extensively on this sample in the past. Future studies may consider employing a neurocognitive battery, with a specific focus on domains related to verbal fluency performance and thought disorder including working memory (Ojeda et al., 2010), processing speed (Ojeda et al., 2008), and executive functioning (Kerns and Berenbaum, 2002). Finally, we applied Latent Semantic Analysis to a semantic fluency task that was only 90 secs in duration as opposed to natural speech. As such, the potential for unveiling more detailed underlying disorganization is limited by the constriction of specific rules governing the semantic fluency task and the total number of words one can produce in a 90 second timeframe. Future studies may benefit from applying computational techniques such as LSA to natural discourse to determine whether the latent disorganization differs in less constricted speech and how this relates to functional outcome. Furthermore, previous research has demonstrated that there is much variability, both inter- and intra-individually, on verbal fluency tasks (Elvevåg and Storms, 2003), suggesting that conclusions drawn from these data may shift depending on individual difference factors and the stability of thought disorder's impact on discourse across multiple test points.

This study demonstrates the association between disorganized discourse and adaptive functioning, and provided an overview of the psychometric properties of a computational language approach to studying disordered speech. Given the pervasive course of thought disorder in schizophrenia, these findings underscore the importance of developing efficacious treatment for thought disorder and using Latent Semantic Analysis to index change in communication patterns as a function of treatment.

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Table 1. Descriptive information

	Mean	SD	Range
Age (years)	66.03	12.27	31.41-93.18
Highest education (n=153)	11.59	2.36	4-18
Age at first hospitalization (n=118)	26.81	10.97	12-66

Table 2. Premorbid cognition, symptoms, and functional behavior

	Mean	SD	Range (maximum)
Estimate of premorbid cognition (n=153)			
WRAT Total Raw score	51.55	17.94	2-95 (100)
Verbal Fluency			
Semantic fluency (1.5 minutes; n=162)	10.17	4.04	2-24 (N/A)
Phonological fluency (3 minutes; n=153)	19.75	11.19	2-70 (N/A)
Symptoms (n=162)			
PANSS Positive factor	19.01	6.81	7-39 (49)
PANSS Negative factor	20.33	6.80	7-39 (49)
Adaptive Functioning (n=162)			
CDRS Judgment & problem solving	1.15	.70	0-3 (3)
CDRS Community affairs	.96	.74	0-3 (3)
CDRS Ward life & hobbies	1.06	.76	0-3 (3)
CDRS Personal care	1.09	.95	0-4 (5)

Table 3. Percentage of total sample characterized by types of thought disorder subsumed under the disconnected subtype

	Absent (%)	Mild (%)	Moderate (%)	Severe (%)	Extreme (%)
Tangentiality	46.70	16.40	20.60	12.70	3.60
Derailment	54.50	15.20	17.60	9.70	3.00
Incoherence	80.00	8.50	8.50	1.20	1.80
Circumstantiality	66.70	20.00	11.50	1.80	N/A
Loss of Goal	58.20	20.60	17.00	4.20	N/A

Note: Absent = No instances over whole interview; Mild = occurs once or occasionally; Moderate = two to four times; Severe = 5 to 10 times or in the case of circumstantiality, many such that this pattern of responding continues despite being interrupted by examiner; Extreme = more than 10 times, interview is largely incomprehensible).

Table 4. Correlations between symptom, demographic, and speech variables

	PANSS positive	PANSS negative	Highest education	Chronological age	WRAT Total	Average vector length	Cosine
Semantic Fluency	.17*	-.14	.06	-.38**	.21*	-.26**	-.06
Phonological fluency	.12	-.18*	.07	-.37**	.25**	-.19**	-.01
Disconnected speech	.37**	-.18*	.04	-.14	.05	-.20**	-.13

* significant at the .05 level
** significant at the .01 level

Table 5. Correlations between symptom, demographic, and speech variables and adaptive functioning variables

	Average vector length	Cosine	PANSS positive	PANSS negative	Highest education	Age at evaluation	WRAT Total
CDRS							
Judgment & problem solving	.09	.03	-.06	.40**	.02	.24**	-.10
Community affairs	.22**	.12	.02	.44**	.05	.23**	-.07
Ward life & hobbies	.16*	.04	-.01	.55**	.03	.09	-.07
Personal care	.19*	.10	-.14	.33**	.09	.31**	-.04

Note: Higher scores on the CDRS are indicative of worse functioning.
* significant at the .05 level
** significant at the .01 level

Table 6. Regression coefficients for verbal fluency, clinical ratings of thought disorder, and adaptive functioning variables

		B	SE	Beta	*t*	*p*
	Semantic Fluency					
Model 1	Age at evaluation	-.13	.03	-.38	-4.68	<.001
Model 2	Age at evaluation	-.13	.03	-.37	-4.58	<.001
	Negative symptoms	-.75	.32	-.19	-2.32	.022
Model 3	Age at evaluation	-.12	.03	-.34	-4.32	<.001
	Negative symptoms	-.73	.32	-.18	-2.30	.023
	Premorbid cognition	.04	.02	.16	1.20	.048
Model 4	Age at evaluation	-.11	.03	-.32	-4.18	<.001
	Negative symptoms	-.74	.31	-.18	-2.41	.018
	Premorbid cognition	.04	.02	.15	1.97	.051
	Average vector length	-43.85	13.75	-.24	-3.19	.002
	Phonological Fluency					
Model 1	Age at evaluation	-.36	.07	-.38	-4.89	<.001
Model 2	Age at evaluation	-.32	.07	-.35	-4.57	<.001
	Premorbid cognition	.18	.05	.27	3.58	<.001
Model 3	Age at evaluation	-.31	.07	-.33	-4.37	<.001
	Premorbid cognition	.19	.05	.29	3.87	<.001
	Positive symptoms	1.65	.73	.17	2.25	.026
	Disconnected Speech					
Model 1	Positive symptoms	1.41	.32	.35	4.44	<.001

Model 2	Positive symptoms	1.35	.31	.34	4.29	<.001
	Negative symptoms	-.73	.33	-.17	-2.21	.028
Model 3	Positive symptoms	1.31	.31	.333	4.27	<.001
	Negative symptoms	-.71	.32	-.17	-2.19	.031
	Average vector length	-37.88	13.95	-.21	-2.72	.007
	CDRS Judgment & Problem Solving					
Model 1	Negative symptoms	.26	.05	.42	5.44	<.001
Model 2	Negative symptoms	.25	.05	.40	5.38	<.001
	Age at evaluation	.02	.01	.26	3.49	.001
	CDRS Community Affairs					
Model 1	Negative symptoms	.28	.05	.42	5.42	<.001
Model 2	Negative symptoms	.26	.05	.40	5.34	<.001
	Age at evaluation	.01	.01	.23	3.03	.003
Model 3	Negative symptoms	.26	.05	.39	5.39	<.001
	Age at evaluation	.01	.01	.21	2.81	.006
	Average vector length	5.51	2.11	.19	2.62	.010
Model 4	Negative symptoms	.25	.05	.37	5.09	<.001
	Age at evaluation	.01	.01	.18	2.47	.015
	Average vector length	7.58	2.23	.26	3.39	.001
	Cosine	1.51	.61	.19	2.46	.015
	CDRS Ward Life &					

	Hobbies					
Model 1	Negative symptoms	.35	.05	.54	7.62	<.001
Model 2	Negative symptoms	.35	.05	.54	7.64	<.001
	Average vector length	4.22	1.96	.15	2.15	.033
	CDRS Personal Care					
Model 1	Negative symptoms	.30	.07	.35	4.43	<.001
Model 2	Negative symptoms	.28	.06	.33	4.34	<.001
	Age at evaluation	.02	.01	.29	3.87	<.001
Model 3	Negative symptoms	.28	.06	.32	4.35	<.001
	Age at evaluation	.02	.01	.28	3.68	<.001
	Average vector length	5.92	2.76	.16	2.15	.034

Note: LSA variables (cosine and vector length) were derived from the category fluency task.