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Speech Illusions and Working Memory Performance in Non-Clinical Psychosis

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Abstract

Psychotic disorders are characterized by auditory verbal hallucinations (AVHs), and research has shown that AVHs are linked to deficits in working memory. Our understanding of AVHs across the psychosis continuum is limited. To date, little research has tested whether hallucination proneness (HP) is linked with abnormalities on experimental multispeaker babble tasks. Few investigations have been conducted to determine how task performance might be linked to cognitive functioning. The objective of the current study is to better understand this empirical gap. A total of 70 adults (30 healthy controls and 40 HP individuals) were administered an experimental task in which they listened to multispeaker babble and were instructed to report any words or chains of consecutive words (CCWs) perceived. Participants also were administered nonverbal and verbal working memory tasks. Findings revealed that relative to the control group, the HP individuals perceived

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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. DeVlyder, Dr. Auerbach, and Dr. Schiffman helped to interpret results and draft the manuscript.

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more words and longer CCWs during the task. While there were no significant differences in working memory tasks between the HP and control groups, longer CCW's were associated with decreased verbal working memory scores in the HP group. AVH proneness may occur across a continuum of psychosis and may be linked with other theoretically relevant cognitive vulnerability factors.

Keywords

NCP; multispeaker babble; working memory; cognition; psychosis; speech illusions

1. Introduction

Psychosis symptoms typically occur as part of a continuous distribution of experiences (Kelleher and Cannon, 2011; van Os, 2002). Within this context, 5–8% of persons within the general population experience non-clinical psychosis (NCP) and these individuals represent the lower end of a psychosis severity continuum (van Os, 2002). NCP groups differ from other individuals on the psychosis continuum in that they are healthy individuals who report symptoms called psychotic-like experiences (PLEs; also termed psychosis experiences) such as fleeting hallucinations that are low in frequency. Identifying vulnerability factors among NCP groups can shed important light on the etiology of psychotic symptoms, in the absence of many of the types of variables that confound research in individuals with psychotic disorders (e.g., medications).

Auditory verbal hallucinations (AVHs) may occur across a continuum; AVHs refer to the perception of sounds or voices in the absence of external auditory stimuli (Bentall, 1990; Sommer et al., 2010; van Os, 2002). The concept of hallucination proneness (HP) relies upon self-report measures that may suggest a predisposition towards experiencing hallucinations on the basis of intermittent positive symptoms and/or schizotypy traits; schizotypy characteristics are traits in contrast to states and these individuals may share similar vulnerabilities as other groups on the psychosis continuum (Siever et al., 2002). Despite a compelling literature linking AVHs to deficits in working memory (WM) in schizophrenia (Hoffman et al., 1999; Jenkins et al., 2017) and emerging support indicating WM is affected across a psychosis continuum (Lee and Park, 2005; Rossi et al., 2016; Ziermans, 2013) there is a paucity of research utilizing experimental paradigms to evaluate non-clinical HP populations (Barkus et al., 2007; Bentall and Slade, 1985), particularly as it relates to linking proneness to AVHs with WM dysfunction.

Studies examining psychotic-like experiences and AVHs have utilized a variety of different paradigms in healthy and HP individuals (based on self-report measures), and schizophrenia populations (Barber and Calverley, 1964; Barkus et al., 2011, 2007; Mintz and Alpert, 1972; Ven and Merckelbach, 2003; Young et al., 1987). One task that has been used with psychosis and psychosis risk samples is the *Babble Stimulus* (Hoffman, 1999). In this task, participants may be asked to listen to simultaneous streams of speech with a high density of phonetic information and report any words or chains of consecutive words (CCW) perceived (Hoffman, 1999). Multispeaker babble tasks may be more sensitive and capable of detecting

low levels of proneness that would be missed by traditional interview or self-report measure approaches. There have been a few studies that have used multispeaker babble tasks to better understand AVHs among schizophrenia (Hoffman et al., 1999) and at risk populations (Hoffman et al., 2007) in which individuals reported perceiving speech illusions.

Prior research also has suggested speech illusions may be associated with cognitive functions such as working memory (Daalman et al., 2011; Hoffman et al., 1999; Rossi et al., 2016; Ziermans, 2013). Working memory aids in storing and processing information, also modulating bottom up and top down mechanisms (Hugdahl, 2009). While ongoing work continues to establish links between AVHs and working memory deficits in schizophrenia (Gisselgård et al., 2014; Hoffman et al., 1999; Jenkins et al., 2017), our understanding of the association across the broader psychosis continuum is limited. However, there are some studies that have found relationships with verbal working memory in individuals from the general population prone to hallucinations (Daalman et al., 2011; Rossi et al., 2016).

Daalman and colleagues (2011), aimed to establish a cognitive profile for otherwise healthy individuals experiencing proneness symptoms assessed by the PSYRATS Auditory Hallucination Rating Scale and observed that high scores (high HP) were related to cognitive deficits including verbal working memory but also inhibition, lexical access and reasoning, and verbal distractibility. In contrast, Korponay and colleagues (2014) found high levels of subclinical positive symptoms in nonpsychiatric controls were related to better performance on cognitive tasks including working memory. Of particular relevance to the present study is work conducted by Hoffman and colleagues (1999) in which the *Babble Stimulus* was implemented to hallucinating and non-hallucinating patients with schizophrenia. It was found that hallucinating patients exhibited poorer performance on the multispeaker babble task and likewise experienced deficits in verbal working memory. The present study is an extension of this work and seeks to look at specific links between multispeaker babble and verbal working memory in an undergraduate college sample with HP, to understand whether these associations generalize to a non-clinical HP sample. If we see similar performance on the multispeaker babble task as psychosis and at-risk populations, it could be that tasks as such may highlight proneness to symptoms such as AVHs.

The present investigation aims to improve our understanding of proneness to AVHs and working memory among HP individuals using a multispeaker babble task. Participants were administered the *Babble Stimulus* (Hoffman, 1999), and based of previous studies in this area (Hoffman et al., 1999), first, we hypothesized that HP individuals would report hearing more words and have longer CCWs during the multispeaker babble task relative to controls. Then, participants were administered a battery of working memory tasks, and consistent with findings linking working memory deficits to AVH in schizophrenia (Hoffman et al., 1999; Jenkins et al., 2017), we hypothesized that elevated scores on the experimental task would be associated with poorer working memory performance across tasks in the HP group.

2. Materials and methods

2.1 Participants

A total of 70 college students (HP=40, and controls=30) aged 18–26 ($M=19.10$, $SD=1.54$) were recruited through the Adolescent Development and Preventive Treatment (ADAPT) program using the University of Colorado Boulder's undergraduate research subject pool. All procedures were approved by the University Institutional Review Board (IRB). A total of 1,248 undergraduate students were given the Launay-Slade Scale Revised (LSHS-R) (Bentall and Slade, 1985), an HP inventory. The Brief Psychiatric Rating Scale (BPRS) (Overall and Gorham, 1976) was administered to ensure that participants with high psychosis levels would not be included and were therefore excluded from the study as this could confound results (no participants were excluded based on this criterion).

2.2 Clinical symptoms

The LSHS-R (Bentall and Slade, 1985) was used to identify HP individuals. This measure is one of the most widely-used instruments to examine psychotic-like experiences in the general population (Barkus et al., 2007; Mittal et al., 2013; Pelletier et al., 2013; van 't Wout et al., 2004; Vellante et al., 2012). This scale is reliable and well-validated (Bentall and Slade, 1985; Fonseca-Pedrero et al., 2010; Morrison et al., 2002; Waters et al., 2003) and it measures the prevalence of abnormal perceptual and unusual thought experiences on a four-item Likert scale ranging from “Never” to “Nearly Always.” Exemplar items include questions centered around perceptual phenomena, “*In the past I have experienced hearing a person's voice and found that no one was there,*” “*I have n the voice of the devil,*” “*I have been troubled by hearing voices in my head,*” as well as symptoms of unusual or bizarre thinking, “*Sometimes a passing thought will seem so real that it frightens me,*” “*People in my daydreams seem so true to life that I sometimes think they are real*”. The option to participate in the study was made available to those scoring in the top and bottom 10th percentile of the total sum score on the LSHS (≥ 23 or ≤ 3) (Mittal et al., 2012). Out of the 250 individuals invited to the study, a total of 70 elected to participate. Of the 70 participants, 30 reported low scores on the LSHS (controls) and 40 reported high scores on the LSHS (HP).

2.3 Babble stimulus

The *Babble Stimulus* (Hoffman, 1999) provides an audio of six speakers overlapping in speech reading neutral texts, which end up sounding like white noise in which no words are discernable. The length of the stimulus is a total of 2.5 minutes and participants are instructed to list any individual words or CCWs they perceive while listening to the multispeaker babble. Consistent with prior work (Hoffman et al., 2007, 1999; Hoffman, 1999), the number of words extracted from the multispeaker babble and the number of words uttered in the longest CCWs perceived are both treated as target variables.

2.4 Cognitive Measures

Participants were administered two tests of working memory: the Wechsler Memory Scale-Third Edition Nonverbal Span (Wechsler, 1997b), a test of nonverbal working memory and

Letter-Number Sequencing (Wechsler, 1997a), a test of verbal working memory. In the Wechsler Memory Scale-Third Edition Nonverbal span, participants are given a board with 10 cubes spaced throughout and are instructed to mimic by taping the cubes a particular sequence that the administrator taps. Letter-Number Sequencing requires the administrator to say a sequence of letters and numbers and participants are asked to reorder this sequence and repeat them back to the administrator. For both tasks, the total number of correct responses were recorded and then these raw scores were converted to standardized t-scores, correcting for both age and gender.

2.5 Data analyses

SPSS Statistics 23 was used to conduct behavioral analyses. Group differences in continuous and categorical demographic variables were evaluated with independent t-tests and Chi-square tests. Independent t-tests were employed to examine group differences on task performance. To investigate relations between task performance and working memory, bivariate correlations were employed. Two-tailed tests were used for all analyses.

3. Results

3.1 Descriptive Statistics

Descriptive statistics are summarized in table 1. There were no significant differences between HP and control participants in demographic characteristics, including age, $t(68) = .47, p = .54$, parental education, $t(68) = -1.19, p = .20$, and gender, $\chi^2(1) = .39, p = .53$. As expected, the HP group reported higher scores on the LSHS compared to the controls, $t(1,67) = 49.20, p = .001, d = -18.52$. There were no group differences in verbal working memory, $t(68) = -.12, p = .90, d = -.03$ or nonverbal working memory, $t(68) = .76, p = .45, d = .18$.

3.2 Group Differences in Babble Stimulus

In line with our hypothesis, the HP group reported hearing more words ($M=14.25, SD=10.42$) during the multispeaker babble task when compared with the control group ($M=8.37, SD=7.53$), $t(68) = 2.62, p = .01, d=.65$. In the HP group, 65% of individuals reported hearing 10 or more words compared to only 43% in the control group. Further, the HP group listed longer CCWs ($M=2.58, SD=1.39$) relative to the control group ($M=1.83, SD=1.44$), $t(68) = 2.17, p = .03, d = .53$. Seventy-eight percent of HP group reported CCWs with 2 or more words, compared to only 60% of the control group (Figure 1).

3.3. Associations Between Babble Stimulus and Working Memory

There was no statistically significant association between number of words extracted and verbal working memory ($r=-.14, p=.40$). However, longer CCW on the task was significantly associated with lower verbal working memory scores ($r=-.38, p=.02$) (Figure 2). There also were no relationships between (a) number of words extracted and nonverbal working memory ($r=-.02, p=.91$) or (b) longest CCW perceived and nonverbal working memory ($r=-.22, p=.18$).

4. Discussion

The main findings of the present study are that HP individuals exhibit a greater tendency to perceive speech illusions elicited from a multispeaker babble task. More broadly, findings of increased frequency of words and length of CCWs in the HP group provide evidence beyond self-report of HP. Further, links between CCWs and poorer verbal working memory are consistent with work suggesting AVHs in schizophrenia may be related to deficits in cognition such as working memory (Hoffman et al., 1999; Jenkins et al., 2017). While in HP populations, HP may be more illusory, these associations indicate that there may be a mechanistic relationships observed in schizophrenia which may also transverse a continuum, and could contribute to our etiological conceptualizations of psychotic disorders.

In the present study, the HP group perceived more words and longer CCWs on the *Babble Stimulus* task, which replicates previous studies (Hoffman et al., 2007, 1999). For example, in a study conducted by Hoffman and colleagues (1999) participants with schizophrenia (with and without auditory hallucinations) and controls were given the *Babble Stimulus* and results suggest that patients with early phase schizophrenia reported more speech illusions compared to controls. A few years later, Hoffman and colleagues (2007) employed the Babble Stimulus to participants at-risk for psychosis randomized to olanzapine (i.e., antipsychotic medication) or placebo conditions. Findings indicate that in the placebo condition, there were elevated CCWs perceived compared to high-risk individuals in the olanzapine group during medication-free intervals, and this was predictive of conversion to schizophrenia.

Findings linking *Babble Stimulus* performance with verbal working memory are consistent with prior research. For example, one study used a compilation of cognitive measures including speed of processing and working memory tasks, and results suggest poorer verbal working memory measured by Letter Number Sequencing, but not other cognitive domains, predicted increased AVHs in patients with first-episode psychosis (Gisselgård et al., 2014). Recently, Jenkins and colleagues (2017) took a trans-diagnostic approach and investigated AVHs (using the Positive and Negative Syndrome Scale) and cognition in individuals with schizophrenia and bipolar disorder with psychosis. This study found that individuals with bipolar disorder with psychosis performed better on cognitive tasks including working memory than schizophrenia patients and further found that working memory significantly predicted the presence of AVHs in both groups. Rossi and colleagues (2016) examined working memory in otherwise healthy individuals with psychotic-like experiences (using the Psychosis-Like Symptoms Interview; PLKISi, which measures positive symptoms broadly and is in an interview format as opposed to self-report) and also used a version of a N-back task (based on a Signal Detection theory framework) to examine working memory, and findings revealed AVHs were related to deficits in working memory capacity (Rossi et al., 2016). The present study is in line with findings from previous work and adds the investigation of a unique task that has not been studied yet in the non-clinical psychosis literature.

We did not detect links between task performance and nonverbal working memory. In this context it is important to consider that both verbal and nonverbal working memory may

differ in function and may not share overlapping neural pathways (Brahmbhatt et al., 2006). In contrast to other studies in non-clinical, prodromal, and schizophrenia samples, there were no group differences between HP and control participants in WM performance (Lenzenweger et al., 2000; Tallent and U, 1999; Ziermans, 2013). This may be due to the higher levels of functioning in this college sample (van Os, 2002). Alternatively, our strategy for evaluating working memory only included two standard tests and did not involve more nuanced subcomponents or functions, and future studies may benefit from a more comprehensive battery and significantly larger sample sizes. It is also important to note we did not detect associations between number of words perceived and verbal working memory. One possibility for this affect is that detecting longer CCWs may take more working memory capacity compared to extracting words, however, future work is needed to tease these relationships apart.

The present results are consistent with theories of AVHs. There have been several different theories that have been used to explain the mechanisms underlying hallucinations and it could be these theories extend to the experiences of speech illusions among HP individuals. More recent studies using neuroimaging and neurophysiology techniques have investigated predictive learning in the context of positive symptoms (Ford et al., 2012; Horga et al., 2014; Kort et al., 2017). Specifically, neural systems such as the temporal cortex are able to update internal models of the world based off of predictions that are formed from past experiences (Friston, 2005). These predictions impact sensory systems and influence the way individuals develop beliefs, which may result in symptoms such as hallucinations (Fletcher and Frith, 2009). Other leading theories posit that hallucinations may occur because of failures in self-monitoring of inner speech which in turn point to difficulties in differentiating the self with external sources (Brébion et al., 2016; Waters et al., 2012). Set shifting has been proposed as a possible explanation for hallucinations in that patients may have deficits in shifting attention away from voices that are heard which may speak to broader executive control abnormalities particularly relevant to bottom up and top down processes (Siddi et al., 2017; Waters et al., 2012). Hoffman (1999, 2007) reported that in the *Babble Stimulus*, it is possible that in schizophrenia and at-risk populations, impaired performance could be attributed to by excessive top down processing of phonetic inputs, distorted perceptual processing, or misinterpretation of percepts. While there have been several informative theories to understand the presence of hallucinations, it is important to note that it is still unclear which mechanisms are underlying these symptoms. The present study contributes to this literature providing a perspective from individuals that are not experiencing AVHs, but may exhibit vulnerability.

Taken together, the findings support theoretical conceptions that link AVHs with working memory dysfunction in psychosis. In the present study, we did not include components that would have allowed for us to compare and contrast alternative models of AVHs, (Barkus et al., 2007; Bentall and Slade, 1985; Seal et al., 2004) and thus, future studies are necessary to improve our understanding of this important area. Further, studies also are needed to compare multispeaker babble tasks and similar paradigms that include discernable words embedded such as Signal Detection Task paradigms to better understand the exact nature of what these tasks measure and how they might relate. Additionally, the present study used a small sample of undergraduate participants (N=70) and future work should consider

investigating similar questions with larger, more generalizable samples and use regression models to examine the predictive nature of these relationships. While the current study focuses on proneness to AVHs, studies in other vulnerable populations, including those with CHR syndromes, indicate that AVHs are just one piece of a larger puzzle; we recommend additional work include several types of positive symptoms, including those that have been shown to have high prognostic indication in other populations such as those at high-risk for psychosis (Cannon et al., 2008). Future studies should also assess for medication use, possible psychiatric diagnoses, and the presence of brain injury among NCP samples. As the present study used correlational approaches, causation cannot be inferred. The present results contribute to an improved understanding of possible underlying mechanisms that contribute to the presence of speech illusions and AVH proneness along the broader psychosis continuum.

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Figure 1.

Group differences between HP and control participants on *Babble Stimulus* performance.

Note. Group differences between HP and control participants on *Babble Stimulus* performance.

Words represent the average total number of words extracted from the task. Longest CCWs represents the average number of words perceived in a chain of consecutive words. Error bars indicate mean standard error. * $p < .05$

Figure 2.

Longest CCWs and verbal working memory associations in the HP group.

Note. CCWs and verbal working memory associations in the HP group.

Verbal working memory scores (from the LNS task) were converted to standardized t-scores, correcting for both age and gender. CCWs are the number of words perceived in a chain of consecutive words from the *Babble Stimulus*.

Table 1

Demographics

	HP	Controls	Total	Statistic	P
Age					
Mean (SD)	19.03 (1.52)	19.20 (1.58)	19.10 (1.54)	t(68) = .47	.64
Gender					
Male	17	15	32		
Female	23	15	38		
Total	40	30	70	$\chi^2(1) = .39$	.53
Parent Education (years)					
Mean (SD)	15.76 (1.57)	14.95 (3.49)	15.41 (2.58)	t(68) = -1.31	.20
LSHS Symptoms					
Mean (SD)	26.67 (2.91)	1.80 (1.06)	15.86 (12.63)	t(67) = -44.46	.001
Number of Words					
Mean (SD)	14.25 (10.42)	8.37 (7.53)	11.73 (9.69)	t(68) = -2.62	.01
Longest CCW					
Mean (SD)	2.58 (1.39)	1.83 (1.44)	2.26 (1.45)	t(68) = -2.17	.03

Note: HP is represented by a total sum score on the LSHS. Number of words refers to the average number of words perceived from the multispeaker babble task. CCWs refer to the average of the greatest number of words in the longest chain of consecutive words perceived on the multispeaker babble task.