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Assessing the Impact of White Noise on Cognition in Individuals with and without ADHD

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ASSESSING THE IMPACT OF WHITE NOISE ON COGNITION IN INDIVIDUALS
WITH AND WITHOUT ADHD

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in

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by
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TABLE OF CONTENTS

LIST OF ABBREVIATIONS

1. AHDH – attention deficit hyperactivity disorder

2. DSM-5 – Diagnostic and Statistical Manual of Mental Disorders – Fifth Edition

3. PFC – prefrontal cortex

4. dlPFC – dorsal lateral prefrontal cortex

5. ACC – anterior cingulate gyrus

6. DTD – dopamine transfer deficit

7. MBA – moderate brain arousal theory

8. CPT – Conner's Continuous Performance Test

9. ISE – irrelevant sound effect

10. BAARS-IV – Barkley Adult ADHD Rating Scale – IV

11. DIVA 2.0 – Diagnostic Interview of ADHD in adults, Second Edition

12. AVLT – Rey's Auditory Verbal Learning Test

13. MANOVA – multivariate analysis of variance

14. ANOVA – analysis of variance

ABSTRACT

Although originally viewed only as a childhood disorder, Attention Deficit Hyperactivity

Disorder (ADHD) is now recognized to persist into adulthood in many individuals.

Adults with ADHD often demonstrate academic, cognitive, and general functioning

deficits as a result of their symptoms. Theorists have suggested that features typically

associated with ADHD, such as distractibility, excessive motor activity, and executive

dysfunction, may stem from being under stimulated at a physiological level. This lack of

arousal potentially causes individuals to seek out stimulation, making them more

susceptible to background noise and other environmental stimuli. However, previous

research primarily focuses on children and adolescents with ADHD, utilizes few

cognitive tasks, and has demonstrated inconsistent results. This study attempted to

address limitations in the current literature by examining the effects of white noise on

verbal memory, working memory, and response inhibition in adults with and without

ADHD. Participants were asked to complete self-report measures of ADHD symptoms

and computerized cognitive tasks assessing verbal memory, working memory, and

response inhibition, while wearing headphones that broadcast white noise, during half of

each task, or no sound, during the other half of each task. A repeated-measures

MANOVA analysis indicated that there was no main effect of noise and no significant

interaction of diagnostic status and noise on scores, suggesting white noise did not

facilitate selective attention. Implications and limitations are discussed.

INTRODUCTION

Overview of ADHD

Originally viewed as a childhood disorder, it is now recognized that many children with Attention Deficit Hyperactivity Disorder (ADHD) continue to have impairing symptoms into adulthood (Daley & Birchwood, 2010; Fischer, Barkley, Fletcher, & Smallish, 1993; Mannuzza, Klein, Bessler, Malloy, & LaPadula, 1993). Today, ADHD impacts approximately 2.5% of U.S. adults (DSM-5). Individuals struggling with ADHD symptoms exhibit symptoms of inattention (i.e. mind wandering, disorganization, lacking persistence), hyperactivity (i.e. excessive fidgeting, overly talkative, standing and moving when inappropriate), and/or impulsivity (i.e. interrupting others, making rash decisions without considering the consequences). A major difference between children and adults with ADHD derives from the manifestation of ADHD symptoms. Children with ADHD are more likely to exhibit impulsive (Biederman, Mick, & Faraone, 2000), hyperactive, and socially aversive behavior than adults (American Psychiatric Association, 2013; Biederman, Mick, & Faraone, 2000; Faraone et al., 2000).

Related to their symptoms, many adults with ADHD experience cognitive deficits (e.g., executive dysfunction, inability to sustain attention, slower cognitive processing). Adults with ADHD are more likely to have profiles on intelligence tests in which they score lower in working memory and processing speed deficits (Hervey, Epstein & Curry, 2003). These cognitive deficits often appear in childhood and persist throughout adulthood, impacting multiple aspects of functioning, and are understudied in the current ADHD treatment literature, which typically focuses on ADHD or other comorbid symptoms (Antshel et al., 2011).

Given the cognitive difficulties commonly associated with ADHD, it is not surprising that academic functioning is often impaired in individuals with ADHD. Previous research suggests that children with ADHD are more likely to underachieve academically than their non-ADHD peers (Daley & Birchwood, 2010). Specifically, ADHD has been associated with reduced skills in reading, mathematics, overall grades, and standardized tests scores (Barry, Lyman, & Klinger, 2002; Loe & Feldman, 2007). Additionally, childhood ADHD has been linked to increased behavioral problems, suspensions, and other behavior-related disciplinary repercussions (Barbaresi, Katusic, Colligan, Weaver, & Jacobsen, 2007; LeFever, Villers, Morrow, & Vaughn, 2002). As might be expected, reduced academic performance and increased behavioral problems at a young age can negatively impact an individual's productivity as an adult. Kuriyan et al. (2013) showed that individuals with a childhood diagnosis of ADHD were significantly less likely to be employed or enrolled in a post-high school education than their non-ADHD peers, citing academic struggles and disciplinary problems as the mediators for these results. These findings are of particular concern, as the importance of post-high school education continues to rise. According to the U.S. Department of Education (2015), from 2002-2012, enrollment in degree-granting institutions has increased by 24%, suggesting an increase in the minimal education requirements needed to fulfill employment opportunities.

ADHD symptoms and associated impairments are targets of pharmacological and psychological interventions. The most common treatment for ADHD symptoms is psychostimulant medications. From 2007-2011, rates of stimulant prescriptions for ADHD rose 39% in the United States (U.S. Drug Enforcement Administration, 2012).

Psychosocial treatments for adults have also been developed, using therapeutic techniques such as cognitive behavioral therapy and family and marital therapy/counseling (Kolar et al., 2008). Cognitive behavior therapy combined with stimulant medications is recommended for adults with ADHD, as these treatments together appear to be most beneficial for the client (Antshel et al., 2011; Kolar et al., 2008). Stimulant medications may reduce some symptoms, but do not address problems related to executive functioning deficits (e.g., poor planning and organization). Scheithaur and Kelley (2014) demonstrated that a medication inclusive, self-monitoring treatment facilitated academic success and mitigated the impact of ADHD symptoms in college students. As new treatments are developed, unaddressed cognitive symptoms found within adult ADHD may continue to be one specific treatment target (Antshel et al., 2011).

Neurobiological Findings and Related Theories

Neuroanatomical and neurobiological differences have been found in studies comparing individuals with and without ADHD, which may relate to symptom presentation and cognitive deficits. Previous research has noted structural differences within regions of the prefrontal cortex (PFC; Carlson 2008; Pironti et al., 2014; Schneider, Retz, Coogan, Thome, & Rosler, 2006) when comparing individuals with ADHD to healthy controls. In particular, individuals with ADHD show a volumetric reduction within the dorsolateral prefrontal cortex (dlPFC; Biehl et al., 2016; Ehlis et al., 2008; Shecklmann et al., 2013; Valera et al., 2010) and the anterior cingulate cortex (ACC; Barkley, 1997; Sonuga-Barke, 2005; Sonuga-Barke, Bitsakou, & Thompson, 2010). Research has linked these regions to cognitive functions responsible for an

individual's ability to regulate attention or perform executive functioning operations (Biehl et al., 2016; Bush et al., 1999; Cortese et al., 2012; Friedman & Miyake, 2016; Schneider et al., 2006).

From a neurobiological perspective, research suggests that a dopaminergic deficiency within the PFC exists amongst individuals with ADHD (Carlson, 2008; Solanto, 2002). Two distinct forms of dopamine release exist: tonic and phasic. Despite their relation to the same neurotransmitter, previous research has shown that these two types of release are associated with very different behavior. Tonic release is the amount of dopamine released over an extended period of time, and is associated with distractibility, while phasic release refers to the immediate release of dopamine associated with reward (Grace, 2000; Grace, 2001; Sikström & Söderlund, 2007). Theories suggest that individuals exhibiting ADHD symptoms experience abnormal levels of both types of dopamine release (Sikström & Söderlund, 2007).

Researchers have proposed different theories for the role of dopamine in ADHD. For example, Tripp and Wickens (2008) suggested the dopamine transfer deficit (DTD) theory, which suggests that individuals with ADHD are unable to anticipate reward cues on a cellular level, due to dysfunctional dopamine cells. Therefore, while healthy peers are able to receive the anticipatory benefits leading up to a particular reinforcer, individuals with ADHD will only receive benefits once that reinforcer occurs. This neurobiological reaction may explain why individuals with ADHD engage in impulsive behaviors; they receive a delayed dopamine signal, creating an undesirable feeling when engaging in tasks that require delayed reinforcement.

Another theory of dopamine functioning and ADHD is the moderate brain arousal (MBA) model (Sikström & Söderlund, 2007), which aims to explain distractibility that often occurs in individuals with ADHD. This theory posits that individuals with ADHD experience lower tonic levels of dopamine as a result of abnormal cellular functioning (Grace, 2001) and dopamine metabolism rates (Kirley et al., 2002). In order to maintain homeostasis, lower levels of tonic dopamine induce an up-regulation in phasic dopamine reactivity. The increased responsiveness of the phasic receptors causes the individual to be hypersensitive to environmental stimuli, which is exhibited behaviorally as increased distractibility. Furthermore, the theory suggests that environments with either excessive or impoverished stimuli may lead to diminished cognitive performance amongst individuals who have this dopamine imbalance. Although increased stimuli causes distractibility (caused by the up-regulation of phasic response sensitivity) and take away from an individual's selective attention, the lack of stimuli within an environment may prevent the individual from experiencing optimum dopamine levels (caused by the individual's low tonic levels) required for cognitive functioning.

Optimal Stimulation Theory

Similar to these theories, Zentall (1975) proposed that individuals with ADHD require greater amounts of physiological stimulation, and will act upon this need by increasing their sensation-seeking behaviors. This is known as the optimal stimulation theory. This theory suggests that lower levels of arousal not only account for the behavioral patterns (e.g., distractibility, hyperactivity) seen amongst individuals with ADHD, but that these patterns are in some ways dictated by environmental stimuli

5

(Zentall, Tom-Wright, & Lee, 2013). Therefore, varying levels of environmental stimuli should evoke both behavioral and attentional variations amongst individuals with ADHD.

According to this theory, common inattentive symptoms such as distractibility, lack of sustained attention, or a decreased ability to pay attention to detail might stem from a combination of insufficient arousal and a desire to take in greater amounts of stimulation. For example, different than their typically developing peers, lapses in attention frequently occur when individuals with ADHD engage in tedious or repetitive tasks (Sergeant, Geurts, Huijbregts, Scheres, & Oosterlaan, 2003; Swanson, Baler, & Volkow, 2011; Zentall et al., 2013). For example, Huang-Pollock et al. (2012) conducted a meta-analysis of the continuous performance test (CPT) amongst individuals with ADHD. The CPT is a tedious and repetitive task which assesses sustained attention to letter stimuli and therefore, is not expected to show sufficient stimulation for those with ADHD. Consistent with their hypothesis, individuals with ADHD performed less well than those without ADHD in distinguishing targets from distractors.

Cognitive Theory of Auditory Distraction

Deficits in attention in ADHD also have been studied with cognitive psychology paradigms used to study attention in non-clinical populations. For example, auditory distractions are commonly employed as a method of studying working memory and/or selective attention. Specifically, it is important for the brain to discern between important, unexpected background information and task-relevant sounds. Having this ability to shift attention towards and away from background noise, essentially, allows a person to stay focused on a given task while remaining alert to their surroundings. Given the highly

6

distractible and inattentive nature of individuals with ADHD, it is important to understand how and why auditory distractors might influence sustained attention.

The duplex mechanism account (Hughes, Vachon, & Jones, 2007) is a theory that divides auditory distractions into two possible explanations: attention capture and interference-by-process. The attention capture component states that, in the presence of a distractor, once an individual is able to construct a mental set, the orienting response, commonly measured by eye movements, decreased heart rate, and skin conductance associated with an attention shift (Elliott & Cowan, 2001) becomes inhibited and the individual is able to regain control of their selective attention. However, if the stimulus' features change beyond the previously established mental set, the auditory distractor will divert the individual's attention away from the focal task, causing an *orienting response* (Cowan, 1995; Sokolov, 1963). Interference-by-process, on the other hand, is a term used to describe an instance when the processing of a distracting stimulus, such as a background noise, reduces the individual's ability to fully engage the necessary cognitive processes required to complete a focal task (Jones, 1999; Jones, Miles, & Page, 1990; Macken, Phelps, & Jones, 2009). This involuntary type of processing will often lead to a reduction in cognitive performance, as the individual is unable to fully engage in the task at hand. Researchers have termed this phenomenon the irrelevant sound effect (ISE, Colle & Welsh, 1976); an effect that has been found in both speech and non-speech sounds, including tones (Elliott & Cowan 2005). The ISE theory suggests that typically developing individuals will not habituate to this sound because it is both constant and stable (Roer et al., 2011; Tremblay & Jones, 1998).

Pelletier et al. (2016) explored the impact of the ISE in adults with and without ADHD, in order to assess sustained and selective attention over time. This study invoked a repeated-measures design, comparing the task performance of individuals with ADHD ($n = 32$) to that of a non-clinical comparison group ($n = 32$). Participants were asked to remember sequences of letters presented visually in the center of a screen, in order to assess serial recall and sustained attention in both a silent and irrelevant sound group. The irrelevant sound consisted of background conversations and office equipment typically heard in a workplace environment. All participants were asked to complete five blocks in five trials within their respective conditions. Consistent with previous research, results of this study suggested that the adults diagnosed with ADHD were more easily distracted by background conversation than individuals without ADHD (Dige, Maahr, & Backenroth-Ohsako, 2010; Goldman, Fristoe, & Woodcock, 1970). The individuals in this study were subjected to fluctuating, sporadic sounds that included discernable speech. These types of sounds create additional challenges during a process known as habituation, which is an orienting response of attentional filtering that occurs from the repeated presentation of a stimulus (Cowan, 1995; Elliott & Cowan, 2001), especially for those with ADHD, who are more easily distracted by irrelevant sounds.

Noise as a Facilitator of Performance in Individuals with ADHD

The previous study highlights the challenges individuals face when presented with background conversations. While both groups show some level of impairment when listening to background conversations, individuals with ADHD demonstrate greater challenges with distraction than individuals without ADHD. However, it is interesting to note that other types of background noise, such as white noise, have been associated with

a different pattern of results. Several studies investigating the effects of white noise on cognitive performance amongst individuals with ADHD or, more broadly, those with symptoms of inattention, have shown that continuous white noise during cognitive tasks has positive effects on task performance (Cook, Bradley-Johnson, & Johnson, 2014; Helps, Bamford, Sonuga-Barke, & Söderlund, 2014; Söderlund, Sikström, & Smart, 2007; Söderlund & Sikström, 2008). In contrast, this facilitation effect does not seem to be present in individuals without ADHD or with low levels of inattentive symptoms (e.g., Helps et al., 2014).

Helps et al. (2014) examined how the presence of white noise during verbal memory and executive functioning tasks impacts varying levels of attention amongst children. Results of this study demonstrated an inverse relationship between task performance and white noise levels, when comparing groups of individuals based on levels of attention. Specifically, individuals exhibiting low levels of attention showed significant improvement on executive functioning tasks (i.e. Go/No-Go task) when the presence of white noise was increased from low (65dB) to moderate (75dB). Additionally, results indicated a significant decrease in performance for individuals who displayed high levels of attention. Taken together, these findings suggest that the presence of white noise may reduce outside distractions for individuals with attention problems, but also act as a distractor for individuals who display high levels of attention.

Other studies found similar results from the presence of background noise in children. Abikoff, Courtney, Szeibel, and Koplewicz (1996) sought to determine how irrelevant sound influenced those with ADHD diagnoses, examining the impact that self-selected music, background speech, and silence had on arithmetic performance. This

study utilized a multiple-comparisons structure as it compared children diagnosed with ADHD to a group of healthy control peers. Results of the study demonstrated that individuals with ADHD showed significant improvements when self-selected music was used during testing, as compared to the background conversations and silent conditions, which did not differ. The healthy controls showed no notable differences across conditions. The results indicated that the familiar music chosen by the ADHD children may have facilitated their attention. Additionally, the results suggested that familiarity with the music may have attributed to the ADHD children's ability to habituate to the sound, resulting in the improvements. Similar to earlier work, individuals with ADHD also self-reported a preference for background noise when engaging in math problems, as compared to their healthy control peers (Zentall & Smith, 1992).

One explanation for reduced inattention amongst the ADHD group might be that the white noise increased cognitive activation levels as the individuals habituated to the sound over time. Söderlund and colleagues (2007) suggested this hypothesis, after conducting a study that looked at ISE amongst children with ADHD. This study sought to examine the impact of white noise on medicated and non-medicated children with ADHD. The participants were asked to recall single verb-noun sentences that were presented in an auditory manner. Subjects were then compared within groups based on types of encoding and noise and between groups, comparing ADHD to non-ADHD groups. Based upon their designated group, the subjects completed the task in silence or in the presence of white noise. Results of this study suggested that children with ADHD showed improved cognitive functioning within the presence of irrelevant white noise. The authors suggested that the MBA model best explains the findings. Additionally, the

findings coincide with Zentall et al. (2013), who suggested that the presence of environmental stimuli may provoke both inattentive symptoms, in order for the individual to reach optimal levels of stimulation. By providing a constant stream of white noise, the individual is not only receiving a constant level of stimulation, but they are also preventing the existence of environmental distractors.

Individuals with ADHD typically exhibit difficulties with sustaining attention, listening when spoken to, and performing tasks that measure executive functioning abilities. It has been suggested that these symptoms may be exhibited, in part, because of their desire to seek out irrelevant environmental stimuli (Zentall, 1975). Previous research suggests that these behaviors might be combated by the presence of white noise, which acts as a source of stimulation, and leads to improved performance on executive functioning tasks (Zentall et al., 2013). Perhaps because they do not have the same deficits in baseline stimulation, white noise has not been shown to have the same positive effects in individuals without ADHD.

Previous research suggests that the presence of white noise should have similar influences on all symptoms of ADHD. White noise appears to reduce levels of distractibility and improve levels of stimulation, which serve to mitigate symptoms of inattention (Helps et al., 2014). Additionally, increased stimulation provided by white noise may reduce the negative influence of hyperactive/impulsive symptoms on task performance, as theorists have suggested that these behaviors are the result of inadequate environmental stimulation (Söderlund et al., 2007; Zentall & Zentall, 1983). Therefore, these findings suggest that similar levels of improvement may be seen on task

performance across all symptoms of ADHD, when tasks are completed in the presence of white noise.

Currently, the literature focusing on how background noise impacts individuals with ADHD has a number of limitations. The majority of previous studies have focused on children and failed to investigate adult ADHD. Typically, studies also have not included multiple measures assessing domains of cognitive performance associated with ADHD. This study intends to address these limitations by investigating the impact of white noise on verbal memory, working memory, and response inhibition in adults with and without ADHD. These aspects of cognition, including those related to executive functioning (i.e., working memory and response inhibition) and verbal memory, are known deficits amongst individuals with ADHD (Boonstra, Oosterlaan, Sergeant, & Buitelaar, 2005). Individuals with and without ADHD were assigned to complete all tasks under either silence or white noise. Based upon previous research, the following hypotheses were made:

Hypothesis 1: There will be a main effect of group such that healthy controls perform better on measures of executive functioning and verbal memory than individuals with ADHD.

Hypothesis 2: Although there will be no main effect of condition (noise vs. silence), there will be an interaction of group (ADHD vs. no ADHD) and condition, such that individuals with ADHD in the white noise condition will perform better than individuals with ADHD in the silence condition while individuals without ADHD will perform similarly in both conditions.

METHOD

Participants

This study included 45 students from Louisiana State University (LSU). Prior to recruiting, power analyses (α = .05 and β = .80) were run using G* Power 3, in order to determine the sample size required for this study. A small effect size (f^2 = .10) was considered during calculations, based on prior research (e.g., Helps et al., 2014). Results of this analysis indicated that a total sample size of N = 32 would be required to test the primary hypothesis of an interaction between condition and group.

Participants were excluded from the study if they were volunteering for the ADHD group, and did not meet diagnostic criteria for a current ADHD diagnosis. Additionally, participant data were not analyzed if a participant reported that they took stimulant medication prior to completing the cognitive tasks. Individuals using stimulant medications have demonstrated a reduction in ADHD symptoms and improvements in reaction time, short-term memory, and response inhibition (Connor, 2005; Kolar et al., 2008; Lakhan & Kirchgessner, 2012). Lastly, participants were required to maintain an 80% accuracy rating throughout the Symmetry Span task and Operation Span tasks, in order to ensure that participants were engaged in both aspects of each task. Additionally, in order to further assess for effort, prior to all analyses, scores from the total sample were converted to z-scores, where any score +/- 3 standard deviations were removed.

The final sample included 35 participants (n = 17 ADHD and n = 18 Non-ADHD). Three members from the non-ADHD group and four from the ADHD-group were removed for under performing beyond 3 standard deviations of the total sample and one member from the ADHD group was removed because they did not meet DSM-5

diagnostic criteria for ADHD during their clinical interview. Additionally, there were

some technical difficulties during administration of the computerized tasks (e.g., program

crashing), and data were unsuccessfully collected from two participants (one from each

group). Given the nature of a MANOVA analysis, individuals who did not have scores

for a given task were removed from all analyses, resulting in a final sample of 35

participants.

Informed consent and demographic information were collected prior to

participating in the study. Overall, participants were predominantly female ($n = 22$) and

had an average age of 19.57 ($SD = 1.52$ years). This sample consisted of individuals who

were Caucasian (71.4%), African American/Black (17.1%), Asian (8.6%), and other

(2.9%). Additionally, 8.6% of participants identified as Hispanic. Lastly, 37.1% were

college freshmen, 31.4% were college sophomores, 14.3% were college juniors, and

17.1% were college seniors, (see Table 1 for group demographics).

Table 1
Demographics comparisons.

	ADHD Mean (SD)	non-ADHD Mean (SD)	t-value	df	p
N	18	18			
Age	20.78 (2.34)	18.72 (0.75)	-3.55	34	0.00
Education	13.78 (1.40)	12.48 (0.60)	-3.55	34	0.00
ADHD Symptom Severity					
Inattention	22.89 (6.66)	13.67 (2.97)	-5.37	34	0.00
Hyperactivity	11.56 (3.37)	7.61 (1.69)	-4.45	34	0.00
Impulsivity	10.11 (3.23)	6.72 (2.65)	-3.44	34	0.00
	ADHD (n)	non-ADHD (n)	X2	df	p
Gender (Female)	12	12	0.00	1,36	1.00
Race (White)	13	11	5.00	1,36	0.48
Ethnicity (non-Hispanic)	18	14	4.50	1,36	0.03

Antisaccade Task. The antisaccade task is a computerized, performance measure designed to assess cognitive inhibition (Friedman & Miyake, 2016). This task requires participants to maintain their attention on the target letter, while a distracting stimulus is presented on the opposite side of the screen. Participants are instructed to identify the target letter by responding with a key press as quickly and accurately as possible. Response latency and letter identification accuracy is used to measure orientation (Kane, Bleckley, Conway, & Engle, 2001). Previous studies suggest that individuals with ADHD demonstrate greater impairments on the antisaccade task than peers without ADHD (Klein, Raschke, & Brandenbusch, 2003; Mostofsky et al., 2001; Munoz, Hampton, Moore, & Goldring, 1999). Additionally, the inclusion of this task is thought to capture an aspect of executive functioning that is not otherwise measured by the other cognitive tasks in this study. Participants could potentially obtain a total score of 24.

Barkley Adult ADHD Rating Scale-IV (BAARS-IV). The BAARS-IV is a diagnostic tool designed to assess ADHD symptoms. Consistent with DSM-IV criteria, this measure addresses symptom presentation in both childhood and adulthood. The BAARS-IV has good test-retest reliability and has population-derived norms used to establish clinically significant cut scores associated with an ADHD diagnosis (Barkley, 2011).

Diagnostic Interview for ADHD in adults, Second Edition (DIVA 2.0). Participants who report having a prior diagnosis of ADHD were given the Diagnostic Interview for ADHD in adults (DIVA 2.0). The DIVA is a structured interview, designed to assess the existence of ADHD symptoms during both adulthood and childhood. The

DIVA 2.0 examines symptoms present for the last 6 months and throughout the ages of 5-12 years old. In order to be considered for an ADHD diagnosis, administrators must consider symptoms that present as chronic traits. Responses from this interview were used to confirm the existence of an ADHD diagnosis.

Operation Span Task. The Operation Span Task is a computerized, performance measure of working memory that was adopted from Unsworth, Heitz, Schrock, and Engle (2005). Based on Foster et al. (2015), the duration of this task was modified to two blocks and ten trials, in order to improve efficiency and maintain measure reliability. Participants are instructed to complete a three-step process of solving a basic, arithmetic equation, discerning between correct versus incorrect responses to an equation, and lastly, remembering a letter that is presented after identifying a correct response. At the end of each trial, the participant is asked to recall the correct letter sequence of the trial by selecting each letter, in order, from a list of presented letters. Partial scores consisted of the total number of letters accurately recalled in the correct order (Turner & Engle, (1989). Participants could obtain a total partial score of 50.

Symmetry Span Task. The Symmetry Span Task is a computerized, performance measure designed to assess visuospatial abilities and working memory capacity (Foster et al., 2015; Kane et al., 2004; Unsworth et al., 2009). Similar to the Operation Span Task, the Symmetry Span Task was also modified, based on Foster et al. (2015), to two blocks and eight trials. Participants are shown an 8 X 8 matrix, and asked to judge the symmetry of the figure. Next, they are presented with a 4 X 4 matrix that has a red square located in one of the boxes. Partial scores were calculated by summing accurate red dot locations that were recalled in the correct order. Participants could obtain a total partial score of 28.

Verbal Learning Task. The verbal learning task created for this study is a computerized, open-response performance measure designed to assess verbal recall. Participants are given three trials to learn 15 words, which were visually presented on an individual basis for 100ms each. Words were selected from the Rey Auditory Verbal Learning Test (AVLT; Schmidt, 1996). Participants were asked to take part in three immediate recall trials. Although the AVLT has five trials, studies have shown that a ceiling effect typically occurs after three trials on the AVLT in undergraduate samples (Uttl, 2005). Previous studies have shown that the AVLT has good test-retest reliability, adequate reliability, and convergent validity with other measures of verbal memory (Magalhaes, Malloy-Diniz, & Cavalheiro, 2012). Scores were calculated by summing correctly recalled words, across all three trials, regardless of word order. Additionally, participants were not penalized for recalling the same word more than once within a given trial. Therefore, participants could obtain a total score of 45.

Procedure

This study compared two samples of students: an ADHD group and a non-ADHD group. Participants in the ADHD group were recruited through two sources: the undergraduate psychology participant pool and fliers posted around the LSU campus and surrounding areas. Fliers were used to recruit individuals with ADHD. Subjects received either course credit or financial compensation for their participation. Participants with ADHD were also asked to complete a separate, abbreviated diagnostic assessment as part of another research study.

Individuals recruited for the ADHD group took part in two sessions. The first session took approximately 1.5 hours to complete and was designed to assess the

presence of an ADHD diagnosis. As part of a separate study, participants took part in a

background and clinical interview and completed self-report and performance-based

measures to examine ADHD symptoms and executive functioning.

The second session was designed to compare cognitive performances and self-

reported ADHD symptoms between groups. All participants were asked to complete an

informed consent before participating in the experiment and no subjects were made aware

of the true nature of the experiment, beyond completing the task with which they were

presented. After being consented, participants were asked to complete a self-report

measure of ADHD symptoms (BAARS-IV). Next, participants were asked to wear a set

of headphones and complete all cognitive tasks noted above. The presence or absence of

white noise during these tasks depended upon the random order of the participant's

assignment. All participants received two versions of the four cognitive tasks, one in the

presence of white noise and one without noise. Same tasks were not administered

consecutively and testing order was counterbalanced throughout the entire sample (see

Figure 1). The entire process took approximately one hour to complete.

Group 1		Group 2	
RAVLT	Silent	RAVLT2	WN
AS	Silent	AS	WN
O-Span	Silent	O-Span	WN
SymmSpan	Silent	SymmSpan	WN
AS	WN	AS	Silent
O-Span	WN	O-Span	Silent
SymmSpan	WN	SymmSpan	Silent
RAVLT2	WN	RAVLT1	Silent
Group 3		Group 4	
RAVLT2	Silent	RAVLT1	WN
AS	Silent	AS	WN
O-Span	Silent	O-Span	WN
SymmSpan	Silent	SymmSpan	WN
AS	WN	AS	Silent
O-Span	WN	O-Span	Silent
SymmSpan	WN	SymmSpan	Silent
RAVLT1	WN	RAVLT2	Silent

Fig. 1 Counterbalance Organization of Tasks
Note: AS: Antisaccade Task; O-Span: Operation
Span; RAVLT: Rey's Auditory Verbal Learning Task;
SymmSpan: Symmetry Span Task

Analyses

Correlation analyses and independent samples t-tests were run to analyze the relationships between each of the cognitive tasks and symptom severity between groups, respectively. Group differences comparing ADHD symptom severity was assessed using self-report data from the BAARS-IV. All three symptoms of ADHD were compared as continuous variables. In order to test the hypotheses regarding the independent and interactive effects of group (ADHD vs. no ADHD) and condition (white noise vs. silence), a repeated measures MANOVA was used to first simultaneously examine performance across cognitive tasks. If significant results were obtained, ANOVAs and post hoc tests would then have been used to examine the existence and strength of relationships across each task, independently.

RESULTS

Independent samples t-tests or chi-square tests were run to test for differences between the ADHD group and non-ADHD group, including for age, gender, race, ethnicity, education, and ADHD symptom severity (see Table 1). ADHD symptoms were measured independently as continuous variables.

Correlations were also run to compare the relationships between performance on each cognitive task. Performance was measured by considering partial scores for each task. Results demonstrated positive correlations between all performance measures. Specifically, significant relationships were indicated between Operation Span and both Symmetry Span ($r = .583$, $p < .001$) and the Verbal Learning Task ($r = .340$, $p < .05$). There were no other significant relationships between performance measures.

A repeated-measures MANOVA was run on performance scores for each cognitive task during both the white noise and silent condition, comparing performance of the ADHD group to the non-ADHD group. There was a non-significant interaction between groups and condition, with cognitive performance (λ (4,30) = .871, p = .493), suggesting that the presence or absence of white noise did not differentially influence either group's cognitive performance. Group differences between task and condition can be found in Table 2. Additionally, there were non-significant main effects for condition (λ (4,30) = .820, p = .523) and group (λ (4,30) = .598, p = .667). These results suggest that white noise did not influence cognitive performance and that there were no differences in cognitive performance between groups.

Given the reduced sample size in the MANOVA due to missing data on one or more dependent variables, a series of post-hoc exploratory analyses where completed using separate ANOVAs for each dependent variable. Results were unchanged; there were no differences between groups, no effects of noise condition, and no interactions between group and noise condition (all p > .05).

Table 2
Group performance across conditions.

Cognitive Performance	ADHD-Group		Non-ADHD Group	
	Mean (SD)	Range (Min - Max)	Mean (SD)	Range (Min - Max)
Antisaccade - Silence	.53 (.16)	.25 - .75	.52 (.18)	.21 - .79
Antisaccade - WN	.56 (.15)	.29 - .83	.54 (.20)	.25 - .88
Operation Span - Silence	39.24 (7.50)	24 - 50	36.11 (11.61)	11 - 46
Operation Span - WN	35.47 (10.90)	9 - 50	36.78 (12.70)	5 - 49
Symmetry Span - Silence	17.71 (5.16)	6 - 26	18.44 (5.13)	9 - 27
Symmetry Span - WN	15.41 (7.05)	0 - 26	17.72 (5.72)	7 - 28
Verbal Learning - Silence	30.29 (6.68)	23 - 45	29.50 (5.68)	18 - 39
Verbal Learning - WN	30.41 (5.16)	20 - 39	28.44 (4.00)	22 - 35

Notes: WN: White Noise

DISCUSSION

This study was conducted to examine the impact of white noise on verbal memory, working memory, and response inhibition in adults with and without ADHD. Executive dysfunction is a cognitive component commonly found amongst individuals with ADHD and several studies examining adolescents with and without ADHD have suggested that white noise may facilitate executive functioning. While prior studies targeted a mix of medication compliant and medication naïve children and adolescents, this study included an adult sample of medication compliant college students who were asked not to take their medication before participating in computerized tasks. Participants completed two versions of the computerized tasks, both in the presence and absence of white noise, and filled out self-report measures assessing ADHD symptom severity. This study was unique to previous literature, as it used an adult sample and attempted to demonstrate different effects within separate cognitive domains.

Previous studies have demonstrated that the presence of white noise during cognitive tasks can sometimes facilitate cognitive performance amongst individuals with ADHD (Allen & Pammer, 2015; Helps et al., 2014; Söderlund et al., 2007; Söderlund et al., 2010). However, counter to the original hypothesis, results from the repeated-measures MANOVA demonstrated that there were no effects of diagnosis or condition (i.e., white noise vs. silence) on a participant's cognitive performance. Results also indicated a non-significant interaction between diagnosis and condition, suggesting that the white noise used during this study did not influence cognitive performance for either group.

Although these findings were not hypothesized, other studies of white noise and ADHD have demonstrated similar null effects. Specifically, Helps et al. (2014) compared non-EF (e.g., list learning and verbal recognition) and EF performance between three groups with varying inattention levels, in the presence of white noise. Results suggested that while white noise may improve EF task performance amongst individuals with low attention, the authors found that white noise did not significantly impact performance on non-EF tasks, regardless of attention levels. Moreover, analyses failed to demonstrate significant effects of group or white noise on both EF and non-EF tasks. Lastly, while previous studies have suggested that white noise may improve cognitive performance, many of these studies demonstrated small effect sizes between groups (Helps et al., 2014; Söderlund et al., 2007; Söderlund et al., 2010), suggesting that the small samples compared in this study may have contributed to the lack of significant findings.

The results of this study may also differ from previous findings because of the differences found in ADHD presentation between adults and children. Specifically, it is well known that children and adolescents with ADHD have more academic challenges than their non-ADHD peers, making them less likely to attend college or even complete high school (Blase et al., 2009). Given that all children are required to attend school, previous studies become more likely to witness a greater degree of symptom severity amongst their ADHD samples, than individuals enrolled in higher education. The ADHD sample from this study came from currently enrolled college students who sought out participation, which suggests that these individuals may have learned to compensate for their ADHD symptoms (Frazier, Youngstrom, Glutting, & Watkins, 2007). Additionally, natural improvement may occur within aspects of executive functioning for adults with

22

ADHD, due to the demands of college. The increase in academic, social, and self-care responsibilities increase significantly between high school and college (for most) and require an inherent ability to organize these obligations.

Finally, the ADHD group did not perform worse on any of the cognitive tasks than the non-ADHD group. Many factors may have contributed to this finding; for example, although participants were not on stimulant medications on the day of testing, medications vary in the length of their effects. Specifically, there are a multitude of factors that can influence the half-life of stimulant medications, including food consumption, dosage, and frequency of use (Auiler, Liu, Lynch, & Gelotte, 2002). Studies have demonstrated that the effects of stimulant medication can be present within someone's system for up to 12 hours (Sherzada, 2012). Taken together, it is possible that some ADHD participants may have benefited from their medication without taking it on the same day as their cognitive testing.

Additionally, previous research notes that while there is often a group difference in EF between those with and without ADHD, there is also a large degree of within group variability (Boonstra et al., 2005). Therefore, the small sample size in this study may have limited the ability to detect group differences.

Limitations

There are several limitations associated with this study. First, although comparable to other studies in the literature, the sample size of each group was modest. The groups differed in age, ethnicity, and years of education; recruiting for the non-ADHD group was done from the psychology subject pool, which has a large number of students enrolled in introductory to psychology, a course often taken by students in their

first and second year undergraduate students. In contrast, the ADHD group was recruited via advertising on campus. Despite including one graduate student in the ADHD group, a post-hoc examination of removing this participant did not change the pattern of results.

Future Directions

Future studies are needed to investigate the impact of white noise on verbal memory, working memory, and response inhibition in adults with and without ADHD. Previous research has suggested that utilizing white noise during cognitive tasks can potentially facilitate attention amongst adolescents with ADHD. This study employed the use of several cognitive tasks designed to measure different aspects of cognition.

Previous studies have suggested that the habituation to irrelevant background noise can potentially improve sustained attention amongst individuals with ADHD (Pelletier et al., 2016). Specifically, the authors suggest that individuals with ADHD may habituate to the ISE, causing them to improve their overall performance over time. Contrary to the study conducted by Pelletier and colleagues (2016), this study used multiple, short duration tasks, in order to capture multiple aspects of cognition. Future studies may benefit from using longer duration tasks, in order to further assess the role of habituation and cognitive performance amongst individuals with ADHD.

Previous studies have examined the effects of different types of sound (i.e., white noise, pink noise, music without lyrics, music with lyrics, irrelevant speech) during cognitive tasks, amongst children with and without ADHD (Abikoff et al., 1996; Allen & Pammer, 2015; Marsh et al., 2009; Söderlund et al., 2007). Additionally, other studies have subdivided their samples by inattention levels, comparing high and low levels of inattention to the effects of background noises (Helps et al., 2014). Taken together, future

24

studies may benefit from expanding these methods to adults, with and without ADHD, to determine if the previously reported theories about auditory stimulation carry over to the adult ADHD population.

Future studies may also benefit from a longitudinal methodology. Cook et al. (2014) examined three children with ADHD for approximately 8-weeks, while using and not using headphones with white noise. Results of the study demonstrated that, in the presence of white noise, the three children exhibited fewer distractions. It may be that individuals need time to adjust to the noise and may explain why few cognitive differences were seen between groups, during a single experimental session. Extending the duration of the study may also increase the opportunity for an individual to habituate to the sound over time (Pelletier et al., 2016).

Summary

This study was conducted to examine the impact of white noise on verbal memory, working memory, and response inhibition in adults with and without ADHD. All participants completed a self-report measure designed to assess ADHD symptom severity and four cognitive tasks, which were administered twice, non-sequentially, under a white noise and silent condition. It was hypothesized that participants in the non-ADHD group would perform better on measures of executive functioning and verbal memory than individuals with ADHD. It was also hypothesized that individuals with ADHD would perform better in the white noise condition than in the silent condition, and that individuals without ADHD will perform similarly in both conditions, regardless of condition. Results demonstrated however, that the presence and absence of white noise had a non-significant effect on cognitive performance. This study was unique to previous

literature, as it used an adult sample and attempted to demonstrate different effects within

separate cognitive domains.

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List of Tables

LIST OF FIGURES

VITA

Scott Michael Roye, raised in Massachusetts, completed his Bachelor of Arts in Psychology from Emory University in Atlanta, GA. There, he conducted a study examining the post-identification feedback. Specifically, he focused on how non-verbal feedback influences confidence.

After concluding his undergraduate career, Scott worked at McClean Hospital in Belmont, MA and at Bradley/Hasbro Children's Research Center in both the Departments of Clinical Psychology and Neuropsychology in Providence, RI. While working in Providence, Scott was trained to code body language and dyadic relationship quality and assisted on projects concerning children with ADHD and epilepsy. He then attended Pepperdine University in Los Angeles, CA, where he obtained a M.A. in psychology. During his time in California, Scott worked as a neuropsychology research assistant at the UCLA Semel Institute for Neuroscience and Human Behavior. Here, he contributed to projects focusing on Huntington's Disease, Friedreich's Ataxia, and HIV.

Scott's interest in clinical neuropsychology led him to Louisiana State University, where he is receiving his doctor of philosophy in clinical psychology under the supervision of Dr. Matthew Calamia. His research interests center on ADHD and executive functioning from both a neuropsychological and neuroimaging perspective.