Towards a Cognitive Resource Limitations Model of Diminished Expression in Schizotypy

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Diminished expression of speech is a pernicious feature of both schizophrenia and schizotypy—defined as the personality organization reflecting a putative genetic schizophrenia liability. As yet, the mechanism underlying diminished expression is unclear. We tested the hypothesis that diminished expression reflects a cognitive resource issue—that is, as cognitive resources are depleted, expression becomes diminished in individuals with psychometrically defined schizotypy. Acoustic analysis of natural speech was procured during experimentally manipulated baseline and high cognitive-load dual tasks and examined in 38 individuals with psychometrically defined schizotypy and 34 controls. For both groups, expression significantly decreased as a function of increased task demands, although there were no group differences in expression or magnitude of change across baseline to high cognitive-load conditions. Participants with self-reported constricted affect showed significant reductions in expression under high-load versus baseline speaking conditions relative to other schizotypal and control participants. Moreover, psychometrically defined schizotypal participants with poor cognitive performance on the high-load task, suggestive of depleted cognitive resources, also showed expressivity reductions compared with other participants. These findings suggest that diminished expression occurs as a function of limited cognitive resources in psychometrically defined schizotypy.

Keywords: schizotypy, schizophrenia, affect, emotion, cognitive, expression, speech

Diminished expression—defined in terms of attenuated communicative behaviors—is an important phenotype of the schizophrenia-spectrum (American Psychiatric Association, 2000). Within schizophrenia, diminished expression (i.e., blunt affect) is pervasive, present at the prodromal, early, active, and residual phases of the illness (Harvey et al., 1996; Malla et al., 2002; Mason et al., 2004; Putnam & Harvey, 2000) often years before onset (Walker, Grimes, Davis, & Smith, 1993). It is considered a negative prognostic indicator (Milver, Ho, Arndt, & Andreasen, 2005; Pogue-Geile & Harrow, 1985) and appears to be resistant to currently available treatments (Arango, Buchanan, Kirkpatrick, & Carpenter, 2004; Kopelowicz, Liberman, Mintz, & Zarate, 1997). In individuals with schizotypy, defined as the personality organization reflective of a putative genetic schizophrenia liability occurring in approximately 10% of the population (Lenzenweger, 2006; Meehl, 1962), diminished expression (i.e., constricted affect) is also present. Of note, reduced facial and vocal expression have been reported in individuals with psychometrically defined negative schizotypal traits (Cohen & Hong, in press; Collins, Blanchard, & Biondo, 2005) and in their biological relatives (Kendler, McGuire, Gruenberg, & Walsh, 1995). These findings suggest that diminished expression may reflect a vulnerability marker of schizophrenia. Despite growing knowledge about the importance of diminished expression in schizophrenia-spectrum disorders, fundamental issues about the mechanisms underlying it remain unclear.

In the nonpsychiatric population, affective expression is dynamic across contexts and is modulated by a number of factors. Of note, affective expression is influenced by an individual’s affective experiential state (e.g., angry, happy; Sobin & Alpert, 1999), level of autonomic (Johnstone et al., 2007) and subjective (Cohen, Minor, Najolia, & Hong, 2009) arousal states, and the presence/absence of social stimuli (Wells & MacFarlane, 1998). Emerging evidence suggests that cognitive load may also be an important variable for understanding affective expression. For example, findings from computer and engineering sciences suggest that the amount and rate of speech decrease as cognitive demands of a speaking task increase (Yin, Ruiz, Chen, & Kijwajaja, 2007; Berthold & Jameson, 1999). Our own work in this area furthered this claim. In a recent study (Cohen, Dinzeo, Donovan, & Morrison, 2010), we compared speech from healthy adults during a dual-task condition designed to induce cognitive load versus speech from a baseline condition without a cognitive load. During the high load condition, participants completed a visual-based dual-task. Results suggested there was a significant decrease in speech production, inflection, and intensity as a function of increased cognitive demands. In the present study, we use similar experimental methodology to examine the degree to which cognitive resource limitations intensify expressive deficits in individuals with psychometrically defined schizotypal versus nonschizotypal...
controls. The degree to which cognitive load maintains or modulates clinically related diminished expression is a critical knowledge gap with both important practical (e.g., for clarifying the optimal circumstances for measuring diminished expression), mechanistic (e.g., for clarifying the neurobiological systems maintaining diminished expression), and potential treatment (e.g., diminished expression could be ameliorated by decreasing cognitive load or increasing cognitive resources) applications (see the discussion for elaboration on these points).

Why would cognitive load decrease affective expression? There are many competing demands on individuals when they are expressing themselves. Within the rubric of social interaction, for example, individuals must use a host of cognitive processes to effectively track and update conversation lines, follow other speakers’ explicit and implicit behavior, effectively plan communication strategies, and integrate and hold important information such as names, phone numbers, and directions. The question at hand is whether these competing cognitive demands can inhibit both the verbal and nonverbal/prosodic aspects of communication. In this regard, cognitive load theory (Sweller, 1994) provides a useful framework. Cognitive load theory uses an information processing model to explain performance on a wide range of tasks, such as those involving problem solving, learning, driving, and other cognitive and motor-based functions (see Plass, Moreno, & Brunken, 2010 and Sweller, 1994 for a review). This theory posits that cognitive functions are inherently limited by two broadly defined factors: working memory, defined as the site “in which all conscious cognitive processing occurs” (Sweller, 1994), and automaticity, the degree to which a task taps into a preexisting schema or rule-set to allow for unconscious processing. Effectively, cognitive functions become restricted as a function of the cognitive demands of the task. We propose that cognitive load reflects a necessary variable for diminished expression to emerge in schizotypy. That is, individuals with schizotypy show abnormally high diminished expression when their cognitive resources become strained.

There are several reasons why cognitive load theory is attractive for explaining diminished expression in schizotypy. First, findings of limited cognitive resources are well documented in individuals with schizotypy (Barch et al., 2004; Cannon, van Erp, & Glahn, 2002), and cognitive deficits tend to be more pronounced in individuals with negative schizotypal traits (Gooding & Tallent, 2003; Park & McTigue, 1997; Tallent & Gooding, 1999). Second, research using dual-task methods in patients with schizophrenia have demonstrated that symptoms of alogia (defined in terms of reduced speech output) worsen in patients with schizophrenia when cognitive resources are taxed (Barch & Berenbaum, 1994, 1997; Melinder & Barch, 2003). In this regard, there is evidence that at least some elements of expression decrease under cognitive load in patients with schizophrenia.

In the present study, we examine whether diminished cognitive resources reflect an important condition for diminished expression to emerge in individuals with a range of psychometrically defined positive, negative, and disorganization schizotypal traits. We used a dual-task paradigm meant to induce states of high cognitive-load while individuals provide free speech regarding an affectively neutral topic. This speech was compared with that from a baseline speaking condition. Speech was processed using a computerized acoustic analysis protocol used in recent research with healthy adults (Cohen, Hong, & Guevara, 2010; Cohen, Iglesias, & Minor, 2009), psychometrically defined schizotypy (Cohen & Hong, in press; Cohen, Iglesias & Minor, 2009), and schizophrenia (Cohen, Alpert, Nienow, Dinzeo, & Docherty, 2008) populations. This protocol, dubbed the Computerized Assessment of Affect from Natural Speech (CANS), quantifies speech along separate speech production, inflection, emphasis, and intensity speech measures. This method of assessing diminished expression was used because it offers a highly sensitive and objective measure of a communicative channel known to be attenuated in some participants with schizotypy and schizophrenia. We hypothesized that all participants in this study would show significantly diminished expression under conditions of high cognitive load compared with the baseline condition (i.e., condition effect). Moreover, we hypothesized that individuals with schizotypy versus controls would show significantly more diminished expression overall (i.e., group effect) and a significantly greater decrease in expression across the two conditions (i.e., interaction effect).

It is important to acknowledge the considerable heterogeneity in affective expression across individuals with schizotypy (Cohen & Hong, in press; Minor, Cohen, Weber, & Brown, 2011) which makes it unlikely that all schizotypal individuals demonstrate abnormally diminished expression under conditions of cognitive load. The present study examined two candidate individual differences that may be related to increased diminished expression under conditions of cognitive load. A first candidate involves negative schizotypal traits. Schizotypy is characterized by a broad swath of co-occurring, but independent positive, negative, and disorganization traits (e.g., Chmielewski & Watson, 2008; Cohen, Matthews, Najolia, & Brown, 2010). We hypothesized that negative traits, defined in part by self-reported constricted affect, will be significantly associated with a reduction in expression in the high cognitive load versus baseline conditions (computed as a change score using partial correlations). In general support of this, individuals with negative schizotypy have shown greater speech deficits when vocalizing their reactions to picture stills compared with other schizotypal and control participants (Cohen & Hong, in press). A second individual difference variable involves availability of cognitive resources. It stands to reason that individuals with decreased cognitive resources would have limited resources to devote to affective expression compared with other individuals. Thus, we hypothesized that poor performance on the high-load measure, which we regard as an index of depleted cognitive resources, will be significantly associated with a reduction in expression in the high cognitive load versus baseline conditions (computed as a change score using partial correlations).

Method

Screening Phase

Participants were undergraduate students enrolled at Louisiana State University approached by email to participate in an online survey and offered a chance to win monetary prizes (total n = 6,887). The survey included a consent form, basic demographic questions, the Schizotypal Personality Questionnaire – Brief Revised (Cohen, Matthews, et al., 2010), the Brief Symptom Inventory (Derogatis & Melisaratos, 1983), and validity items (Chapman & Chapman, 1983). Response was modest (n = 1,148). This study was approved by the LSU Human Subject Review Board.
and all participants offered informed consent before completing the surveys.

**Laboratory Phase**

Individuals scoring in the 95th percentile (1.65 SD from the gender determined means) on the positive or disorganization (n = 21) and/or negative (n = 24) subscales from the SPQ-BR (Cohen, Matthews et al., 2010) were invited to participate in the laboratory study phase of the study. Schizotypy has an estimated 10% population incidence (Lenzenweger, 2006; Meehl, 1962), and our use of a conservative cutoff score (i.e., the top five percent vs. the top 10% of scorers) reflects an attempt to reduce false positives. To address concerns that depressive symptoms can lead to “false positives” on negative schizotypy subscales, we adopted a strategy where individuals scoring high on the negative subscale (defined as a sum of “constricted affect” and “no close friends” subscales; Cohen, Matthews et al., 2010) were considered for the study if they a) also showed elevations (defined as the 95th percentile or higher) on the positive or disorganization subscales, or b) had a depression subscale score from the Brief Symptom Inventory (Derogatis & Melisaratos, 1983) below their gender determined mean. Thus, participants were eligible for the study if they reported having negative symptoms as long as they reported also having positive or disorganized traits, or were not reporting high levels of depression. Thirty-seven control participants randomly selected from participants scoring below the gender determined means for each of the positive, disorganization, and negative SPQ-BR factors, were also recruited. The 50th percentile was selected based on our prior research that individuals scoring below this cut-off are highly unlikely to have a history of schizophrenia diagnosis, inpatient hospitalization, or psychiatric/psychological treatment more generally (Cohen & Najolia, in press). For reasons described below, some participants in this study were excluded for not responding at all during the high cognitive load task. The final sample consisted of 38 schizotypal and 34 control participants.

**Schizotypal Symptoms**

The Brief-Revised version of the Schizotypal Personality Questionnaire (Cohen, Matthews et al., 2010) was used. The SPQ-BR comprises 32 items reflecting seven subordinate (i.e., odd/ eccentric behavior, odd speech, constricted affect/no close friends, excessive social anxiety, unusual perceptual experiences, odd beliefs, ideas of reference/suspiciousness) and three superordinate (i.e., positive, negative, and disorganization) factors (see Cohen, Matthews et al., 2010 for psychometric details). The original SPQ uses a forced choice “yes” or “no” response format. To address concerns that dichotomous response formats are insensitive to trait intensity (Peltier & Walsh, 1990), we adopted a five-point likert type response scale that has been used in recent SPQ research (Wuthrich & Bates, 2005). Participants response options ranged from “Strongly Disagree” to “Neutral” to “Strongly Agree.” The likert scale version of the SPQ has shown high convergence and improved internal reliability when administered in either computer or standard paper and pencil formats compared with the forced-choice dichotomous response version (Wuthrich & Bates, 2005). Internal consistency was acceptable for each of the superordinate (α’s > .83) and subordinate (α’s > .66) scores used in this study.

There is adequate construct validity for the SPQ as a measure of schizophrenia spectrum pathology, as a) more than half of participants scoring in the top tenth percentile have met criteria for schizotypal personality disorder using clinical interviews (Raine, 1991), b) participants scoring in the top fifth percentile showed an eightfold increase over those scoring below the 50th percentile in self-reported history of psychiatric hospitalization and prior diagnosis of schizophrenia (Cohen & Najolia, in press), and c) high SPQ scorers have shown a range of “schizophrenia-like” neurocognitive, physiological, psychosocial, and other anomalies (Raine, 2006).

**Cognitive-Load Narrative Task**

Participants were seated in front of a computer monitor and asked to perform two separate 90-s narrative tasks. During the baseline condition, participants provided free-speech without a competing task. During the high-load condition, participants provided their narratives while performing a one-back test—a commonly used test of attention and working memory. We were unable to identify an n-back task suitable for our study, so we developed a procedure based on consultation with the prior literature (e.g., Tsuchida & Fellows, 2009) and extensive testing in a healthy adult sample (Cohen, Dinzeo, Donovon, & Morrison, 2010). This task involved responding to stimuli when consecutively appearing visual symbols on a computer screen were identical. A total of six different visual symbols were used; approximately one third of reflected targets (15 of 45). Stimuli were presented at 2000-millisecond ISIs. Visual symbols, as opposed to verbal or alphabetic characters, were used. Based on Baddeley’s model of attention (Baddeley, 1992), visual and verbal short-term memory abilities are distinct but converge into working memory. In this manner, even a simple visual spatial task can divide cognitive resources without directly affecting verbal expression (except through depleting working memory stores more generally). This experiment was run using Eprime professional software version 2.0 (Psychology Software Tools, 2002). Participants underwent a practice block without the narrative component to become familiar with the task. Feedback was offered during this practice.

Free speech topics concerned either hobbies or living conditions and were counterbalanced across the speaking conditions. These topics were selected because they were valence-neutral and open-ended. Participants were encouraged to speak for the duration of the 90-s task. Below is an example of a probe used to elicit speech.

What kinds of hobbies do you have? You can discuss any hobby that you can think of, such as sports, walking, watching TV, or anything else you can think of.

Hit rate and false alarms are reported for the one-back task. Performance was also characterized using signal detection theory statistics. Sensitivity was measuring using d′, a measure taking into account both correct hits and false alarms. Increasing scores reflect better performance (i.e., higher hit rate, lower false alarm rate). Response bias was measured using the b ratio statistic with increasing scores indicating a more conservative bias (fewer correct and incorrect responses) and lower scores indicating a more liberal bias (greater number of both correct and incorrect responses). Seven participants with schizotypy and four controls
were excluded from the present study for not responding at all during the high cognitive load task. The false alarm scores were abnormally distributed (skew > 2.0) and were square-root transformed for all statistical analyses in this study.

**Computerized Assessment of Prosody**

The Computerized assessment of Affect from Natural Speech protocol (CANS), developed by our lab to assess vocal expression, was used here. Speech was digitally recorded at 16 bits per second at a sampling frequency of 44,100 Hz using headset microphones.

The digitized recordings were analyzed using PRAAT (Boersma & Weenink, 2006), a program that has been used extensively in speech pathology and linguistic studies. The PRAAT system organizes sound files into “frames” for analysis, which for the present study was set at a rate of 100 frames per second. During each of these frames, frequency and volume were quantified. We are interested in four variables, based on our prior work (Cohen and Hong, in press; Cohen et al., 2009) and the larger extant speech prosody literature (Boersma & Weenink, 2006): inflection, computed as the variability in fundamental frequency; emphasis, computed as the variability in volume; and intensity, defined as the mean volume of speech. We also measured linguistic expression in terms of speech production, defined as the percentage of frames that were voiced during the speaking task. All fundamental frequency values were converted to semitones to control for their nonlinear distribution, which has the added benefit of controlling for differences in fundamental frequency between men and women.

We used entropy statistics to understand variability in frequency and volume (i.e., inflection and emphasis) because they provide a more sensitive measure of signal variability than variance and standard deviation scores (Lai, Mayer-Kress, & Newell, 2006). As in our prior research, entropy scores reported here reflect a percentage of maximal entropy to correct for individual differences in amount of speech production. Increasing entropy scores reflect increasing variability in signal. For further discussion of our use of entropy statistics for understanding vocal prosody, see Cohen and Hong (in press) and Cohen, Iglesias, and Minor (2009).

**Analyses**

The analyses were conducted in four steps. First, we examined potential demographic and cognitive performance differences between the schizotypy and control groups that might inform subsequent analyses. Second, we compared groups (schizotypy vs. controls) on vocal characteristics for the baseline and high-load tasks using repeated-measures ANOVAs. We predicted significant group (i.e., that the schizotypy group is less expressive overall), condition (i.e., that participants as a group are less expressive during the high-load condition), and interaction (i.e., that the schizotypy group shows a more dramatic declination in expression under high load) effects. Third, we sought to determine the degree to which individual differences in negative schizotypy traits and high-load performance variables were related to diminished expression from baseline to high-load condition within the schizotypy group. We hypothesized that negative schizotypy traits would be significantly inversely correlated with high-load speech characteristics, controlling for baseline speech characteristics using partial correlations. We also hypothesized that poorer performance (i.e., hit rate, false alarms d’, b) would be associated with decreased expression from baseline to high-load conditions. This was also tested using partial correlations between high-load performance measures and high-load speech variables, controlling for baseline speech variables. We reasoned that poor performance on the high-load task would denote individuals with notable limitations in cognitive resources; signaling fewer resources being available for expressive functions. As part of this set of analyses, we also computed partial correlations between positive and disorganization schizotypal traits and depressive symptoms and high-load performance variables (controlling for baseline speech characteristics), which we expected to be statistically nonsignificant. The third set of analyses was limited to the schizotypy group, so it was unclear the degree to which any effects of cognitive performance variables were specific to the schizotypy group. The fourth analysis set examined the specificity of these effects using regressions. We examined whether any significant relationships between cognitive performance and decreased speech from the baseline to high-load condition were more pronounced in the schizotypy versus control groups. In effect, we examined the moderation effects of high-load performance on expressive deficits in schizotypy versus controls using regressions (Baron & Kenny, 1986). Significant interactions were graphed to facilitate interpretation. The fourth analysis set is explained further below. All analyses in this study are two-tailed, and all variables are normally distributed (skew < 1.5) unless otherwise stated.

**Results**

**Demographic, Trait, and Performance Characteristics**

Descriptive statistics were computed and compared between the schizotypy and control groups (see Table 1). There were no significant group differences in age, gender, or ethnicity. Individuals with schizotypy showed a significantly more conservative response bias overall, t(70) = 2.31, p = .02, Cohen’s d = .55, but there were no other significant performance variable differences between groups. There were no significant differences between men and women or between Caucasians and African Americans in any of the speech variables or performance variables from the n-back test in the high-load dual-task condition (all p > .10).

**Group Comparisons on Speech Characteristics**

Data for these analyses are presented in Figure 1. As hypothesized, significant condition effects were observed for the speech production [Wilk’s Lambda F(1, 70) = 41.10, p < .001, ηp² = .37].

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1 Correlational and regression analysis using the SPQ-BR subscales requires there to be sufficient variability in schizotypy traits within the schizotypy group. Our inspection of the data suggests that this was the case. Both the ranges and standard deviations (SD) of the positive range of z-scores computed from the screening sample (Range) = −.83 – 3.21, standard deviation in z-score format (SD) = .88), negative (range = −1.34 – 3.23, SD = 1.10), and disorganization (range = −.11 – 2.66, SD = .55) subscales suggest there was adequate variability within the schizotypy group. Kurtosis and skewness variables were also low (< 1.00) for each of these variables, suggesting a relatively normal distribution of scores.
inflection \( \text{Wilk's Lambda } F(1, 70) = 12.04, p = .001, \eta^2_p = .15 \), and intensity \( \text{Wilk's Lambda } F(1, 70) = 9.98, p = .002, \eta^2_p = .13 \) variables. In contrast to our hypotheses, the condition effect for the emphasis variable was not significant \( \text{Wilk's Lambda } F(1, 70) = 1.53, p = .22, \eta^2_p = .02 \). Also in contrast to our hypotheses, the between-groups \( F \) values for the speech production, inflection, emphasis, and intensity values were not statistically significant (all \( p > .10 \), and neither were the interaction terms for each of these variables (all \( p > .10 \). The interaction effect for the intensity variable was a trend \( \text{Wilk's Lambda } F(1, 70) = 3.58, p = .06, \eta^2_p = .05 \). These results suggest that participants as a group produced less speech with less inflection and spoke more softly when cognitive resources were taxed. However, there were no overt group differences in speaking characteristics between the control or schizotypy groups. Individuals with schizotypy showed a similar declination in speech characteristics compared with control participants suggesting that their expressive reactions to heavy cognitive load were not abnormal as a group.

**Correlates of change in speech characteristics in the schizotypy group.** Table 2 contains the partial correlations, set up so that speech characteristic variables from the high-load condition were correlated with the individual difference variables of interest, controlling for baseline speech characteristics. Negative schizotypal traits were significantly associated with attenuated speech production under high cognitive load, but, in contrast to our hypotheses, none of the other speech characteristic variables. Interestingly, constricted affect, but not the “no close friends” variable, was significantly associated with attenuated speech production and emphasis under high cognitive load. As predicted, neither positive, disorganization, nor depression scores were associated with changes in speech characteristics under high cognitive load. With respect to performance variables, individuals with a more liberal response bias spoke less and with less emphasis during the high versus baseline conditions at a significant level. These correlations

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**Table 1**

*Descriptive Statistics for Demographic and Clinical Variables for the Control and Schizotypy Groups*

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 34)</th>
<th>Mean</th>
<th>SD</th>
<th>Schizotypy (n = 38)</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td>18.94</td>
<td>1.12</td>
<td>19.44</td>
<td>1.61</td>
<td></td>
</tr>
<tr>
<td>% Men</td>
<td></td>
<td>31%</td>
<td></td>
<td>20%</td>
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<tr>
<td>Ethnicity</td>
<td></td>
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<tr>
<td>% Caucasian</td>
<td></td>
<td>88%</td>
<td>88%</td>
<td>88%</td>
<td></td>
<td></td>
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<tr>
<td>% African American</td>
<td></td>
<td>6%</td>
<td>5%</td>
<td>5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Other</td>
<td></td>
<td>6%</td>
<td>4%</td>
<td>4%</td>
<td></td>
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<tr>
<td>Schizotypal traits*</td>
<td></td>
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<tr>
<td>Cognitive-perceptual</td>
<td></td>
<td>0.15</td>
<td>0.19</td>
<td>1.83</td>
<td>0.63</td>
<td></td>
</tr>
<tr>
<td>Negative</td>
<td></td>
<td>0.22</td>
<td>0.26</td>
<td>2.32</td>
<td>0.96</td>
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</tr>
<tr>
<td>Disorganization</td>
<td></td>
<td>0.16</td>
<td>0.20</td>
<td>1.74</td>
<td>0.72</td>
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<tr>
<td>Psychological symptoms*</td>
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<tr>
<td>Depression</td>
<td></td>
<td>0.16</td>
<td>0.21</td>
<td>1.25</td>
<td>0.82</td>
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<tr>
<td>Performance on high-load cognitive task</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Hit rate</td>
<td></td>
<td>0.34</td>
<td>0.19</td>
<td>0.39</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>False alarms</td>
<td></td>
<td>0.07</td>
<td>0.19</td>
<td>0.04</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Sensitivity – d’</td>
<td></td>
<td>1.53</td>
<td>0.93</td>
<td>1.90</td>
<td>0.75</td>
<td></td>
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<tr>
<td>Response bias – b</td>
<td></td>
<td>8.69</td>
<td>5.20</td>
<td>11.32</td>
<td>4.46</td>
<td></td>
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</tbody>
</table>

*Average response reported here, with increasing scores reflecting increasing traits.

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**Figure 1.** Means and standard error values for Control (light bar) and Schizotypy (dark bar) groups on speech characteristics for the baseline and high-load speaking conditions.
appeared to be largely driven by false alarm errors. Poorer sensitivity was significantly associated with less emphasis during the high versus baseline conditions.

We also ran bivariate correlations between the positive, negative, and disorganization trait scores from the SPQ and the performance variables from the high-cognitive load condition (omitted from Table 2 for space concerns). “Constricted affect” but not “no close friends” was significantly associated with poorer sensitivity \( p < .02 \), and a more liberal response style \( r(38) = .34, p = .04 \) and \( r(38) = .02, p = .91 \), respectively] and a more liberal response style \( r(38) = -.37, p = .02 \) and \( r(38) = -.32, p = .06 \). None of the correlations between positive, negative, or disorganization traits were significantly associated with performance variables (all \( p \)'s > .10). Collectively, these analyses suggest that the schizotypal individuals who showed the most dramatic attenuation from baseline to high-load condition were those with a liberal response bias and those with self-reported constricted affect.

**Testing the moderation effects of cognitive performance.** The results of the partial correlations suggest that performance variables were relatively strong predictors of expressive deficits under conditions of high load. Only the schizotypy group was examined in these analyses, so it is unclear whether these findings are specific to schizotypy or whether they reflect a phenomenon generalizable to the larger nonschizotypy population. We next used regression analyses to determine whether there was a group interaction in predicting change in speech characteristics across baseline to high load conditions. In essence, we were testing whether the relationship between group status (entered in step 1) and expressive deficits under high cognitive load (entered as the dependent variable) were moderated by performance variables (centered and entered in step 1; group \( \times \) performance product entered in step 2). Baseline speaking characteristics were also entered in step 1. Sensitivity and response bias, the two performance variables of chief interest in this study, were separately examined. The results are presented in Table 3. Results suggest a significant group by sensitivity (i.e., \( d' \)) interaction for the emphasis variable and a significant group by response bias interaction for the speech production and emphasis variables. Thus, performance variables moderated the relationship between group status and speech production and emphasis deficits.

To illustrate these interaction effects for the performance variable, we plotted the speech production and emphasis variables as a function of performance, dichotomized by median split. For response bias, this reflected high (i.e., relative conservative bias) and low (i.e., relative liberal bias) groups and for the sensitivity measure, this reflected good (high scores) and poor (low scores) performance groups. As can be seen in Figures 2 (response bias) and 3 (sensitivity), abnormal declination of speech production and emphasis reflected the interaction of schizotypy group status and a liberal response bias. Abnormal declination of emphasis also reflected the interaction of group status and poor sensitivity.

**Discussion**

The present study tested the hypothesis that cognitive resource limitations contribute to expressive deficits in schizotypy. Our results partially supported this hypothesis. For participants as a whole, increased cognitive demands resulted in declination of a range of speech characteristics; a finding consistent with prior work from our lab (Cohen, Dinzeo, Donovan, & Morrison, 2010). Interestingly, individuals with schizotypy as a group did not differ from controls. However, expressive deficits under high cognitive load were more pronounced in a subset of schizotypal individuals—those with self-reported constricted affect and an abnormally liberal response bias characterized by an unusually high number of false alarm errors. Moderation analyses suggested that this performance by expression change interaction was different for controls and individuals with schizotypy, suggesting that the relationship between performance and speech deficits is unique to schizotypy.
Table 3
Examinign Whether the Relationship Between Task Performance (i.e., Sensitivity and Response Bias) and Changes in Speaking Characteristics From Baseline to High Load Conditions Differs by Group (Schizotypy Versus Controls)

<table>
<thead>
<tr>
<th></th>
<th>High-load speaking characteristics (dependent measure)</th>
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<tbody>
<tr>
<td></td>
<td>Speech production</td>
</tr>
<tr>
<td></td>
<td>$\beta$</td>
</tr>
<tr>
<td>Sensitivity – $d^a$</td>
<td>0.11</td>
</tr>
<tr>
<td>Group</td>
<td>−0.15</td>
</tr>
<tr>
<td>Baseline speech characteristic $^b$</td>
<td>0.72**</td>
</tr>
<tr>
<td>Group × $d^a$ interaction $^c$</td>
<td>0.57**</td>
</tr>
</tbody>
</table>

Step 1
Response bias

|                           | $\beta$ | $\Delta F$ | $\beta$ | $\Delta F$ | $\beta$ | $\Delta F$ | $\beta$ | $\Delta F$ |
| Response bias $^a$        | 0.12    | 31.72*     | 0.02   | 26.22*     | 0.23*  | 12.00*     | 0.02    | 114.27*     |
| Group                     | −0.15   | −10.10     | −0.10  | −13.13     | −0.13  | −10.10     | −0.10   | −10.10      |
| Baseline speech characteristic $^b$ | 0.72** | 0.72**     | 0.55** | 0.91**     | 0.57   | 5.57*      | 0.35    | 1.75        |
| Group × bias interaction $^c$ | 0.57** | 5.57*      | 0.35   | 1.75       | 1.11** | 14.89*     | 0.05    | 0.12        |

Step 2

$^a$ Significant $\beta$ values indicate that the performance variable is associated with high-load speaking characteristic.  $^b$ Significant $\beta$ values indicate that baseline and high-load speaking characteristics are associated with each other.  $^c$ Significant $\beta$ indicates that the schizotypy and control groups differ in relationship between task performance and change in speaking characteristic.

That is, expression diminished as a function of decreased cognitive resources, but this effect was much more pronounced for individuals with schizotypy compared with controls. Depressive symptoms were unrelated to the vocal characteristics examined in this study.

An interesting issue concerns why speech characteristics under high load were attenuated in individuals with schizotypy compared with controls. Depressive symptoms were unrelated to the vocal characteristics examined in this study.

An important issue concerns why speech characteristics under high load were attenuated in individuals with schizotypy with a liberal response bias. This is striking because the schizotypy versus control group showed a significantly more conservative response bias overall. We believe the most plausible explanation for this is that the liberal response bias demarcated schizotypal participants who exerted more cognitive effort on the $n$-back task and thus exhausted their resources more so than other participants. That is, they may have been simply trying harder on the $n$-back task compared with other participants and, as a consequence, their expression was reduced. The difficult nature of the dual-task may have led some participants to give less than full effort on the cognitive task, instead allocating efforts to expression. The fact that a sizable minority of participants (i.e., seven from the schizotypy and four from the control groups) did not respond during the cognitive task offers some support for this claim. Despite potential variability in effort on the cognitive task, statistical significance was still found, suggesting that any true effects of cognitive load on expression were underestimated by this study. Another possibility is that schizotypal individuals whose expression diminished under high cognitive load suffered from as-yet unidentified liabilities that made the dual task particularly difficult for them. That is, cognitive overload may have been achieved much more easily for these individuals. Judging from the relatively poor performance overall on the $n$-back task for both the controls and schizotypy groups, it appears that most participants either achieved a high cognitive load state or, as noted above in the first possibility, were not channeling maximal effort on the cognitive task (presumably because resources were also being marshaled to the competing speaking task). In this regard, the former possibility is more compelling than the latter. Regardless, both possibilities have important and interesting implications for a cognitive load theory of diminished expression in schizotypy.

It is also interesting that negative schizotypal traits were on the whole, not significantly related to vocal deficits in this study, particularly given that we have demonstrated a modest relationship between negative traits and decreased expression in a prior study (Cohen & Hong, in press). There are several important things to note. First, the prior study used a speaking task that may have had a relatively heavy cognitive load. Participants were asked to verbalize their reactions to picture stimuli from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999) showcasing a range of affectively valenced stimuli (e.g., mutilated bodies) for which few speakers had well-formed, automatic responses. As noted in the introduction, cognitive load theory (Sweller, 1994) asserts that task automaticity is an important factor in terms of cognitive load. Thus, the cognitive load during the speaking task in this prior study may have been unintentionally high, perhaps even higher than that in the present study. Second, the present study did find a number of significant correlations between self-reported constricted affect and various speech characteristics. The magnitudes for the correlations between the “no close friends” scores and speech characteristics were negligible, suggesting that only certain facets of negative schizotypy, at least as measured via self-report, are related to expressive deficits. In some regard, this offers convergent/discriminant validity for these two scales of the SPQ-BR, as they show different correlates in terms of speech characteristics. Perhaps more important are the implications for future research of negative schizotypy. Studies examining negative schizotypy tend to define it in terms of social anhedonia or as a broader negative trait factor, but only a small
portion of studies specifically examine constricted affect. Facets of negative schizotypy likely differ in terms of pathophysiological process despite their statistical co-occurrence (Cohen, Matthews, et al., 2010), and it stands to reason that diminished expression should be examined separate from social anhedonia/no close friends trait dimensions when attempting to delineate their pathophysiological underpinnings.

The present findings should be interpreted in light of the following limitations. First, the sample was composed of college students. While typical for schizotypy research, the degree to which these results generalize to the larger schizotypy population is unclear. Second, our measures of schizotypy were based on self-report. Although common for this type of study, future studies examining schizotypy should assess traits across both self-report

Figure 2. Graphing the relationship between cognitive performance and speaking characteristics as a function of Group: Means and standard error values for baseline and high-load speech characteristics, plotted as a function of conservative (solid line) versus liberal (hashed line) response bias, and graphed separately for Control and Schizotypy groups.

Figure 3. Graphing the relationship between cognitive performance and speaking characteristics as a function of Group: Means and standard error values for baseline and high-load speech characteristics, plotted as a function of good (solid line) versus poor (hashed line) performance ($d'$ scores), and graphed separately for Control and Schizotypy groups.
and observer-rated domains. Third, we focused on vocal expression, which is but one channel of expressive behavior. It will be important in future studies to examine the impact of cognitive-load on facial expressions and hand gestures. Fourth, we did not control for multiple comparisons in our correlational analyses. Given the novelty of acoustic analysis of speech in individuals with schizotypy and the relative power of our study, we chose to err on the side of type II versus type I errors. Fifth, the present project used a one-back task as a cognitive load measure. Cognitive load theory suggests that disruption of working memory stores is one of the most direct methods of increasing cognitive load. Nonetheless, the ecological validity of the one-back test can be questioned. Further research using more ecologically valid methods should be pursued. Finally, while criteria for the control group were average or below in terms of schizotypal trait severity, the trait scores were quite low. The “control” participants may not be representative of all “nonschizotypal” individuals.

While a cognitive-resource limitations model for understanding diminished expression in schizophrenia-spectrum conditions is clearly in its infancy, it has three critical implications for research and practice more generally. These implications do not follow directly from the findings of this study but are briefly mentioned here to highlight the potential benefits of a cognitive-resource limitations model. First, the model highlights the importance of accounting for cognitive load when assessing diminished expression, ideally by measuring it under controlled conditions where cognitive load can be directly manipulated. Diminished expression is often assessed during clinical interview (e.g., Loranger et al., 1994) and expression can vary significantly as a function of question difficulty. For example, the cognitive load associated with relatively straightforward concrete questions (i.e., What did you have for lunch yesterday?) is likely quite different than that associated with more abstract questions (i.e., What were you like as a child?). Moreover, self-report items assessing diminished expression, such as that used in this study, could be rephrased to account for cognitive load (i.e., “I find it difficult to express myself when asked a difficult question”). Second, understanding the cognitive and neurobiological underpinnings of diminished expression may be informed by cognitive-resource model. Finally, potential interventions may be indicated by this model. By relieving cognitive load or by improving cognitive resources more generally, it is possible that diminished expression might be less likely to manifest. In sum, clarifying the role of cognitive load in expressive deficits may yield important insights into the mechanism underlying them.

References


