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# Automated analysis of written narratives reveals abnormalities in referential cohesion in youth at ultra high risk for psychosis

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## ABSTRACT

Schizophrenia and at-risk populations are suggested to exhibit referential cohesion deficits in language production (e.g., producing fewer pronouns or nouns that clearly link to concepts from previous sentences). Much of this work has focused on transcribed speech samples, while no work to our knowledge has examined referential cohesion in written narratives among ultra high risk (UHR) youth using Coh-Metrix, an automated analysis tool. In the present study, written narratives from 84 individuals (UHR = 41, control = 43) were examined. Referential cohesion variables and relationships with symptoms and relevant cognitive variables were also investigated. Findings reveal less word “stem” overlap in narratives produced by UHR youth compared to controls, and correlations with symptom domains and verbal learning. The present study highlights the potential usefulness of automated analysis of written narratives in identifying at-risk youth and these data provide critical information in better understanding the etiology of psychosis. As writing production is commonly elicited in educational contexts, markers of aberrant cohesion in writing represent significant potential for identifying youth who could benefit from further screening, and utilizing software that is easily accessible and free may provide utility in academic and clinical settings.

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## 1. Introduction

Schizophrenia patients exhibit symptoms of thought disorder in which thoughts may seem illogical or bizarre and are often characterized by language disturbances in speech and writing (Andreasen and Grove, 1986; Andreasen, 1979; Docherty, 2005; Harrow and Quinlan, 1985). Individuals experiencing thought disorder are suggested to produce language that may lack coherence, and these aberrations can impact social-occupational functioning and overall quality of life (Kuperberg and Caplan, 2003). While it is well established that language disturbances are a core symptom (Bleuler, 1950), work examining these disturbances in individuals at ultra high risk (UHR) for psychosis is more limited. Studying UHR populations can provide clinical utility as current research suggests that 15–35% of UHR youth go on to develop a psychotic disorder within two-years (Cannon et al., 2008; Fusar-Poli et al., 2013, 2012). In this context, understanding language disturbances in the UHR period may improve early detection and contribute to our etiological conceptualizations.

Cohesion is an important characteristic of both written and spoken language, reflecting the extent to which a discourse provides grammatical and lexical markers for how concepts are linked across sentences (Halliday and Hasan, 1976). An especially important form is *referential cohesion*, which refers to the overlap of identical or semantically related words and concepts across units in a text, or co-reference. For example, one type of referential cohesion is pronominal anaphora, in which a pronoun is used to refer backwards to a previously mentioned entity. Consider the pair of sentences, “Roy had to go to the grocery store after work. He dreaded going because the store would be crowded.” In this mini-discourse, “He” in the second sentence refers anaphorically to “Roy” in the first sentence, signaling to a listener that these two sentences are related (Halliday and Hasan, 1976; Haviland and Clark, 1974). Another source of referential cohesion in this example comes from the overlap between “the grocery store” and “the store.” This has direct practical clinical relevance for understanding social dysfunction in psychosis; when a discourse lacks cohesion, listeners must work that much harder to extract meaning from the text or speech (Graesser et al., 2004; Haviland and Clark, 1974; McNamara and Graesser, 2014).

Referential cohesion deficits have been consistently reported among schizophrenia patients (Ditman and Kuperberg, 2010; Ditman et al., 2011; Docherty et al., 1996; Hoffman, 1986; Hoffman et al., 1982; Noel-Jorand et al., 1997; Rochester and Martin, 1979). In a landmark

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study conducted by Rochester and Martin (1979), investigators developed a coding system to examine referential cohesion markers and applied this to transcribed speech of individuals with schizophrenia; the investigators found fewer referential markers used in this group compared to controls. Similarly, Docherty et al. (2003) found, in a sample of schizophrenia patients, higher levels of referential cohesion in transcribed speech compared to controls. Other work has observed similar deficits in speech samples from parents and siblings of schizophrenia patients (Docherty et al., 2004, 1996) and individuals with childhood schizophrenia (Caplan, 1994; Caplan et al., 2000).

Recently, researchers have proposed that specific cognitive deficits characteristic of psychosis may also underlie the language disturbances particularly related to verbal learning, working memory, and attention (Ditman and Kuperberg, 2010; Docherty et al., 1996; Stain et al., 2012). One study administered a written story production pictorial task to patients with first episode psychosis and found that story production (assessed by examining words and corrections per minute) was positively associated with verbal learning and fluency (Stain et al., 2012). However, this study did not examine referential cohesion markers. Researchers examining patterns of cohesive deficits in speech samples have also posited that limits in working memory capacity, commonly found in schizophrenia populations (Lee and Park, 2005), may be an important contributor to these individuals' difficulties in establishing appropriate coherence relations (Ditman and Kuperberg, 2010). These working memory impairments may contribute to language disturbances because working memory capacity, which also requires sustained attention, may be overloaded, interfering with the reliable establishment of anaphoric relationships (Ditman and Kuperberg, 2010; Docherty et al., 1996). In a study conducted by Docherty et al. (1996) that examined language and cognition in a schizophrenia sample, referential deficits were associated with both lower working memory and attention scores. While this has been studied in schizophrenia populations, cognition and language dysfunction in UHR youth also make an excellent target.

Together, these studies provide evidence of deficits in referential cohesion in individuals with schizophrenia, yet limited work has been done among UHR youth. Existing studies have examined transcribed speech in UHR youth and identified cohesive deficits, including in the area of referential cohesion, and found that these abnormal features of speech were predictive of conversion to psychosis (Bearden et al., 2011; Bedi et al., 2015). However, less attention has been given to features of referential cohesion in the production of written language, or how potential difficulties in appropriately marking coherence relations might be related to patterns of cognitive differences. Using the Coh-Metrix tool, we examined whether indices of referential cohesion in the narratives produced by UHR youth were associated with symptomology and cognitive measures of verbal learning, working memory, and attention. Based on previous work (Bearden et al., 2011; Bedi et al., 2015; Ditman and Kuperberg, 2010), we predicted that the narratives of UHR youth would exhibit significant abnormalities in all referential cohesion features (i.e. difficulties with using pronouns and nouns cohesively) on a local (adjacent sentences) and global (all sentences) level when compared with healthy controls. Further, consistent with prior investigations observing relationships between referential cohesion and clinical features (Caplan, 1994; Elvevåg et al., 2007; Moro et al., 2015) and cognition (Docherty and Gordinier, 1999; Docherty et al., 1996; Stain et al., 2012) in individuals with psychosis, we predicted that these impairments will be related to elevated positive, negative, and disorganized symptoms and decreased performance on verbal learning, working memory, and attention.

## 2. Materials and methods

### 2.1. Participants

A total of 84 adolescents and young adults (UHR = 41, control = 43), aged 13–24 (UHR mean = 19.33, SD = 1.44; Control mean =

18.76, SD = 2.63) were recruited through the Adolescent Development and Preventive Treatment (ADAPT) program using email, newspaper, media announcements, Craigslist, and flyers. The exclusion criteria for all participants included history of significant head injury or other physical disorders affecting brain functioning, mental retardation (defined by an IQ of <70), or history of a substance dependence disorder in the prior 6 months. Additionally, UHR exclusion criteria included an Axis I psychotic disorder diagnosis. Control exclusion criteria included any diagnosis of an Axis I disorder or a first-degree relative with psychosis. UHR inclusion criteria included the presence of an Attenuated Positive Symptom (APS) or Genetic Risk and Deterioration (GRD) with a decline in functioning (Miller et al., 1999).

### 2.2. Clinical interviews

The Structured Interview for Prodromal Syndromes (SIPS; Miller et al., 1999) was used to detect UHR syndromes and assess symptomatology. The Structured Clinical Interview for the DSM-IV (SCID, research version; First et al., 1995), was used to rule out Axis I psychotic disorders and substance dependence. Role functioning was also examined using the Global Functioning Scale: Role (GFS-R) (Niendam et al., 2006). On the GFS-R, a score of 10 indicates “Superior Role Functioning” (e.g., independently maintains superior functioning in demanding roles), whereas a low score of 1 reflects “Extreme Role Dysfunction” (e.g., on disability, non-independent status).

### 2.3. Cognitive assessment

The Word Reading subtest of the fourth edition of the Wide Range Achievement Test (WRAT) was used as a measure of general intelligence (Wilkinson and Robertson, 2006). Participants were also given the Hopkins Verbal Learning Test – Revised (HVLT-R) (Brandt, 1991), which measures verbal learning, the Letter Number Sequencing (LNS) test, which assesses verbal working memory (Wechsler, 1997), and the Continuous Performance Test, identical pairs version (CPT-IP) (Cornblatt and Lenzenweger, 1989), a computerized measure of sustained attention. For all tests, the number of correct responses was recorded and raw scores converted to standardized t-scores, correcting for both age and gender.

### 2.4. Written narratives

To obtain the written language samples, participants were administered a narrative description task using the Boston Cookie Theft Image (Goodglass and Kaplan, 1983). In this task, participants were instructed to write a brief story about an image depicting a woman washing dishes while two children take cookies from a jar. Participants were given up to 10 min to produce their narratives. After data collection was complete, the handwritten narratives were entered verbatim into computer files by a naive research assistant, which were then submitted to Coh-Metrix 3.0, a web-based computational language analysis tool (<http://cohmetrix.com/>) (McNamara and Graesser, 2014).

Although the Coh-Metrix tool provides numerous measures covering a range of text and discourse characteristics, here we focused on three indices related specifically to referential cohesion, measured both locally and globally. To compute these indices, Coh-Metrix first applies a part-of-speech tagger and syntactic parser to the text input, as well as dictionary look-up functions to identify the root and morphological forms (e.g., plurals, past tense) of words. From these linguistic properties, the tool can then identify particular types of relational connections, or “overlap,” across different segments of the text (Graesser et al., 2004; McNamara and Graesser, 2014). Specifically, Coh-Metrix computes three forms of referential overlap. First, *stem overlap* refers to the proportion of sentences in the text with nouns that match any words (regardless of part of speech) in an adjacent sentence or

all other sentences that share a common morphological stem (e.g., “swims” and “swimmer”). Second, *noun overlap* refers to the proportion of sentences in the text with nouns that exactly match the surface form of nouns in an adjacent sentence or all sentences (e.g., “hat” and “hat”). Third, *argument overlap* also refers to the proportion of sentences in the text with nouns that overlap with nouns in an adjacent sentence or all other sentences, but this index also includes overlap between nouns and pronouns referring to the same entity, as well as matches between the singular and plural forms of the same noun (e.g., “school” and “schools” or “Jill” and “she”). For each of these measures, the range of scores can fall between 0 and 1, with 0 indicating no referential cohesion between sentences and 1 indicating the highest levels of cohesion (Graesser et al., 2004; McNamara and Graesser, 2014).

## 2.5. Statistical approach

To examine descriptive characteristics and group differences, we computed independent *t*-tests, chi-square tests, and analysis of covariance (ANCOVA) controlling for general intelligence, which has been suggested to be related to language impairments (Rodriguez-Ferrera et al., 2001). Partial correlations were used to investigate associations between referential cohesion variables, symptoms, and the cognitive measures, with estimates of general intelligence as a covariate. Two-tailed tests were employed for all analyses. The control group showed low symptoms with minimal variability and therefore we examined symptom and cognitive correlates within the UHR group alone.

## 3. Results

### 3.1. Demographic characteristics

There were no significant between-group differences in demographic characteristics, including age,  $t(81) = 1.23$ ,  $p = 0.22$ , parental education,  $t(80) = -1.44$ ,  $p = 0.16$ , and gender,  $\chi^2(1) = 1.70$ ,  $p = 0.19$ . Across the entire sample, 90% of participants were native English speakers. Of the individuals who were not native English speakers, the age in which English was learned ranged from ages 4–12, with a mean of age 8. As expected, the UHR group showed significantly more positive symptoms,  $t(1,82) = 14.86$ ,  $p \leq 0.001$ ,  $d = 3.26$ , negative symptoms,  $t(1,82) = 7.28$ ,  $p \leq 0.001$ ,  $d = 1.72$ , and disorganized symptoms,  $t(1,82) = 9.03$ ,  $p \leq 0.001$ ,  $d = 1.95$  when compared with controls. There were also significant group differences in role functioning,  $t(1,80) = -5.49$ ,  $p \leq 0.001$ ,  $d = 1.21$  in that the UHR group exhibited lower scores compared to controls. There were no group differences in cognitive variables including verbal learning,  $t(1,80) = 0.67$ ,  $p = 0.45$ , working memory,  $t(1,81) = -0.08$ ,  $p = 0.94$ , and attention,  $t(1,80) = 0.663$ ,  $p = 0.51$ . There were no group differences in general intelligence,  $t(82) = 1.40$ ,  $p = 0.17$ . In the UHR group, the most frequently prescribed medications were mood stabilizers (14%), SSRI's (14%), stimulants (7%) and antipsychotics (7%). See Table 1 for demographic details.

To ensure that any group differences in referential cohesion were not due to basic descriptive characteristics of the written narratives, we examined the overall length of the samples in words and sentences, as well as average sentence length, across the UHR and control groups. There were no group differences in descriptive language variables

**Table 1**  
Descriptive statistics.

	UHR	Control	Total	Statistic	P
Age					
Mean (SD)	19.33 (1.44)	18.76 (2.63)	19.05 (2.12)	$t(81) = 1.23$	0.22
Gender					
Male	25	18	43	$\chi^2(1) = 1.70$	0.19
Female	18	23	41		
Total	43	41	84		
Parent education (years)					
Mean (SD)	15.30 (3.13)	15.81 (2.55)	15.66 (2.99)	$t(80) = -1.44$	0.16
Symptoms domains					
Mean (SD)					
Positive	11.80 (5.02)	0.34 (0.72)	6.32 (6.80)	$t(1,82) = 14.86$	$\leq 0.001$
Negative	8.80 (7.41)	0.45 (1.38)	4.80 (6.75)	$t(1,82) = 7.28$	$\leq 0.001$
Disorganized	4.80 (3.60)	0.17 (0.38)	2.64 (3.58)	$t(1,82) = 9.03$	$\leq 0.001$
Role functioning					
Mean (SD)	7.27 (1.45)	8.70 (.84)	7.99 (1.38)	$t(1,80) = -5.49$	$\leq 0.001$
Native English speakers (%)	98	90	90	$t(1,82) = -1.42$	0.16
Ethnicity (%)					
Hispanic	23	12.2	17.6	$t(1,82) = 1.33$	0.19
Race (%)					
Asian	5	12	8	$t(1,82) = -0.16$	0.88
African American	0	2	1		
Caucasian	67	73	67		
Central/South American	16	10	13		
First Nations	7	0	3		
Other	5	3	8		
Estimate of general intelligence					
Mean (SD)	111.42 (12.28)	107.56 (12.94)	109.54 (12.68)	$t(82) = 1.40$	0.17
Cognitive variables					
Mean (SD)					
Verbal learning	50.95 (8.75)	49.42 (9.40)	50.21 (9.05)	$t(1,80) = 0.67$	0.45
Verbal working memory	48.69 (8.89)	48.83 (7.59)	48.76 (8.22)	$t(1,81) = -0.08$	0.94
Attention	47.0 (10.72)	45.43 (10.77)	46.23 (10.71)	$t(1,80) = 0.66$	0.51
Descriptive language Variables					
Mean (SD)					
Number of sentences	8.84 (4.17)	9.56 (4.90)	9.19 (4.53)	$t(82) = 0.73$	0.47
Number of words	129.67 (49.02)	144.46 (48.79)	136.89 (49.18)	$t(82) = 1.39$	0.17
Number of words per sentence	15.82 (5.18)	16.60 (4.71)	16.20 (4.94)	$t(82) = 0.72$	0.47

Positive, negative, and disorganized symptoms reflect total sums from domains from the Structured Interview for Prodromal Syndromes (SIPS). Role functioning scores are represented on a scale from 1–10, with 1 indicating extreme role dysfunction and 10 indicating superior role function. Cognitive variables are age and gender corrected *t*-scores.

including number of sentences  $t(82) = 0.73, p = 0.47$ , number of words,  $t(82) = 1.39, p = 0.17$ , and number of words per sentence  $t(82) = 0.72, p = 0.47$ . This indicates that both groups engaged with the writing task to a similar extent and any content differences are not due to writing sample sizes.

### 3.2. Group differences in cohesion variables

The narratives differed significantly across groups in local stem overlap  $F(1,81) = 4.18, p = 0.04, \eta_p^2 = 0.05$  in that consistent with predictions, the UHR narratives exhibited lower local stem overlap scores compared to controls. However, although in the predicted direction, the other local cohesion indices did not differ across groups: noun overlap:  $F(1,81) = 1.77, p = 0.19, \eta_p^2 = 0.02$ ; argument overlap:  $F(1,81) = 0.305, p = 0.58, \eta_p^2 = 0.004$ . There were no significant differences across groups in global cohesion indices, including stem overlap ( $F(1,81), p = 0.50, \eta_p^2 = 0.006$ ), noun overlap ( $F(1,81) = 0.079, p = 0.78, \eta_p^2 = 0.001$ ), and argument overlap ( $F(1,81) = 0.255, p = 0.62, \eta_p^2 = 0.003$ ) (See Table 2).

### 3.3. Associations between referential cohesion and symptoms

A series of partial correlations were used to examine the relationships between local cohesion variables (the domain where there was a group difference) and symptoms in the UHR group. Results indicate that lower stem overlap was significantly associated with increased positive ( $r = 0.31, p = 0.04$ ), negative ( $r = -0.33, p = 0.03$ ), and disorganized symptoms ( $r = -0.31, p = 0.04$ ) (Fig. 1). Further, lower noun overlap was marginally associated with increased positive symptoms ( $r = -0.29, p = 0.06$ ), and was significantly associated with elevated negative ( $r = -0.31, p = 0.05$ ), and disorganized symptoms ( $r = -0.31, p = 0.05$ ). Argument overlap was not associated with positive ( $r = -0.24, p = 0.12$ ), negative ( $r = -0.26, p = 0.10$ ), or disorganized symptoms ( $r = -0.23, p = 0.14$ ).

### 3.4. Associations between referential cohesion and cognitive variables

We also computed partial correlations to examine relationships between local referential cohesion and verbal learning, working memory, and attention. One participant in the UHR group had missing data on all cognitive tasks. Findings from the UHR group ( $N = 42$ ) show that lower verbal learning was found to be associated with lower stem ( $r = 0.44, p = 0.004$ ), noun ( $r = 0.40, p = 0.01$ ), and argument ( $r = 0.42, p = 0.007$ ) overlap. There were no associations between working memory and stem, ( $r = -0.12, p = 0.47$ ), noun, ( $r = -0.16, p = 0.33$ ), or argument ( $r = 0.16, p = 0.31$ ) overlap. There were no significant associations between sustained attention and stem ( $r = 0.09, p = 0.59$ ) or noun ( $r = 1, p = 0.54$ ) overlap, but there was a significant correlation with argument overlap in the predicted direction ( $r = 0.32, p = 0.04$ ) (see Fig. 2).

**Table 2**  
Group differences in referential cohesion variables.

	UHR	Control
Local referential cohesion		
Mean (SD)		
Stem overlap	0.29 (0.23)*	0.40 (0.24)
Noun overlap	0.27 (0.22)	0.34 (0.23)
Argument overlap	0.49 (0.25)	0.54 (0.24)
Global referential cohesion		
Mean (SD)		
Stem overlap	0.28 (0.19)	0.31 (0.18)
Noun overlap	0.26 (0.20)	0.28 (0.17)
Argument overlap	0.47 (0.22)	0.45 (0.20)

Referential cohesion variables are represented using means and standard deviations. Means range from 0 (no cohesion) to 1 (highest levels of cohesion).

\*  $p \leq 0.05$ .

## 4. Discussion

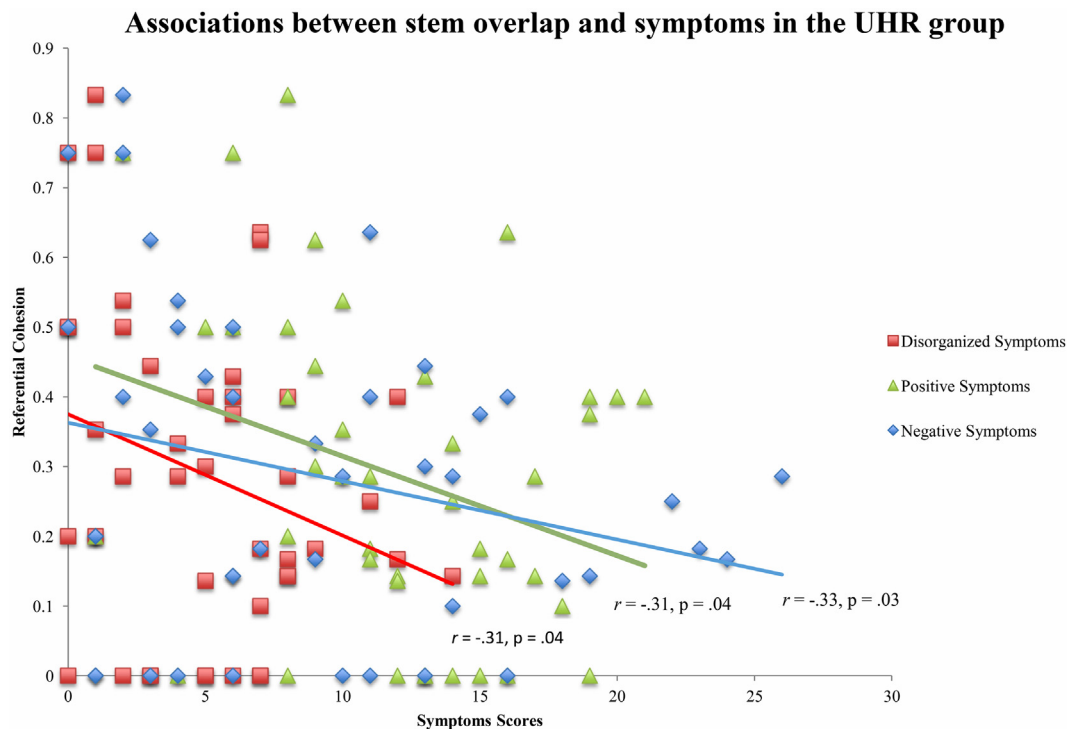
To our knowledge, the present study is the first to use Coh-Metrix, an automated text analysis tool, to assess cohesion in written narratives produced by UHR youth. Taken together, these results indicate that UHR youth may experience difficulties compared to controls in the use of referential cohesion, and these language disturbances are related to symptoms and cognitive function within this group. These data offer a novel perspective by utilizing automated analysis tools in examining referential cohesion in written narratives and provide critical information regarding early markers of disordered language production in populations at-risk for the development of psychosis.

Although we observed the same patterns in all three indices of local referential cohesion, there was a significant difference across the UHR and control groups for local stem overlap only. One factor to consider is that stem overlap represents the least restrictive measure of cohesion, because it involves instances of overlap between a noun and any content word in a comparison sentence that shares the same lexical stem, including other nouns, verbs, or adjectives. In contrast, both noun and argument overlap are restricted to nominal forms. Given the relatively brief narratives elicited by our picture description task, the stem overlap measure may be able to pick up on more subtle differences in how UHR and control individuals choose to mark cohesion across a variety of parts of speech. These findings are also consistent with a study conducted with a schizophrenia sample in which Strous et al. (2009) asked participants to write about an important person in their life and exhibited a variety of language disturbances, including reference errors (Strous et al., 2009). Somewhat unexpectedly, we found no evidence of group differences in the measures of global referential cohesion. This pattern could be attributed the length of the narratives used (many of the samples were brief because participants were given only up to 10 min to complete the task) and to the age range of our sample. Previous research on the development of writing has found that as young adults become more skilled writers, they often start to use fewer local cohesion devices (e.g., less lexical repetition) and instead rely on more complex syntactic constructions to connect ideas implicitly (McCutchen and Perfetti, 1982). Thus, it may have been the case that differences in global cohesion across groups were reduced in this adolescent sample, many of whom may have been less-experienced writers.

Results suggesting associations between local cohesion markers and symptoms are consistent with the broader literature. For example, Bedi et al. (2015) examined relations between semantic and syntactic features in high-risk youth and found relations between language features and symptoms. Because the present study found the same pattern, despite important differences in performance (in contrast to Bedi et al., 2015, there were no group differences in number of words or sentences), the combined findings may speak to the strength of the effect. Notably, these differences could be related to the type of task administered in the present study, which is in contrast to transcribing speech samples from clinical interviews (Bedi et al., 2015). Another study found that greater language disturbances such as reference errors in parents of patients with schizophrenia are related to increased positive symptoms among patients (Docherty et al., 1997). While some studies have suggested stability of referential features as clinical symptoms change in schizophrenia populations (Docherty et al., 2003, 1996), other studies in clinical high-risk samples suggest that language disturbances may map onto clinical course evidenced by studies showing language impairments may predict conversion to a psychotic disorder (Bearden et al., 2011; Bedi et al., 2015). However, the present study did not examine clinical state changes and while symptoms may be a relevant factor linked with referential cohesion errors, more work is needed to examine clinical state changes and language deficits among this group.

Despite no significant group differences in cognitive performance, there were associations between indices of local cohesion in the narratives of UHR youth such that those UHR youth with lower performance

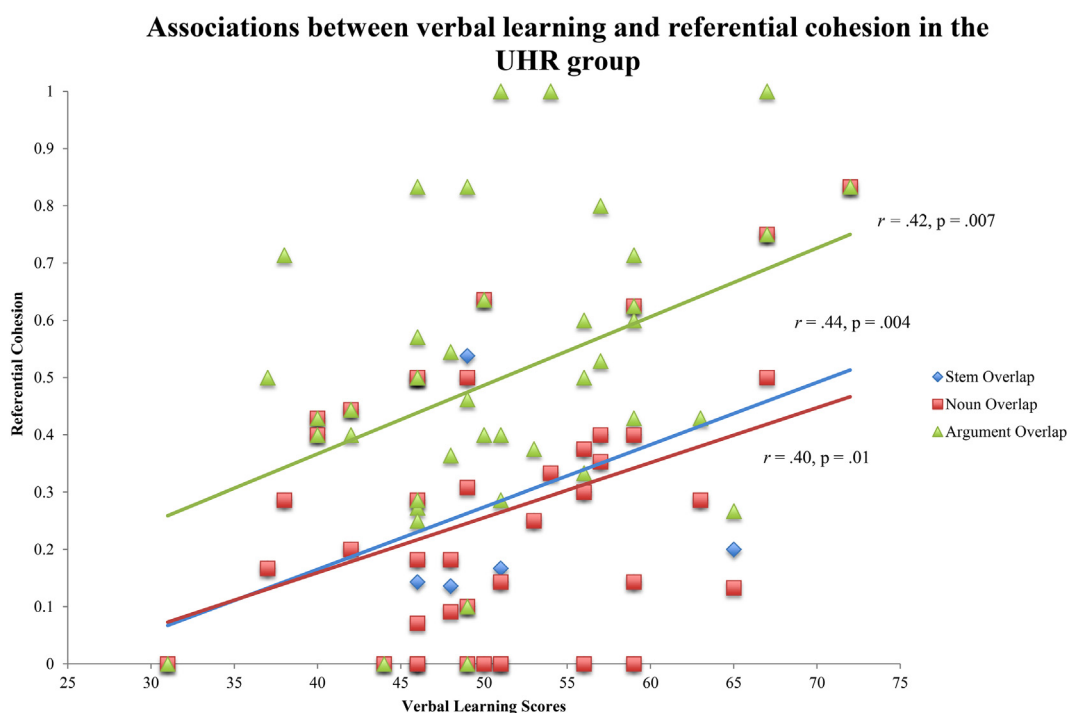




**Fig. 1.** Stem overlap and symptoms within the UHR group. Note: Stem overlap reflects a score from 0 to 1, 0 represents no stem overlap and 1 is the highest level of stem overlap. Positive, negative, and disorganized symptoms reflect total sums from domains from the Structured Interview for Prodromal Syndromes (SIPS).

on verbal learning and attention also showed the greatest cohesion deficits. These findings are broadly consistent with results from Stain et al. (2012), who also found links between written language deficits (i.e., reduced number of words and corrections) and verbal learning and verbal fluency performance in first-episode participants. Surprisingly, we did not detect associations between indices of cohesion and working memory. However, it is important to note that in contrast to other studies,

which found this link in schizophrenia (Docherty et al., 1996), the present clinical sample did not exhibit deficits in working memory. It will be important to evaluate this link in other prodromal syndrome samples (where working memory deficits have been observed) to determine if this association occurs later in the disease course. Finally, associations between argument overlap and attention are broadly consistent with previous work in that some studies have shown impairments in the use of



**Fig. 2.** Associations between verbal learning and indices of referential cohesion. Note: Verbal learning scores are age and gender corrected *t*-scores. Referential cohesion variables reflect a score from 0 to 1, 0 being no cohesion, and 1 indicating highest levels of cohesion.

pronouns (Caplan et al., 2000) and cognition (Buck et al., 2015) in schizophrenia populations. While argument overlap includes the use of both nouns and pronouns to refer to previous entities, the use of pronouns may be also impaired in this group, and more work is needed to understand pronoun use. Differences between writing and transcribed speech may be important to consider in interpreting these findings with cognition, as writing is relatively effortful compared to speech production.

It is also important to note that in the schizophrenia literature, cohesion difficulties and other language disturbances have been measured in a variety of ways (Bearden et al., 2011; Bedi et al., 2015; Docherty et al., 2004; Hoffman, 1986). For example, Bearden et al. (2011) instructed clinical high-risk participants to verbally construct a story based on a prompt, and investigated story cohesion using a coding system based on the seminal model formulated by Halliday and Hasan (1976). This system, also employed by Caplan et al. (2000) to examine the verbal output of children with schizophrenia, requires hand coding to identify the frequencies of a variety of cohesion devices, including pronouns, demonstratives, conjunctions, or comparatives (Bearden et al., 2011). In contrast, the Coh-Metrix tool (used in the present study) automatically extracts information related to over 100 linguistic features of written texts, ranging from descriptive measures like word and sentence counts to measures of lexical diversity, connective use, and syntactic complexity (Graesser et al., 2004; McNamara and Graesser, 2014). Coh-Metrix is able to provide an accurate index of cohesion on relatively brief narratives, given the way it is computed. Other relevant Coh-Metrix measures that could shed light on language disturbances in UHR youth, such as the use of causal (“and” or “so”) or temporal (“first” or “until”) connectives, are based on raw frequencies, and as such are likely to be more problematic with short texts. Ultimately, both approaches such as those based directly on the Halliday and Hasan (1976) are useful, and with longer written language samples it would be entirely appropriate to examine a fuller range of cohesion devices utilizing these multiple techniques, which could provide greater generalizability of findings. Even so, we believe that there is significant utility in an analysis tool like Coh-Metrix, developed to automatically assess discourse cohesion in written texts (Graesser et al., 2004; McNamara and Graesser, 2014), can reliably identify difficulties with successful referential cohesion in the language output of at-risk youth, and does so in an objective manner that does not require extensive training and that can be readily replicated with a variety of text types.

While these findings show promise for the use of automated language analysis methods to identify difficulties with referential cohesion in the language production of UHR youth, we recognize that these data are preliminary, and that future studies with larger samples will be necessary. Moreover, longitudinal data, examining language delays or prior language impairments, and comparing persuasive, personal, and descriptive writing could be beneficial as well as using different computational approaches such as LSA and Part of Speech (POS). Future directions also include examining role functioning and language variables similar to Bearden et al. (2011). Finally, some of the UHR youth in the sample were on medications, which may have attenuated writing ability and future work will be needed in order to understand the role of medication on writing ability among this group.

#### Conflicts of interest

V.A.M. is a consultant to Takeda Pharmaceuticals. No other authors have any disclosures.

#### Contributors

Dr. Mittal attained funding and oversaw data collection. Dr. Mittal and Ms. Gupta conceptualized the study, conducted analyses, interpreted the data and drafted the manuscript. Dr. Hespos and Dr. Horton helped to conceptualize the study, interpret data, and draft the manuscript.

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