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Piecing together fragments: Linguistic cohesion mediates the relationship between executive function and metacognition in schizophrenia

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Abstract

Speech disturbances are prevalent in psychosis. These may arise in part from executive function impairment, as research suggests that inhibition and monitoring are associated with production of cohesive discourse. However, it is not yet understood how linguistic and executive function impairments in psychosis interact with disrupted metacognition, or deficits in the ability to integrate information to form a complex sense of oneself and others and use that synthesis to respond to psychosocial challenges. Whereas discourse studies have historically employed manual hand-coding techniques, automated computational tools can characterize deep semantic structures that may be closely linked with metacognition. In the present study, we examined whether higher executive functioning promotes metacognition by way of altering linguistic cohesion. Ninety-four individuals with schizophrenia-spectrum disorders provided illness narratives and completed an executive function task battery (Delis-Kaplan Executive Function System). We assessed the narratives for linguistic cohesion (Coh-Metrix 3.0) and metacognitive capacity (Metacognition Assessment Scale – Abbreviated). Selected linguistic indices measured the frequency of connections between causal and intentional content (deep cohesion), word and theme overlap (referential cohesion), and unique word usage (lexical diversity). In path analyses using bootstrapped confidence intervals, we found that deep cohesion and lexical diversity independently mediated the relationship between executive functioning and metacognitive

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Contributors

Dr. Lysaker designed the protocol and oversaw data collection. Ms. Lundin and Dr. Hochheiser conceptualized the hypotheses, conducted statistical analyses, and interpreted the data. Ms. Lundin wrote the first draft of the manuscript. Dr. Minor, Dr. Hetrick, and Dr. Lysaker helped to conceptualize the study, interpret data, and contributed to the manuscript.

Declaration of competing interest

All authors declare that they have no conflicts of interest.

capacity. Findings suggest that executive control abilities support integration of mental experiences by way of increasing causal, goal-driven speech and word expression in individuals with schizophrenia. Metacognitive-based therapeutic interventions for psychosis may promote insight and recovery in part by scaffolding use of language that links ideas together.

Keywords

Discourse coherence; Metacognition; Executive control; Psychosis; Mediation analysis

1. Introduction

A cardinal feature of psychosis described by Bleuler (1911) in coining the term "schizophrenia" is a loosening of associations evident in fragmentation of language, thought, and behavior. Language disturbances such as tangentiality, derailment, and illogical speech, often categorized as thought disorder (Andreasen, 1979), have been documented in chronic schizophrenia (Barch and Berenbaum, 1996), early-stage psychosis (Minor et al., 2016), and those at clinical-risk for psychosis (Bearden et al., 2000; Elvevåg et al., 2010). These findings indicate that language disturbances are not purely a function of illness severity and occur across stages of psychosis. Some evidence suggests that impaired executive functioning common to psychotic illness (Heinrichs and Zakzanis, 1998) may hinder the production of cohesive discourse (Kerns and Berenbaum, 2002).

Less is known about how these observable language disturbances relate to interruptions in the ability to synthesize mental experiences and make sense of one's life and challenges. This set of psychological processes, referred to as metacognition, involves an awareness of one's own thoughts and desires and beliefs about other people's mental experiences (Flavell, 1979; Semerari et al., 2003). Metacognitive impairment may be a fundamental source of the disruptive symptoms in psychotic illness (Lysaker and Klion, 2017). Individuals with compromised metacognitive capacity may perceive their thoughts to be disjointed and the actions of others to be random, manifesting in a disorienting existence devoid of agency. Lower metacognitive capacity in psychosis has been associated with greater concurrent and prospective negative symptoms (Hamm et al., 2012), higher levels of anhedonia (Buck et al., 2014), lower levels of functional competence (Lysaker et al., 2011), and a more sedentary lifestyle (Snethen et al., 2014). While the etiology of metacognitive deficits is multifaceted, one potential source is impaired executive functioning. If one is unable to fluidly shift their attention, monitor thoughts and actions, and inhibit inappropriate or irrelevant behaviors, piecing together complex information to form a coherent sense of self may be challenging. Research suggests that executive function deficits may contribute to impairments in metacognition (Lysaker et al., 2008) and related abilities of perspective-taking (Long et al., 2018; Wardlow, 2013) and theory of mind (Wade et al., 2018). However, researchers have yet to examine whether impaired executive function leads to metacognitive deficits in psychosis by way of producing fragmented speech.

One explanation for this knowledge gap is that discourse studies have historically used manual hand-coding systems that are unable to characterize deeper semantic structures.

Recent technological advances offer new ways to measure the relationship between language disturbances and metacognition in psychosis. In particular, computational linguistic approaches enable objective and comprehensive depictions of underlying syntactic and semantic cohesion (Cabana et al., 2011; Cohen and Elvevåg, 2014). Studies employing Latent Semantic Analysis (Landauer and Dumais, 1997) and graph theoretic techniques (De Deyne et al., 2013, 2016) have found decreased semantic coherence (Elvevåg et al., 2007) and connectedness (Mota et al., 2017) in the discourse of individuals with psychosis relative to healthy individuals. Automatic classification analyses using linguistic indices have accurately distinguished discourse between individuals with schizophrenia and controls (Corcoran et al., 2018; Elvevåg et al., 2007; Mota et al., 2017; Strous et al., 2009; Willits et al., 2018), unaffected first-degree relatives (Elvevåg et al., 2010), and individuals experiencing mania (Mota et al., 2012). Computational linguistic approaches have also accurately predicted psychosis onset (Bedi et al., 2015; Corcoran et al., 2018) as well as explained greater variance and predicted diagnosis better than clinician-rated scales (Minor et al., 2019; Mota et al., 2012). Fine-grained characterization of discourse via automated techniques may aid in revealing semantic structures related to disordered thought and integration of complex information in psychosis.

Computational tool Coh-Metrix (McNamara et al., 2014) produces an array of indices that measure complex discourse structures. One Coh-Metrix study found decreased deep cohesion, or causal and goal-driven connecting phrases, in individuals with schizophrenia compared to an adversity-matched comparison group of HIV positive individuals (Willits et al., 2018). This supports findings of an impaired sense of agency in psychosis (Jeannerod, 2009; Synofzik et al., 2010) given that deep cohesion in part measures one's connections between intentional events and actions. Discourse analyses have also assessed word and theme overlap as a measure of referential cohesion, thought to aid the reader/listener by repeating parts of speech. A Coh-Metrix study found that individuals at ultra-high risk (UHR) for psychosis had reduced referential cohesion in the form of word stem overlap compared to controls (Gupta et al., 2018), aligning with prior work in thought disorder using hand-coded techniques (Harvey, 1983). This reduction in referential cohesion correlated with higher psychotic symptoms and lower verbal learning in the UHR group. Studies have also found reduced lexical diversity, or usage of unique words, in the discourse of individuals with thought disorder compared to controls and patients without thought disorder (Manschreck et al., 1981, 1984). Interestingly, however, referential cohesion and lexical diversity are inversely related (McNamara et al., 2014). A potential explanation for findings of impairments in both indices in psychosis across studies is that word repetition due to thought-disordered perseveration may impede effective communication, whereas intentional lexical repetition aids in connecting relevant threads for the listener (Crider, 1997). Collectively, these findings catalyzed our investigation as to whether particular discourse structure abnormalities in psychosis hinder one's ability to integrate thoughts and affect.

In the present study, we assessed the relationship between metacognition, executive function, and linguistic cohesion in individuals with schizophrenia-spectrum disorders. We measured metacognition using the Metacognition Assessment Scale – Abbreviated (MAS-A; Lysaker and Klion, 2017; Lysaker et al., 2019) based on narratives from the Indiana Psychiatric Illness Interview (IPII; Lysaker et al., 2002). We used the Delis-Kaplan Executive Function

System (D-KEFS; Delis et al., 2001) to measure executive function and formed subcomponents of inhibition, monitoring, and conceptual flexibility (Hecht and Latzman, 2018; Latzman and Markon, 2010). We analyzed linguistic cohesion in the rich discourse sample provided by the IPII with the Coh-Metrix tool (McNamara et al., 2014). Based on prior research outlined above, we selected three linguistic indices that measure logical and intentional connections within speech (deep cohesion), content overlap (referential cohesion), and unique word usage (lexical diversity). For data analysis, we performed correlations followed by path analyses to test whether linguistic cohesion mediated the relationship between executive function and metacognition.

Our central hypothesis was that higher executive function promotes greater metacognitive capacity through altering linguistic cohesion. In other words, we predicted that greater abilities to shift, inhibit, and monitor behavior enable the production of coherent discourse, which in turn supports the integration of complex information about oneself, others, and the world. This prediction is supported in part by evidence suggesting that executive functioning is associated with the ability to form organized and coherent narratives. A meta-analysis examining cognitive impairments in schizophrenia found consistent positive associations between thought disorder and executive function, particularly the abilities to inhibit and maintain goal-relevant content in memory (Kerns and Berenbaum, 2002). Executive function deficits may be particularly related to disjointed speech rather than incorrect language usage in general. This idea is supported by findings that impaired ability to sequence information in individuals with schizophrenia predicted failures to make explicit connections between words or phrases but not the frequency of incorrect or unclear wording (Docherty et al., 2006). Some researchers have posited that reduced working memory capacity in psychosis may lead to distinct types of speech disturbances in different individuals. For example, one study found an inverse relationship between reduced speech production and discourse abnormalities such as tangentiality and derailment in schizophrenia (Barch and Berenbaum, 1997). The authors theorized that reduced working memory resources could either lead an individual to produce less speech yet maintain coherence, or produce more speech but fail to monitor speech content. Developmental evidence in children suggests that the abilities to structure coherent narratives and utilize executive functions support one another over time. In particular, one study found that formation of organized narratives predicted future response inhibition and was predicted by prior attentional capacity (Friend and Bates, 2014). In sum, these findings suggest that capacities to flexibly monitor, inhibit, and update one's thoughts and actions to accomplish tasks promote the maintenance and planning of effective communication.

Additional support for our hypothesis includes preliminary findings that executive function and linguistic cohesion predict metacognitive abilities. One study found that the metacognitive capacity to reflect upon one's own thoughts positively correlated with mental flexibility, whereas awareness of others' thoughts correlated with inhibition (Lysaker et al., 2008). Other studies found positive associations between working memory, inhibition, and switching with perspective-taking, an important facet of metacognition that allows one to distinguish between one's own thoughts and the thoughts of others (Long et al., 2018; Wardlow, 2013). Lastly, studies have found that lexical measures indicative of thought complexity predicted overall metacognitive capacity (Buck et al., 2015; Minor et al., 2019).

Overall, we sought to examine whether abilities to flexibly monitor and inhibit behavior (i.e., executive function) support the capacity to derive meaning from mental experiences (i.e., metacognition) by way of increasing coherent speech (i.e., linguistic cohesion) in schizophrenia.

2. Methods

2.1 Participants

Data from the present study were collected from 94 outpatients diagnosed with schizophrenia ($n = 54$) or schizoaffective disorder ($n = 40$) at a midwestern VA Medical Center. Participants included 12 females and 82 males aged 31–74 years old (mean [*M*]: 58.28, standard deviation [*SD*]: 8.6) with 7–18 years of education ($M = 12.73$, $SD = 1.8$). Fifty participants identified as African American (53%), 43 as Caucasian (46%), and one participant identified as Hispanic or Latino (1%). Most participants were either divorced ($n = 41$, 44%) or never married ($n = 38$, 40%), and the rest were currently married ($n = 15$, 16%). All participants were prescribed antipsychotic medications at the time of the study.

Exclusion criteria included hospitalizations and/or changes in psychiatric medication within one month of testing, active substance dependence, and intellectual disability based on medical chart review. Participants were enrolled in a study measuring metacognition that was approved by Veterans Affairs Institutional Review Boards and provided written informed consent to study procedures. Data in the present report are from the baseline assessment. Trained raters conducted diagnostic interviews using the Structured Clinical Interview for DSM-IV Disorders (SCID-I/P; First et al., 2002). Psychotic symptoms were assessed with the Positive and Negative Syndrome Scale (PANSS; Kay et al., 1987). PANSS total scores of participants ranged from 44 to 107 ($M = 76.57$, $SD = 13.85$).

2.2 Illness narratives

The Indiana Psychiatric Illness Interview (IPII; Lysaker et al., 2002) is a semi-structured interview designed to assess metacognition in which an individual is invited to provide narratives about their mental illness. The interviewer asks open-ended questions regarding the individual's life story, their mental illness, and the impact the illness has had on their functioning (i.e., emotional, cognitive, vocational) and their relationships with others. Throughout the IPII, the interviewer aims to present with a nonjudgmental, conversational attitude and limit their inquiries, allowing for more accurate assessments of the individual's metacognitive capacity. The interview typically lasts 30–90 min. Interviews were audio recorded and later transcribed.

2.3 Metacognition

The Metacognition Assessment Scale – Abbreviated (MAS-A; Lysaker and Klion, 2017; Lysaker et al., 2019) is a scale with four domains designed to rate individuals' metacognitive capacity. The first domain of self-reflectivity (ranging from 0 to 9) assesses the degree to which an individual is able to recognize that they have autonomous thoughts and synthesize complex personal narratives of their own thoughts and affect. The second domain of understanding of others' minds (0 to 7) measures one's ability to integrate the thoughts and

affective experiences of other people in their life. The third domain of decentration (0 to 3) indexes one's capacity to perceive that other people have perspectives and motivations that are independent of the participant. Lastly, the fourth domain of mastery (0 to 9) measures one's ability to utilize unique knowledge of their strengths and limitations in order to cope with psychological challenges. Trained raters assessed the IPIIs with the MAS-A, with prior research indicating good-to-excellent interrater reliability (Lysaker and Dimaggio, 2014). We used total MAS-A score as an overall measure of metacognitive capacity.

2.4 Linguistic cohesion

The Coh-Metrix 3.0 system is a computational tool that evaluates the coherence and cohesion of transcribed spoken or written discourse (McNamara et al., 2014) (http://cohmetrix.com). It was originally developed to assess the ease of reading level of academic texts for educational settings. Coh-Metrix 3.0 produces 108 linguistic indices that assess cohesion at levels of words, sentences, syntax, and discourse genre. We analyzed indices of deep cohesion, referential cohesion, and lexical diversity based on past psychosis research. Deep and referential cohesion are principal component z-scores resulting from a factor analysis of individual Coh-Metrix variables computed on a corpus of language arts, science, and history texts (Graesser et al., 2011). In this factor analytic study, deep cohesion had positive loadings of variables including causal, logical, and intentional content and connectives; it thus assesses the ease of understanding causal and goal-driven events and processes in the text. Referential cohesion had positive factor loadings of variables such as content, argument, noun, and stem overlap. This index assesses the overlap of ideas in the text, aiding the reader/listener in making explicit connections between themes. Lastly, we measured lexical diversity in the form of a variant of type-token ratio, or the ratio of unique to total words. Type-token ratio is highly correlated with text length, as the likelihood of a word being unique decreases as text length increases (McNamara et al., 2014). Therefore, we used the Coh-Metrix measure of textual lexical diversity (index LDMTLDa) that adjusts for text length by calculating the mean length of consecutive words that have a fixed, empirically determined type-token ratio value (McCarthy and Jarvis, 2010).

2.5 Executive function

The Delis-Kaplan Executive Function System (D-KEFS; Delis et al., 2001) is a neuropsychological test battery of nine subtests designed for use in children and adults. In the present study, we averaged particular D-KEFS scaled scores to represent distinct executive function components of inhibition, monitoring, and conceptual flexibility in accordance with prior factor analytic work (Hecht and Latzman, 2018; Latzman and Markon, 2010). Specifically, inhibition was comprised of the inhibition and inhibition/switching scores from the Color-Word Interference Test and the number-letter switching score from the Trail-Making Test. Monitoring was comprised of category switching total correct and accuracy scores from the Verbal Fluency Test. Conceptual flexibility consisted of free sort, free sort description, and sort recognition scores from the Sorting Test. Five participants were missing inhibition/switching scores from the Color-Word Interference Test, and two participants were missing number-letter switching scores from the Trail Making Test. For these individuals, mean scores of the remaining subscales formed the corresponding executive function component.

2.6 Data analysis

We conducted data analyses using SPSS (IBM SPSS Statistics for MacOS, Version 25.0, Armonk, USA). We first calculated descriptive statistics of MAS-A, D-KEFS, and Coh-Metrix raw scores. Next, we computed Spearman bivariate correlations between scores from MAS-A subscales, executive function component measures, and Coh-Metrix variables. We used nonparametric rank-order correlations due to the ordinal nature of the MAS-A and D-KEFS variables. Correlation tests were two-tailed with an alpha of $p < .05$. Coh-Metrix indices that significantly correlated with measures of executive function and metacognition were entered into subsequent mediation models.

We used the PROCESS macro version 3.2.01 to examine mediation effects (Hayes, 2018). In our primary models, we tested whether standardized linguistic cohesion indices (M) separately mediated the relationship between average executive function (X) and overall metacognitive capacity (Y). For each model, we conducted two ordinary least squares regressions. The regression for path a estimated the effect of executive function on the linguistic cohesion index. The regression for path b estimated the effect of linguistic cohesion on metacognitive capacity while controlling for executive function. Lastly, we calculated the direct effect of executive function on metacognitive capacity while controlling for linguistic cohesion (path c'), the indirect effect of executive function on metacognitive capacity mediated by linguistic cohesion (path ab), and the total effect ($ab + c'$). We utilized 95% confidence intervals with 10,000 bootstrap samples to assess the indirect effect for mediation and concluded that mediation was present if the bootstrap confidence interval did not include zero (Hayes, 2018). Lastly, we tested the influence of age, education, and discourse length on our results. We conducted the above mediation models again while covarying for age and education and finally conducted a separate model with IPII length as the mediator between executive function and metacognition.

3. Results

3.1 Descriptive statistics and associations between study variables

Means, standard deviations, and ranges of MAS-A, Coh-Metrix, and D-KEFS raw scores are presented in Table 1. Spearman correlations are presented in Table 2. To summarize, deep cohesion and lexical diversity were weakly to moderately positively correlated with most MAS-A subscales. Deep cohesion was positively correlated with inhibition and monitoring components of executive function, whereas lexical diversity was positively correlated with conceptual flexibility. Referential cohesion negatively correlated with lexical diversity but did not significantly correlate with metacognitive or executive function variables; therefore, this linguistic index was not tested in mediation analyses.

3.2 Mediation analyses

We first examined whether deep cohesion mediated the relationship between executive function and metacognitive capacity (see Fig. 1; Table 3). The regression for path a was significant, indicating that higher executive function predicted higher deep cohesion ($R^2 = 0.08$, $F(1, 92) = 8.12$, $p = .005$). The regression for path b also reached significance, indicating that greater deep cohesion predicted higher metacognitive capacity while

controlling for executive function (R^2 = 0.19, F(2, 91) = 10.37, p < .001). The results of the bootstrapped confidence intervals (CI) revealed that deep cohesion mediated the relationship between executive function and metacognition. The direct effect (c') of executive function on metacognition after adjusting for the mediator approached but did not reach statistical significance (p = .054), and the total effect of the mediation model was significant.

We next tested whether lexical diversity mediated the relationship between executive function and metacognition (see Fig. 2; Table 3). The regression for path a was significant, indicating that higher executive function predicted higher lexical diversity (R^2 = 0.08, F(1, 92) = 7.68, p = .007). The regression for path b was also significant, indicating that higher lexical diversity predicted higher metacognition while controlling for executive function (R^2 = 0.15, F(2, 91) = 7.76, p < .001). Lexical diversity mediated the relationship between executive function and metacognitive capacity based on the bootstrapped confidence intervals. The direct effect (c') of executive function on metacognition remained significant after adjusting for lexical diversity, and the total effect was also significant.

Lastly, we conducted follow-up analyses to ensure that our mediation results were not explained by age, years of education, or length of discourse. We first repeated the mediation analyses for both deep cohesion and lexical diversity while including age and years of education as covariates. The covariates had small and non-significant model coefficients (age: p > .7; education: p > .2) and negligibly influenced the results. Of note, using Spearman's rho, age did not significantly correlate with any study variables, and education significantly correlated with executive function measures of inhibition (ρ = 0.32, p = .002) and conceptual flexibility (ρ = 0.27, p = .008). We next conducted a mediation analysis with IPII length as the mediator to assess whether quantity of speech production explained our results instead of the more complex linguistic indices tested in our primary models. IPII length did not mediate the relationship between executive function and metacognition (bootstrapped 95% CI: −0.3 to 0.51).

4. Discussion

Results of this study support the hypothesis that the formation of causal and goal-driven connections and lexical diversity independently mediate the relationship between executive function and metacognition among individuals with schizophrenia-spectrum disorders. In addition, we found that deep cohesion significantly correlated with inhibition and monitoring, whereas lexical diversity correlated with conceptual flexibility. Lastly, we found that referential cohesion did not significantly correlate with any measures of executive function or metacognition. This study is novel in its application of automated discourse analysis to the examination of how language disturbances in psychosis interface with one's ability to make sense of their illness and other people in their lives.

Prior work has suggested that impaired metacognition, a fragmented sense of the mental experiences of oneself and others, is a central underlying disturbance in psychosis (Lysaker and Klion, 2017). Extensive research has also characterized aberrant executive functioning (Heinrichs and Zakzanis, 1998) and language (Andreasen, 1979; Andreasen and Grove, 1986; Berenbaum and Barch, 1995; Covington et al., 2005) as other cardinal impairments in

psychosis. In this study, we present one possibility as to how these functions interact in schizophrenia. Higher levels of executive functioning predicted greater deep cohesion, aligning with prior studies suggesting that greater capacity to monitor and inhibit goal-directed behavior aids in organizing and maintaining a discourse plan (Barch and Berenbaum, 1997; Kerns and Berenbaum, 2002). Of note, lexical diversity correlated specifically with the executive function domain of conceptual flexibility, perhaps indicating that flexible cognitive control allows one to identify a rich variety of words within their lexicon to describe their experiences. Higher executive function also predicted greater metacognitive capacity, suggesting that basic cognitive control abilities are useful in integrating thoughts and affect (Long et al., 2018; Lysaker et al., 2008; Wade et al., 2018; Wardlow, 2013). Importantly, our mediation results suggest that targeting discourse in psychosis may improve metacognition even when executive functioning is compromised. We further interpret our results to mean that building coherent semantic structures with rich usage of language promotes clearer thinking, such that one can more fluidly derive meaning from experiences and actively confront challenges. An alternative possibility is that one's capacity to integrate mental experiences leads to rich, causally linked narratives, or even that metacognition and usage of deep semantic structures have a bidirectional relationship. Future longitudinal work that characterizes metacognitive capacity and linguistic cohesion over time could disentangle these possibilities.

We did not expect that referential cohesion would negligibly correlate with executive function and metacognition. Based on prior findings of reduced referential cohesion in individuals with psychosis and at clinical risk, we predicted that greater content overlap throughout the narratives would be associated with improved cognitive function (Gupta et al., 2018; Harvey, 1983). Here we offer one interpretation of this finding, which considers the ways in which speech repetition can be useful or problematic in the context of thought disorder. Higher referential cohesion is helpful in guiding a reader or listener through complex material, particularly in academic contexts (McNamara et al., 2014). However, perseveration hinders comprehension when the speaker does not provide useful connecting phrases (Crider, 1997). Therefore, the index of referential cohesion in schizophrenia may encompass both perseveration and productive repetition of themes, resulting in a weak association with cognitive functions.

In contrast to referential cohesion, a text higher in lexical diversity or unique words is interpreted to be lower in cohesion in the context of academic writing (McNamara et al., 2014). However, reduced lexical diversity in individuals with thought disorder has been interpreted as a reflection of speech disturbances due to unnecessary repetition of utterances and lack of flexibility in thought in studies that controlled for discourse length (Manschreck et al., 1981, 1984). Of note, another Coh-Metrix study from our group found lexical diversity to negatively associate with metacognition, contrasting with the current findings; however, the authors noted that the simple type-token ratio used did not account for varying text length (Minor et al., 2019). In the present data, IPII length had a strong negative Spearman correlation with simple type-token ratio ($\rho = -0.84$, $p < .001$), but not with our selected measure of textual lexical diversity ($\rho = 0.11$, $p = .282$). Therefore, as discussed by the authors, Minor et al. (2019) findings of higher lexical diversity relating to lower metacognition are likely explained by the relationship between shorter IPII length and lower

metacognition. We interpreted our mediation findings as a whole to mean that individuals with schizophrenia who are able to provide richer narratives (higher lexical diversity) with cohesive causal and goal-driven speech (greater deep cohesion) are better able to integrate thoughts and affect.

There are limitations to the present study. The IPII narratives were used as speech samples for both discourse cohesion analysis and ratings of metacognition. It is possible that an illness interview is more likely to elicit linguistic disturbances than other discourse measures. These constructs were also assessed simultaneously with the same speech sample. Findings should be interpreted cautiously until they are replicated using different speech samples and across multiple testing sessions for the same participants to ensure adequate test-retest reliability. Lastly, whereas Coh-Metrix provides an in-depth array of information about syntactic and semantic structures, it was developed to assess the coherence of complex academic texts, which may differ in important ways from the structures useful in fluid human conversation. Disorganized and negative psychotic symptoms such as perseveration and poverty of speech may be associated with higher cohesion according to some linguistic indices but may equate to less effective communication in social contexts. Discourse analyses using a natural language corpus may ameliorate this issue.

With replication, this work has clinical implications. While cognitive remediation interventions for psychosis have resulted in improved cognitive task performance, these benefits minimally generalize to psychosocial functioning without an added psychiatric rehabilitation component (McGurk et al., 2007; Wykes et al., 2011). The present findings suggest an alternative target for recovery. Therapeutic interventions such as Metacognitive Recovery and Insight Therapy (MERIT; Lysaker and Klion, 2017) that elicit meaningful life narratives from individuals may support recovery in part by exercising linguistic abilities. Such interventions may help individuals to craft syntactic and semantic structures jointly with a therapist over time, leading to improved thought integration and mastery. In addition, future work employing automated discourse analysis has the potential to identify individuals at risk for developing psychosis (Bedi et al., 2015) and bolster the study of psychopathology as dimensional constructs rather than categorical disorders (Cohen et al., 2017; Elvevåg et al., 2016), aligning with the Research Domain Criteria initiative (Insel et al., 2010).

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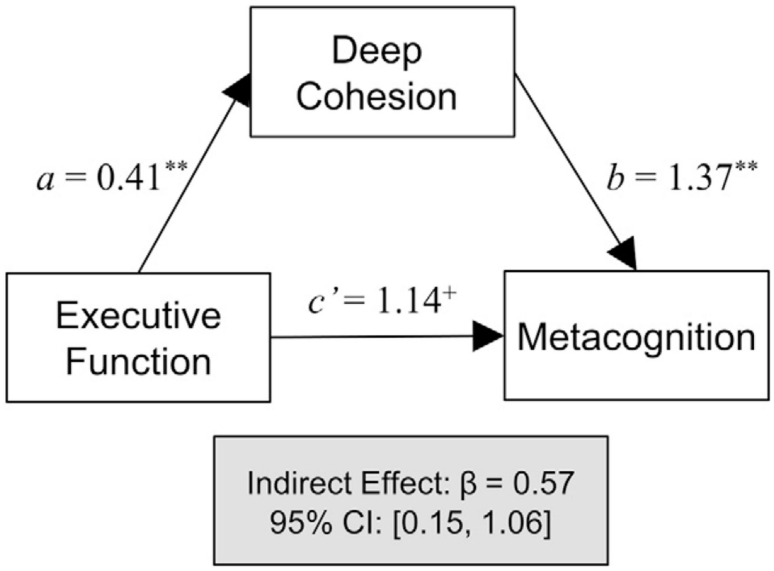

Fig. 1.

Deep cohesion mediates the relationship between executive function and metacognition. Coefficients are unstandardized. +$p < .1$; *$p < .05$; **$p < .01$; ***$p < .001$.

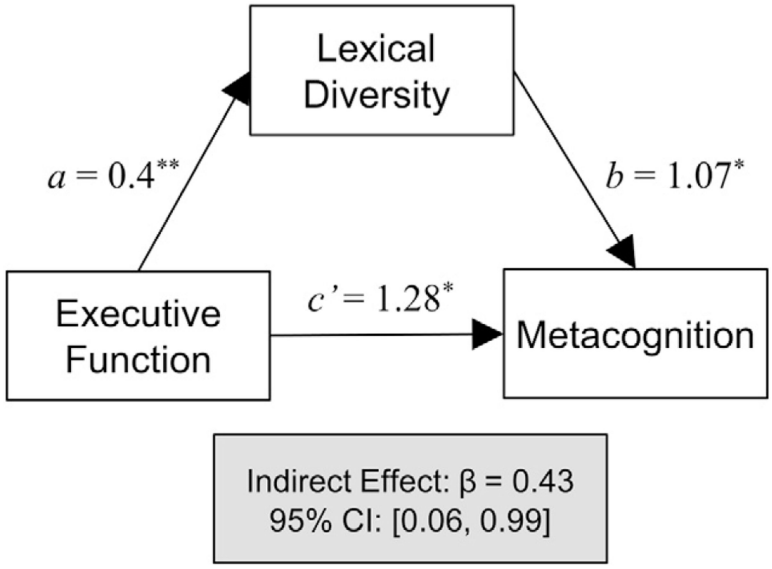

Fig. 2.

Lexical diversity mediates the relationship between executive function and metacognition. Coefficients are unstandardized. *$p < .05$; **$p < .01$; ***$p < .001$.

Table 1

Descriptive statistics of study variables ($N = 94$).

Measure	Variable	*M*	*SD*	Minimum	Maximum
MAS-A	Self-reflectivity	4.26	1.4	1.5	7
	Understanding others' minds	3.06	0.95	1	6
	Decentration	1.02	0.84	0	3
	Mastery	3.63	1.61	0.5	7.5
Coh-Metrix	Deep cohesion	0.47	0.71	−0.99	3.28
	Referential cohesion	1.23	0.6	−0.21	3.37
	Lexical diversity	47.97	9.71	29.42	72.15
D-KEFS	CWT inhibition[a]	6.56	3.72	1	14
	CWT inhibition/switching[a]	6.92	4.01	1	15
	TMT number-letter switching[b]	5.72	3.64	1	14
	VFT category switching correct	7.02	3.7	1	17
	VFT category switching accuracy	7.45	3.39	1	15
	ST free sort	7.43	3.03	2	14
	ST free sort description	7.53	3.13	1	14
	ST sort recognition	6.95	3.14	1	14

Note: MAS-A, Metacognition Assessment Scale-Abbreviated; D-KEFS, Delis-Kaplan Executive Function System; CWT, Color-Word Test; TMT, Trail Making Test; VFT, Verbal Fluency Test; ST, Sorting Test.

[a] Five participants' data are missing.

[b] Two participants' data are missing.

Table 2

Correlations between metacognition, linguistic cohesion, and executive function ($N = 94$).

Measure	Variable	1	2	3	4	5	6	7	8	9	10
MAS-A	1. Self-reflectivity	–									
	2. Understanding others' minds	0.68***	–								
	3. Decentration	0.63***	0.6***	–							
	4. Mastery	0.66***	0.54***	0.64***	–						
Coh-Metrix	5. Deep cohesion	0.36***	0.31**	0.42***	0.36***	–					
	6. Referential cohesion	0.13	0.004	0.03	0.09	0.15	–				
	7. Lexical diversity	0.25*	0.36***	0.35**	0.2	0.3**	−0.6***	–			
D-KEFS	8. Inhibition	0.33**	0.15	0.26*	0.18	0.21*	−0.03	0.2	–		
	9. Monitoring	0.31**	0.27**	0.33**	0.23*	0.29**	0.1	0.18	0.5***	–	
	10. Conceptual flexibility	0.15	0.16	0.26*	0.07	0.12	−0.1	0.27**	0.42***	0.35***	–

Note: Correlation coefficients are Spearman's rho. MAS-A, Metacognition Assessment Scale-Abbreviated; D-KEFS, Delis-Kaplan Executive Function System.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 3

Effects of executive function on metacognition mediated by linguistic cohesion ($N = 94$).

***X* – executive function; *Y* – MAS-A total**					
Mediator	**Path**	**Coefficient**	**SE**	***p***	**LLCI, ULCI**
Deep cohesion	*a*	0.41	0.14	0.005**	[0.13, 0.7]
	b	1.37	0.4	0.001**	[0.57, 2.18]
	c′: direct	1.14	0.59	0.054	[−0.02, 2.3]
	ab: indirect	0.57	0.23	–	[0.15, 1.06]
	ab + *c′*: total	1.71	0.59	0.005**	[0.53, 2.88]
Lexical diversity	*a*	0.4	0.15	0.007**	[0.11, 0.69]
	b	1.07	0.41	0.011*	[0.25, 1.89]
	c′: direct	1.28	0.6	0.036*	[0.09, 2.47]
	ab: indirect	0.43	0.24	–	[0.06, 0.99]
	ab + *c′*: total	1.71	0.59	0.005**	[0.53, 2.88]

Note: Coefficients are unstandardized. MAS-A, Metacognition Assessment Scale-Abbreviated; SE, standard error; LLCI and ULCI, upper and lower bootstrapped 95% confidence intervals.

* $p < .05$.

** $p < .01$.