ABSTRACT

Title of Thesis: EXECUTIVE FUNCTION, ENGAGEMENT, AND ATTENTION: EFFECTS ON COMPREHENSION

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Cognitive control/executive function (EF) and attention deficits are prevalent among students and impact comprehension performance. While EF and attention impairments are well-studied, the interaction between cognitive control/EF, attention, arousal/engagement, and comprehension has yet to be explored. Undergraduates' ADHD symptoms, cognitive abilities, and cognitive control were assessed prior to listening to passages of varying degrees of emotional valence and responding to comprehension questions. Exploratory EEG data were also collected to examine patterns of cognitive engagement/emotional arousal. Results showed that comprehension for participants with high numbers of ADHD symptoms and/or proactive cognitive control types were influenced by the emotional valence of the context. In emotional contexts, those with high ADHD symptoms showed better comprehension overall and deep levels of processing, and those with proactive cognitive control types showed better deep processing. These findings indicate the need for further research to tease apart the interaction of EF, attention, and arousal on comprehension across different contexts.

EXECUTIVE FUNCTION, ENGAGEMENT, AND ATTENTION: EFFECTS ON COMPREHENSION

by

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

Abbreviation	*Explanation*
EF	Executive Function
ADHD	Attention Deficit Hyperactive Disorder
EEG	Electroencephalography
WM	Working Memory
CPT/AX-CPT	Continuous Performance Test/AX-Continuous Performance Test
PBSI	Proactive Behavioral Score Index
RT	Reaction Time
DMC	Dual Mechanisms of Control Model
SVT/IVT	Sentence/Inference Verification Task
UMD	University of Maryland, College Park
GAD-7	Generalized Anxiety Disorder-7 Rating Scale
PPQ	Post Passage Questionnaire
BAARS	Barkley Adult ADHD Rating Scale
WJ-III	Woodcock-Johnson III Tests of Cognitive Abilities and Tests of Achievement

Chapter 1: Introduction

The ability to comprehend text and discourse is the central goal of literacy at the heart of academic achievement and is an important indicator of life outcomes, including health, career, and economic freedom. However, only 37% of 4th graders and 36% of 8th graders can comprehend at proficient levels (NAEP, 2017). Several factors play a role in comprehension, including executive function (EF), also known as cognitive control in the neuroscience literature, which refers to an individual's ability to regulate, coordinate, and sequence thoughts and actions according to internal behavioral goals (Moss et al., 2011).

Executive functioning can be broken into components—including attention and working memory—which individually are predictive of comprehension. Comprehension is affected by attention, and this specific mechanism has been investigated at length in the attention deficit hyperactivity disorder (ADHD) literature (e.g., Brock & Knapp, 1996; Friedman et al., 2017; Stern & Shalev, 2013). Increasing numbers of children are being identified for specific learning disabilities, many of which are stemming from or comorbid with ADHD, cognitive processing, or broad EF difficulties (Powell & Voeller, 2004). These individuals have difficulty processing information, focusing attention, and regulating behavior, particularly in the context of academic tasks such as discourse processing and discourse comprehension. Discourse processing refers to the many levels of representation that are constructed when individuals read or listen to connected text, and discourse psychologists have developed models that specify how these levels are mentally represented and built during comprehension (Graesser et al., 1997; van Dijk & Kintsch, 1983). For the purpose of this paper, the terms "comprehension" or "discourse comprehension” will be used in the context of general discourse processing to differentiate from reading comprehension.

Accounting for the roles of attention and EF/cognitive control, another important factor to comprehension is motivation. If EF/cognitive control is the set of gears for maintaining and regulating mental goals and plans, motivation is the fuel for the system. Numerous studies have identified the role of motivation in developing literacy skills and academic achievement in general (e.g., Logan et al., 2011; Taboada et al., 2009; Neugebauer & Gilmour, 2020), wherein motivation predicts and causally influences reading comprehension assessment scores of K-12th grade students (Guthrie & Wigfield, 2005) and contributes heavily to comprehension independently of other cognitive processes (Taboada et al., 2009). Reading engagement—the level of involvement with text—is influenced by motivation (Guthrie et al., 1996). Engagement involves the joint functioning of motivation and cognitive strategies that result in comprehension and can be reflected in behavior, affect, or cognition (Guthrie et al., 2012). Relations between motivation and engagement may be bidirectional, with greater levels of each promoting achievement (Patall et al., 2016).

The question that this thesis aims to address is how differences in EF/cognitive control and clinical indicators of attention disorders interact with engagement/arousal to impact overall discourse comprehension. That is, if EF is the effortful process of planning, monitoring, and maintaining information (working memory) in the face of distraction (inhibition), and attention is required to maintain all of these processes, then the individual learner who is less attentionally aroused and engaged is less likely to invoke these mental functions, leading to poor comprehension. On the same note, a learner who struggles with these cognitive functions will likely depend on a text to be more arousing in order to engage and comprehend at all. Conversely, individuals who tend to have strong cognitive and/or attentional control will be better able to maintain engagement in reading regardless of the nature of the discourse or text.

One of the greatest difficulties in the study of motivation/engagement in discourse processing and comprehension has been observing engagement online in real-time while individuals process written text. Unfortunately, measures of engagement and motivation for reading are largely measured either before or after an event using self-report methodology or outside report (Picton, 2014). Not only does this lead to biases and errors from self-report, but this fails to provide a strong valid criterion for the extent and duration of engagement for sustained effortful tasks, like reading or listening.

Over the past twenty years, efforts to crack the code of measuring engagement in an ongoing effortful task using neural measures such as EEG has to lead to the successful development of adaptive online games (Ewing et al., 2016) and work environments (Scerbo et al., 2003). Specifically, these studies have used time-frequency measures such as power in the alpha (7-12Hz) and theta (4-7Hz) to gauge mental effort and arousal in real-time and to adapt such tasks to increase or decrease engagement, and activity in the alpha and theta frequency bands may reflect cognitive and memory performance (Klimesch, 1999). Applying this approach to educational studies of comprehension will have far-reaching benefits for education curricula and for online, machine-learning driven education platforms that may be able to track and adapt material based on individual performance and level of engagement with the content.

The primary goal of this thesis was to investigate whether arousal/engagement interacts with individuals' overall executive function ability and attentional capacity to affect discourse comprehension. Specifically, I set out to investigate psychophysiological markers of arousal during discourse comprehension in the brain by manipulating engagement through discourse characteristics and determining whether these markers fluctuate as a function of individual differences in cognitive control. Results from EEG measurement are presented as exploratory due to insufficient sample size, while behavioral results of the relationship between EF and engagement on comprehension are the focus of the paper to provide proof of concept and serve as a foundation to pursue an EEG study in the future.

The findings of this study have implications for literacy education and could help identify students with weaker overall executive functioning for early intervention and extra support during early literacy development. Identifying these variations in individuals for EF and understanding how they interact with engagement may provide a springboard for intervention research as well as adapting educational environments to prevent comprehension and learning failures.

Theoretical Background

Executive Function, Attention, and Cognitive Control

Executive Function

EF is important to health and achievement outcomes, and at its core includes processes such as cognitive flexibility, attention, working memory, and inhibition, which together comprise more complex processes such as reasoning and planning (Diamond, 2013). These functions, also called cognitive control functions, depend on late-maturing prefrontal cortex regions and are critical for success (Diamond, 2011). EF is associated with early literacy skills prior to and beyond kindergarten (Schmitt et al., 2017) and can be conceptualized as a single construct that differentiates into related but methodologically distinct subcomponents (i.e., inhibitory control, cognitive flexibility) with age (Anderson, 2002; Zelazo, 2020). Particularly, research demonstrates that the working memory and attention components of EF can influence academic achievement and reading comprehension (Booth et al., 2014; Cain et al., 2004; Kieffer et al., 2013; Miller et al., 2014). In individuals with ADHD, deficits in reading comprehension and achievement have been observed and attributed to attentional deficits (Brock & Knapp, 1996). However, more recent work has implied that ADHD may in fact be a disorder of EF rather than a disorder of attention (Castellanos et al., 2006; Martel et al., 2007). Some researchers have suggested that both attention and working memory, components of EF, underlie deficits seen in individuals with ADHD (Friedman et al., 2017; Kofler et al., 2010; Rapport et al., 2009).

Working Memory. Working memory (WM) in particular plays a central role in cognition and strongly relates to a person's ability to reason with new information and direct attention to goal-driven information. Traditionally, the contents of WM can be understood as "activated" representations from within long term memory that are currently within the focus of attention in limited capacities and has a multi-item limit (Cowan, 2011; Cowan et al., 2005). Numerous theories of working memory are present in the field, as working memory has been studied extensively. One approach has been to emphasize the unitary nature of WM as a general capacity model (e.g., (Engle et al., 1999; Engle, 2002; Kane & Engle, 2002), while another approach argues for a more domain-specific, non-unitary view (Cocchini et al., 2002, Unsworth & Spillers, 2010). Another popular model treats WM as a multi-component construct (Baddeley & Hitch, 1994; Hitch, 2002), the most well-known of which is the Baddeley model (Baddeley, 1992). This model suggests that WM is made up of multiple components: the visuo-spatial sketchpad, phonological loop, and central executive (Baddeley, 2002 & 2003). Thus, in the current study, working memory is assessed using a standardized test of cognitive abilities typically used in clinical practice.

Attention

Attention is the ability to attend to specific targets or regions that are relevant for the task at hand while not attending to, or inhibiting, irrelevant components (Diamond, 2013). Attention has been further classified as internal or external attention (Aron & Poldrack, 2005). In other words, it is the selection and modulation of sensory or internally generated information; working memory lies at the intersection of these two hierarchies by acting as a filter for what information is deemed relevant (Chun et al., 2011). Recently work has identified selective attention and WM as separable but interacting processes at both the cognitive (Awh et al., 2006; DeBettencourt et al., 2019) and the neural (Zanto & Gazzaley, 2009; Sahan et al., 2020) levels. Attention shifting has been shown to significantly influence reading comprehension along with inhibitory control in middle childhood (Kieffer et al., 2013). Behavioral attention, as rated by teachers, has also been shown to predict reading comprehension in third-grade students (Miller et al., 2014). Attention is crucial to building mental representations of language in context, and along with decreased comprehension accuracy and increased error rate, has been associated with changes in neural activity in the alpha band (Boudewyn & Carter, 2016; 2018).

While EF and its subcomponents certainly play a role in or even underlie many of the deficits seen in ADHD, researchers have suggested that measures of cognitive abilities do not necessarily align with rating measures, such that the measures do not pick up on the same aspects of EF (Toplak et al., 2013). This has specifically been suggested by ADHD researchers regarding clinical ADHD rating scales and performance-based tasks (Russell A. Barkley & Murphy, 2010; Epstein et al., 2003), which has been corroborated by recent work from my lab in a study showing no correlation between a clinical ADHD rating scale and performance-based tests of cognitive abilities (Weisman, 2020).

Continuous performance tests (CPT), however, demonstrate significant relationships to ADHD symptoms, and poorer performance on these tasks occurs in populations with ADHD (Epstein et al., 2003; (McGee et al., 2000). Specifically, performance on CPT in children with ADHD shows an association with inattention and vigilance symptoms (Egeland et al., 2009). Thus, to create an accurate indicator of EF ability, in this study, attention and working memory are viewed as critical cognitive ability components of EF and will be examined as indicators of EF separately from the continuous performance test, which will be examined alongside clinical self-report of ADHD symptoms. In this study, attention as a component of EF is measured both with a standardized test of cognitive abilities, and attention as a symptom of ADHD is measured using a clinical adult self-report scale for ADHD.

Cognitive Control

Individuals with EF difficulties or attention disorders struggle to process information, focus attention, and regulate behavior, particularly in the context of academic tasks. These tasks all make up critical components of EF, also known as cognitive control in the neuroscience literature. Cognitive control areas of the brain, such as the anterior prefrontal cortex, are activated when people engage in reading comprehension strategies, and brain regions associated with both cognitive control/EF and comprehension are activated during comprehension (Moss et al., 2011).

Cognitive control has been studied from a neurological perspective, of which the most notable framework is the dual mechanisms of control (DMC) model (Braver, 2012; Braver et al., 2009). This theory suggests that individuals differ with respect to being more “proactive” in their attentional control, allowing them to have sustained attention according to task goals, in comparison to being more “reactive” to events that occur in the environment. It is argued that those who are more proactive in their cognitive control have greater top-down (or self-directed) effortful control of their attentional or EF processes, whereas those who are more reactive in nature are more likely to depend on environmental cues to draw their attention and to maintain their effortful EF processes over long periods of time (Braver, 2012). Cognitive control is distinct from working memory in that the individual differences in working memory manifest as intra-individual variability in cognitive control, lending support to the DMC framework of low WM being associated with reactive control, and high WM associated with proactive control (Wiemers & Redick, 2018). Children also evidence a shift from the reactive to the proactive around age 7, and this shift develops in tandem with working memory

(Gonthier et al., 2019), suggesting a trait-like quality and developmental trajectory similar to that of other higher order cognitive abilities, becoming immutable after adulthood (Luck & Vogel, 2013).

The framework relies on the use of a continuous performance test (AX-CPT) to measure proactive and reactive cognitive control (Barch et al., 1997; Botvinick & Braver, 2015; Braver et al., 2009). The AX-CPT is expected to be associated with clinical indicators of ADHD symptoms and will serve as another measure of EF independently of tests of cognitive ability. The purpose of the breakdown of these measures is to distinguish the role of traits from states in an effortful task. Individuals' abilities may fluctuate from day to day, and cognitive tasks may not capture the depth of an individual's ability. However, this study manipulates the task context and relies on multiple measures of cognitive abilities, including a self-report rating scale of clinical ADHD symptoms, to address this. The key question that I will attempt to address is how differences in individual executive function abilities affect discourse comprehension, and how arousal/engagement with the situational context, in the form of emotional valence, interacts with these abilities to influence discourse comprehension.

Arousal, Motivation, and Engagement

Motivation is thought to be one of the key factors influencing reading comprehension and learning strategies for reading. Intrinsic motivation has been observed as a driving factor behind the growth of reading comprehension skills in readers with lower ability (Logan et al., 2011), and this motivation is predictive of short-term longitudinal growth of reading comprehension skills in fourth-grade students (Taboada, et al., 2008). Motivation underlies engagement such that it is a necessary precursor to engagement and the two influence one another in a bidirectional manner (Patall et al., 2016). Engagement is defined in terms of learners' active participation in learning contexts or commitment to learning goals; it is typically studied as cognitive, affective/emotional, or behavioral and often depends on interest and context of the environment (Renninger & Bachrach, 2015). The growth and long-term maintenance of reading engagement can be affected by situational/instructional context as well as individuals' motivation to read, student independence, and degree of teacher support (Guthrie & Wigfield, 2005; Wigfield et al., 2016). Both motivation and engagement play a role in and are important to comprehension outcomes, while taking external contextual factors into account (Guthrie & Wigfield, 2005).

On a neurological level, motivation is conceptualized as approach or avoidance in the context of goal-directed behavior (Arnsten & Rubia, 2012). Motivation requires arousal to facilitate interactions with the environment, but arousal is distinct from attention; arousal underlies the top-down modulation of attentive neural response and is a precursor for sustained attention (Knudsen, 2007; Posner & Petersen, 1990). Motivation, arousal, and attention are behavioral processes that rely on each other in the context of goal-driven behavior (Arnsten & Rubia, 2012), and arousal underlies cognitive and attentional workload in a goal-directed task (Gevins & Smith, 2003). Most recently, cognitive control is viewed as a domain of reward based decision making based on motivational factors (Botvinick & Braver, 2015) and positive emotional contexts (Chiew & Braver, 2013, 2014). Motivation and arousal interact with cognitive control in effortful tasks involving some type of decision-making, and stem from differential recruitment and integration of regions of the pre-frontal cortex (Kouneiher et al., 2009).

Given that arousal and motivation are important to cognitive control and task performance and are dependent on environmental context, it follows that individuals with lower EF ability and lower attentional capacity underperform on tasks requiring effortful control and motivation/engagement for task completion because they are unable to engage with the task to a sufficient level to perform highly. In other words, the environment may not be stimulating enough to trigger a high level of arousal and engagement in these individuals. Researchers have suggested that this may be the case, the primary examples being individuals with diagnosed ADHD (Anderson, 2002; (Loe & Feldman, 2007). When comparing clinical ADHD symptom rating scales and EF deficit rating scales, arousal predicted ADHD symptoms and related impairments (Kamradt et al., 2014). These individuals also show increased distractibility in continuous performance tests compared to typically developing controls (Cassuto et al., 2013). Additionally, individuals with ADHD tend to perseverate on or be influenced by the larger context during task performance, showing differential performance from healthy populations both behaviorally (Berger & Cassuto, 2014; López-Martín et al., 2013) and through differences in EEG activation patterns (Whalen et al., 1997). This pattern has also been observed in relation to lower cognitive abilities/EF (Straub et al., 2020). Therefore, arousal is an important factor in facilitating effortful task performance for individuals with ADHD and related EF deficits.

In order to measure arousal and engagement with the task, this study manipulated emotional valence through stories that participants heard and answered questions about, and examined arousal patterns in the alpha and theta frequency bands on EEG to measure cognitive engagement. Activation patterns in these two frequency bands have been shown to reflect cognitive performance and arousal in response to external cues (Klimesch, 1999). Emotion is significantly related to motivation, engagement, and achievement (Pekrun, 2006) and qualifies as a form of arousal from a neurological perspective. Emotional engagement can be viewed as a category of engagement, along with cognitive and behavioral engagement (Sinatra et al., 2015). Furthermore, emotional/affective valence of stories influence the mental representations created by readers when they comprehend (Gernsbacher et al., 1992). In this way, the study manipulates the context within which the task occurs as well as potential levels of arousal/engagement to examine its interaction with individual differences in EF/cognitive control and attention on task performance.

Comprehension

Comprehension is an important academic outcome that has been examined extensively in the literature; reading comprehension and its component skills (i.e., inference making, comprehension monitoring, story structure knowledge) are the most common outcomes that have been the focus of studies in language and education (Cain et al., 2004). Studies have demonstrated links between aspects of EF and comprehension, such as working memory (Cain et al., 2004) and attention and inhibition (Cain, 2006). In these studies, poor comprehenders showed lower ability to recruit aspects of working memory or inhibit their attention to irrelevant information. Studies have also demonstrated links between cognitive control and comprehension, wherein domain-general cognitive control is recruited during language comprehension with differing levels of specificity in brain regions (Fedorenko, 2014). Finally, as reviewed previously, engagement and motivation play a role in reading comprehension. However, it remains unclear how aspects of EF, cognitive control, and attention affect discourse comprehension in the context of emotional engagement.

Reading comprehension occurs in an academic context and has direct educational and developmental applications, but discourse comprehension encompasses a wider range of contexts within which comprehension occurs. Discourse comprehension involves constructing a mental representation of discourse, whether it is written or spoken, and different mental functions can be performed on this representation, which is taken as evidence for comprehension (Kintsch, 1988; van Dijk & Kintsch, 1983). The situation model suggests that comprehension is a bottom-up, flexible, and interactive process that is context-sensitive. Comprehending under this model involves the reader detecting pieces of information that make the text coherent, complete, and interpretable in relation to their prior knowledge, and can be inferred from both the text and prior knowledge. Multiple situation models may be constructed from the same text, and when people comprehend a story, they may make inferences that are not given directly in the text, being influenced both by the context within which they are hearing the story and their own prior experiences (Kintsch, 1988).

From this situation model, the SVT/IVT test was created by Royer and colleagues (Royer et al., 1979), which is based on the assumption that comprehension is a constructive process involving an interaction between incoming discourse (text or speech) and the individual's prior knowledge, allowing the person to create a representation that preserves meaning but not the exact verbatim of the discourse. Measuring discourse comprehension would ideally show how successful an individual was at establishing meaning (Royer, 2001). This model and test of comprehension is ideal to use in this study to determine the success at comprehending spoken discourse within particular environmental contexts (i.e., emotional valence of the passages heard).

For this study, I modified the SVT/IVT task slightly to include questions rather than statements to present them in a way that participants could indicate their answers in the affirmative or negative using a keyboard press. I also modified it by including some surface level items and some inference level items, and the inference level items included some that were detail-based and some global thematic questions. The reasoning for this is that research indicates that some readers who are affected by context make quick, surface level judgments, while others take more processing time to determine their judgments on a piece of discourse (Kintsch et al., 1990). I endeavored to measure depth of comprehension processing by creating questions that target both surface and deep levels of processing. Furthermore, memory for text base (the main details and overall ideas of the story) is better in auditory stories (Wannagat et al., 2018), which is the mode of presentation used in this study. I felt that this approach to comprehension measurement would provide a more representative reflection of comprehension ability while leaving room for the influence of context and individual attention and EF abilities.

Intersections of Executive Function, Attention, Engagement, and Comprehension

Recent studies have examined cognitive factors and the contributions of motivation and engagement in comprehension both behaviorally and neurally. A study from Cartwright and colleagues (Cartwright et al., 2020) examines the contributions of EF and motivation to reading comprehension. The authors examined the unique contributions of domain-general and reading-specific EFs and cognitive intrinsic motivation to reading comprehension beyond basic language comprehension and word-reading in 122 university students. They found that motivation and EF (including working memory, attention, and inhibition) uniquely contribute to reading comprehension, and reading specific EF (cognitive flexibility) contributes to comprehension beyond other predictors and controls. This study used multiple predictors of EF, motivation, and comprehension to construct a multifactor model with domain-general and reading-specific EFs and intrinsic motivation, but the study did not consider the influence of context, engagement with the context, or attention to comprehension. The study also examined reading comprehension with text in particular. However, this study laid a foundation for the current thesis by establishing a strong relationship between multiple facets of EF, motivation, and reading comprehension in a large sample of college students.

A study from Liu and Gu (Liu & Gu, 2020) examining the influence of learning situations on reading comprehension and attention in 129 Chinese 5^{th} graders. They investigated specific effects on comprehension, engagement, and attention when reading occurred in a continuous, congruous setting or an interrupted, fragmented one. Importantly, they found that the context within which reading processing occurred affected comprehension and attention scores and that there was a relationship between different levels of reading engagement and reading skill, such that readers with medium to high levels of engagement had high comprehension scores regardless of the context in which the reading occurred. This is an important foundation for the current study, and shaped my hypothesis that individuals with high levels of EF and attentional control will engage with the discourse regardless of the context.

Further, a review from Fedorenko (2014) examining the contributions of cognitive control and working memory to language comprehension suggests that the regions of the prefrontal cortex that are responsible for coordinating these processes interact, with domain general cognitive control brain circuits being necessary to understand linguistic input. According to reviewed brain-imaging data, cognitive control abilities and high-level linguistic processing are supported by neurally separate regions. This review demonstrated the relationship between cognitive control and high level discourse processing and comprehension, establishing a theoretical link between the two for further investigation alongside other variables.

Finally, a study from Boudewyn & Carter (2018) examined the relationship between comprehension and attention using EEG. Forty-four participants listened to two stories while being recorded on EEG and completed multiple choice comprehension questions. During listening, participants were probed to see if their attention was focused on listening to the story. They found that when participants indicated that they were not paying attention, the subsequent accuracy on comprehension questions was reduced. They also found increased oscillations in the alpha band during periods when participants indicated that they were not paying attention to the story. This study critically connects lapses in attention to decreased comprehension performance on both a behavioral and neural level, and demonstrates the usefulness of EEG in tracking engagement online during a discourse comprehension task. This study served as the primary inspiration for the current thesis, and established a relationship between states of attention and engagement on comprehension in real time.

While these other studies have examined executive function, attention, and the contributions of motivation/engagement to comprehension, no previous study to date has examined executive function and attention alongside ADHD symptoms, interactions with engagement, and effects on listening comprehension from a behavioral and neural perspective. Identifying variations in individuals for EF ability and understanding how these abilities interact with engagement in discourse comprehension will provide a springboard for intervention research as well as adapting educational environments to promote comprehension, and since motivation and engagement can vary by subject and by day (Neugebauer & Gilmore, 2020), this type of research may be helpful to promote comprehension and engagement in the content areas that are less engaging and arousing for most individuals. By using behavioral measures of comprehension in conjunction with neural measures of arousal and engagement, this relationship may be observed more directly in real time and used to hone the teaching methods for comprehension strategies or how they are programmed for use across electronic learning platforms.

Purpose

This study will examine working memory and broad sustained attention as components of EF as well as clinical self-report measures of ADHD and cognitive control, and how these components independently interact with emotional engagement to affect discourse comprehension in a listening task. While studies have examined EF, cognitive control, and engagement or motivation in comprehension (Cartwright et al., 2020; Fedorenko, 2014; Boudewyn & Carter, 2016) and attention and engagement (Liu & Gu, 2020), no study to date has examined both EF and cognitive control, while including clinical measures of ADHD, and their interactions with engagement/arousal on comprehension. This study also presents exploratory work with EEG examining alpha band activation patterns in the frontal lobe during a listening task, and how this activity may relate to comprehension. This study carries important implications for educational approaches to comprehension that may lead to new approaches in education to make teaching strategies more effective for students based on their individual EF capabilities and their levels of engagement and arousal with a variety of discourse across situational contexts.

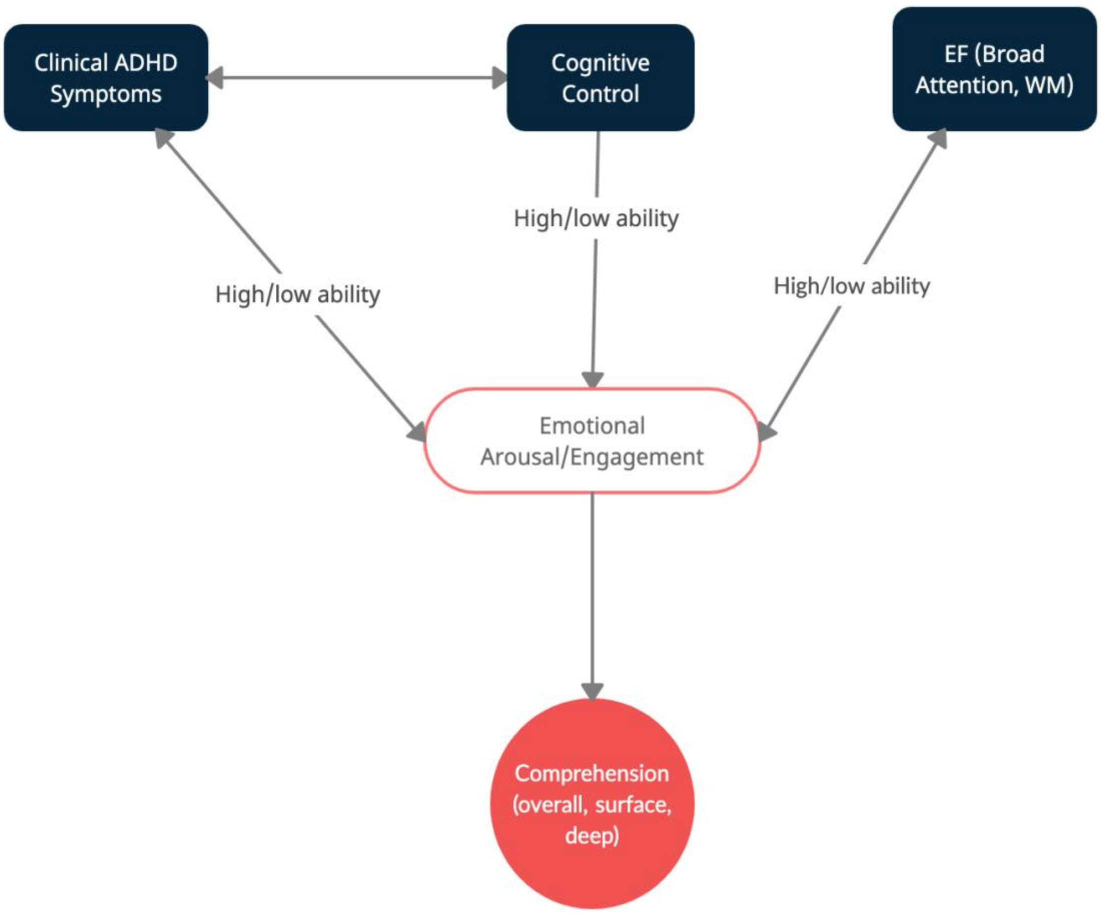
Hypotheses

The proposed study investigates whether comprehension performance fluctuates as a function of individual differences in executive function abilities by manipulating arousal/engagement through discourse characteristics. Figure 1 illustrates the theoretical model that I developed to investigate my research questions.

I predicted that individuals with better control of attention/less ADHD clinical symptoms, better overall executive function, and/or more proactive cognitive control will show stable comprehension performance regardless of emotional engagement with the story. Conversely, I predicted that comprehension in individuals with greater ADHD symptoms/lower control of attention, lower overall executive function, and/or reactive cognitive control would be driven by the emotional valence, or engagement with the situational context, for individual stories. Given that task performance in individuals with ADHD and individuals with low EF abilities are dependent on context (Carretié, 2014; Straub et al., 2020) and that individuals with ADHD require greater stimulation from the context to trigger arousal/attention to engage with a task (Barkley & Murphy, 2010), I expected that these individuals in my sample will show better comprehension in the emotional engagement condition versus the neutral condition. Arousal levels in the alpha band as measured on an EEG (frontal lobe alpha frequency bands) were considered exploratory analysis and may serve as an eventual psychophysiological measure of cognitive engagement.

Figure 1

Illustration of theoretical model



Chapter 2: Methods

Participants

Approval for the study was obtained from the University of Maryland (UMD) Institutional Review Board (IRB) before recruiting participants or running experimental measures. Participant recruitment was done through the UMD Psychology Sona system, the participant pool for psychology course credit. Additional recruitment was conducted through posting flyers in campus buildings to promote visibility to non-psychology students. Participants were eligible if they were native-English speaking UMD students and had normal to correct-normal vision and hearing.

Exclusion criteria were having a language disability or other neurological impairment impacting language, history of head injury leading to unconsciousness, neurological damage, a history of any kind of brain abnormality (such as cyst, tumor, etc.), or neurological disorder (such as cerebral palsy); seizures within the last 3 years, or current use of seizure medication; history of tic disorder or presence of any sort of tics. There were no exclusion criteria regarding previous psychological diagnoses. Even though this participant pool was not a clinical population, there was still interest in individuals with and without psychopathology to provide a more diverse spectrum of participants with varying attention and executive function skills.

Fifty-six participants were recruited from the Sona system to complete the study; of these, eleven were excluded due to missing data from attrition and one was excluded for being a non-native English speaker. Forty-four eligible participants completed the entire study (N = 44, both visits 1 and 2, spaced between 2-8 days apart) and were used for analysis. Of these, ten participants (n = 10) completed the EEG portion of the study and were considered in the exploratory analyses of EEG data.

Measures

This study used a variety of standardized questionnaires and cognitive tests, and some questionnaires and study measures were developed by my lab for use in previous studies. Detailed descriptions are provided.

Questionnaires

The Neuropsychology, Education, and Lifestyle Status Questionnaire. This questionnaire was written and used for a previous study in my lab for demographic and descriptive purposes. It was given to participants to self-report previous and current neurological/psychiatric diagnoses, medication use, educational status, and lifestyle factors at both visit 1 and 2. Most items on the questionnaire required yes/no responses with occasional explanations or elaborations required after a response of "yes." First, participants were asked to report any neuropsychological diagnoses and prescription medications, undergraduate class status, major, and approximate current GPA. Following those questions, participants were asked to report their average and current lifestyle factors, including items regarding amount of sleep, consumption of breakfast, amount of exercise, smoking, and substance use. See Appendix A for full questionnaire.

Post Passage Questionnaire (PPQ). The PPQ is a questionnaire developed in my lab for a previous study and was given to participants after they heard (or read, as in the pilot study described in the next section) a passage to assess different aspects of the passage and the participant's understanding of the content. Not all participants in the sample completed the PPQ (*n* = 37), so it is only used descriptively in this paper. The PPQ is a 7-item questionnaire that first has three Likert response scale items for arousal (1 being "completely unarousing," 4 being "neither unarousing nor arousing," and 7 being "completely arousing"), emotional valence (1 being "completely negative," 4 being "neither negative nor positive," and 7 being "completely positive"), and relatability (1 being "completely unrelatable," 4 being "neither unrelatable nor relatable," and 7 being "completely relatable"). Following those, there were three open-ended questions asking participants to summarize the passage they heard/read, explain how the passage made them feel, and list any emotions they experienced during or after hearing/reading the passage. Finally, participants were asked whether the passage evoked a memory (and if so, a positive or negative memory) or no memory. The Likert data from this questionnaire was used to initially select passages and to produce reliability and validity data for passage selection (McDonald's omega, $\omega = 0.48$). See Appendix A for the full questionnaire.

Barkley Adult ADHD Rating Scale-IV: Self Report: Current Symptoms (BAARS, Barkley, 2011). To assess levels of ADHD symptoms and domains of impairment, participants completed the BAARS, which consisted of 27 items reflecting the core symptoms of ADHD (9 items reflecting inattentive symptoms, 9 items reflecting hyperactive/impulsive symptoms, and 9 items reflecting sluggish cognitive tempo (SCT) symptoms commonly associated with ADHD) as defined by the DSM-V (American Psychiatric Association, 2013). This measure employed a Likert response scale ranging from 1 (symptom "Never or rarely" occurs) to 4 (symptom "Very often" occurs). Ratings of either a 3 (“Often”) or 4 (“Very often”) were considered symptomatic, and ratings of either a 1 (“Never or rarely”) or 2 (“Sometimes”) were considered asymptomatic or subclinical (see Appendix A for individual items).

General Anxiety Disorder-7 (GAD-7; Spitzer et al., 2006). To assess and screen for participants with high levels of anxiety symptoms and impairment, participants were asked to complete the GAD-7, which consists of 7 items reflecting participants' recent experience of generalized anxiety symptoms, as defined by the DSM-V (American Psychiatric Association, 2013), over the previous two weeks. This measure used a Likert response scale ranging from 0 (“Not at all”) to 3 (“Nearly every day”). The GAD-7 also prompted the participant to check off how difficult these symptoms have made it for them to function. There were four options ranging from “Not difficult at all” to “Extremely difficult” from which the participant can select. The GAD-7 is scored by totaling the symptom scores. The sum can total anywhere between 0 and 21 with total scores between 0-4 indicating minimal anxiety, scores between 5-9 indicating mild anxiety, scores between 10-14 indicating moderate anxiety, and scores between 15-21 indicating severe anxiety. See Appendix A for the full rating scale.

Cognitive Tests

Woodcock-Johnson III Tests of Achievement and Tests of Cognitive Abilities (WJ-III; Woodcock, McGrew, & Mather, 2001). To evaluate aspects of short-term memory, working memory, and attentional abilities, participants completed a selection of subtests from the WJ-III. Two subtests were selected from the Tests of Achievement (Story Recall–Immediate and Story Recall–Delayed) and four subtests were selected from the Tests of Cognitive Abilities (Numbers Reversed, Auditory Working Memory, Auditory Attention, and Pair Cancellation). The four selected subtests from the Tests of Cognitive Abilities make up the WJ-III broad attention battery, typically used to assess attentional abilities in a variety of clinical and non-clinical populations (Ford et al., 2003).

The tests used from Tests of Achievement are as follows: Story Recall–Immediate evaluates short-term memory and immediate recall for verbal information, and Story Recall–Delayed assesses longer-term memory. Stories increased in difficulty throughout the test. The tests used from Tests of Cognitive Abilities are as follows: Numbers Reversed assesses both short-term and working memory, Auditory Working Memory assesses both short-term and working memory, Auditory Attention assesses auditory processing, speech-sound discrimination, and resistance to auditory stimulus distortion, and Pair Cancellation which evaluates processing speed, attention, and concentration. For any subtest that required items to be read aloud to participants, the official WJ-III recording was played through speakers for participants to hear.

Continuous Performance Task (AX-CPT; Braver et al., 2009). The AX-CPT is a computerized sustained attention and working memory task. There are 4 standard trial types: AX, AY, BX, and BY – with B and Y as placeholders for any other letter that is not an X nor an A.

The relative proportions of these trials match that used in previous work (i.e., Barch et al., 1997; Braver et al., 2009; Braver, 2012; Troller-Renfree et al., 2020), with target sequences (AX) occurring on 70% of the trials, and the remaining 30% were divided equally among three of the non-target sequences: 1) invalid cue-target probe (BX); 2) valid cue non-target probe (AY); and 3) invalid cue non-target probe (BY).

Presentation time of cues and probes was 500 msec. The cue-probe delay interval was 1400-1600 msecs. Subjects performed the task continuously for 2-minute blocks, each of which contained 50 trials. There was a brief delay (~10-20 sec) between blocks, allowing the subject to rest prior to the next block and a screen display prompted the subject to take a break and press the spacebar when they were ready to continue. Participants completed a practice block of 60 trials which had to be completed at 70% accuracy or greater in order to move forward to the full test. The practice test (60 trials) and the full test (150 trials; 105 AX, 15 AY, 15 BX, 15 BY) took approximately 20-30 minutes to complete at the end of the first visit.

Passages

Three passages were selected to manipulate participants' arousal/emotional engagement during the story listening task. In order to select which texts to use, 10 pilot participants read 8 stories (one authored by a research assistant and two authored by public domain online sources) and provided initial data using the Post-Passage Questionnaire (described above) on arousal, emotional valence, and relatability for each passage. From this preliminary data, one neutral passage and two arousing passages, one positive valence and one negative valence, were selected to be used in the study. The passages were selected depending on highest mean rating across the pilot participants for each category of emotional valence across both the arousal and emotional valence Likert items (neutral passage average rating was 4.5, positive passage average rating was 6.1, and negative passage average rating was 1.4).

The neutral valence passage was an excerpt from the methods section of a biology laboratory report for a college-level biology course at UMD authored by an undergraduate research assistant in my lab. The passage outlines the specific methods for an experiment regarding the impact of different drugs on daphnia flies. As this passage was technical, it was intended to be un-arousing for participants and as close to neutral emotional valence as possible.

The positive valence emotional passage was an entry found on "Thought Catalog," an online platform for individuals to share their thoughts and feelings in a blog-style fashion, called "You Will Find These Words When You Need To" by Jacqueline Whitney. This passage is a series of inspirational, emotional, and thought provoking statements aimed to make the audience feel motivated, hopeful, content, and optimistic, emotion words that have been shown to characterize positive emotional valence in brain imaging data (Kensinger & Schacter, 2006).

The negative valence passage was a series of excerpts from a Washington Post article called "Sandy Hook Elementary shooting leaves 28 dead, law enforcement sources say" (Vogel et al., 2012). This article factually reports the events of the Sandy Hook Elementary School shooting from December 2012. The passage features quotes and accounts from people who were at the school in Newton on that day, or had close family and friends impacted by the event. The passage can be mildly graphic at times when it outlines some of the injuries or experiences that people underwent.

The passages were screened for complexity and chosen because they were written for adults with at least a high school level competency. For this reason, one of the exclusion criteria was non-native English speakers, since spoken English can be harder to understand than written text in English, and in this study, comprehension depended on processing and understanding spoken English at a proficient level. The passages were edited for grammar and then recorded (Audacity, version 3.0.0) with a reading speed of 120 words per minute. The audio files for each story were between 4.5-5 minutes in length.

The participant was prompted to listen to one of three passages while looking at the on-screen fixation cross. There was a 60 second resting period prior to the onset of each passage audio where participants were instructed to remain still and look at the on-screen fixation cross. Participants listened to two out of three possible stories and answered comprehension questions about those stories; all stimuli were presented using PsychoPy software (Peirce, 2007). All participants heard a neutral story, but participants were randomly assigned to listen to either a negative or a positive story. After the passage, the participants filled out the PPQ for the preceding passage.

Comprehension Questions. This set of five sentence verification and ten global comprehension questions was used to assess participant comprehension for each of the three passages. They required both shallow and deep levels of processing and were based on the Sentence and Inference Verification Techniques (SVT & IVT; Royer, 2001; Royer et al., 1996). The SVT task was used as outlined in Royer (2001) for the five sentence verification questions; sentences presented to participants were either original, meaning change, or distractor sentences. Participants were asked to press the Y key (if yes) or N key (if no) to answer if they thought the sentence shown on the screen was exactly from the passage. The IVT task was modified from Royer (2001), and questions were presented in the form of questions rather than inference statements in order to create ease of response for participants using a keyboard press to answer the question in the affirmative or the negative. Five of the global comprehension questions were near inference questions that required the participant to take information from the passage and draw a valid inference connecting the information. The other five comprehension questions were questions that required the participant to verify details from the passage. Participants were instructed to advance to the next screen for the comprehension questions. Participants were shown sentences on the screen and asked to press the “Y” key if the sentence shown was verbatim from the passage or the “N” key if it was not. Similarly, they were then asked yes/no response detail and main idea comprehension questions about the passage and were instructed to respond using the “Y” and “N” keys in the same way as before. By including these types of questions, the study required shallow and deep processing of the stories (Royer, 2001).

Procedure

This study was completed in two visits, each lasting between 45 and 90 minutes. The first visit was used to obtain questionnaire data and run cognitive assessments to assess attention and working memory. 2-8 days later (as per the WJ-III Story Recall–Delayed limits), the second visit was used to collect data for the experimental comprehension task under different levels of laboratory-induced emotional load to manipulate level of engagement with the task. A small subset of participants (n = 10) completed visit 2 with EEG to collect electrophysiological data. Experimental measures in each visit lasted between 45-90 minutes, though for EEG participants, visit 2 typically lasted closer to 120 minutes due to EEG set up and clean up.

Visit 1

Questionnaires. After obtaining informed consent from each participant, participants were asked to fill out the Neuropsychology, Education, and Lifestyle Status, PSS, GAD-7, and BAARS questionnaires (see Materials for descriptions).

Cognitive Assessments. After completing the questionnaires, participants completed the cognitive assessment portion of the study. First, the researcher administered one subtest from the Woodcock-Johnson Tests of Achievement: Story Recall–Immediate, where the participant was instructed to listen to a recorded story and then repeat it back as close to verbatim as possible immediately after hearing it through the speakers. Following this, the researcher then administered the Broad Attention Battery from the Woodcock-Johnson Tests of Cognitive Abilities. This battery featured four subtests, described below.

Numbers Reversed. The participant was instructed to listen to a string of numbers from a recording and then repeat back the numbers in backwards order between trials. The test begins with four numbers per string and, if the participant makes it to the end, finishes with eight numbers per string. The string of numbers gets one number longer after every four trials. Basal and ceiling rules were applied.

Auditory Working Memory. The participant was instructed to listen to a string of numbers and things from a recording and then repeat back first the numbers in the order they heard them, and then the things in the order they heard them. The test begins with a combined total of three numbers and things and, if the participant makes it to the end, finishes with a combined total of eight numbers and things. Strings get longer by one number or thing every three trials. Basal and ceiling rules were applied.

Auditory Attention. This task required the participant to listen to a recording of words and, after each word, point to the corresponding picture. However, the recording has intentional background noises that get increasingly louder throughout the test to make it harder to hear the words being spoken. Before beginning the test, the researcher trained the participant on the words and corresponding picture pairs.

Pair Cancellation. The participant was first shown two sample pictures: one of a soccer ball and one of a dog. The participant was then told that their job for this test was to draw a circle around any instance of a ball followed by a dog. They were then shown that there were other pictures across the row (coffee cups) and that each picture in the row was either a dog, a ball, or a cup. Before completing the test, the participant completed a sample item with two rows of pictures to ensure comprehension of the task. The participant had three minutes to complete the test with 21 rows (with 23 picture items per row).

Continuous Performance Test (AX-CPT). Participants completed an adapted version of the AX-CPT task (Barch et al., 1997; Braver et al., 2009, Braver, 2012), administered using E-prime stimulus presentation software (Psychology Software tool, Inc., Sharpsburg, PA). As different letter-pairings are flashed on the computer screen (one letter at time), the participant pressed either 2 or 3 on the keyboard depending on the letter and its pair. For any first letter, the participant should press 2 as soon as they can following the letter flashing on the screen. As for the second letter, the participant should press 2 for all second letter pairs, except if the second letter is an X that was preceded by an A. For example, in the AX pairing only, the participant would press 2 after the A and then 3 after the X. Stimuli were presented against a black computer screen and participants were seated 30 inches away from the screen. Participants trained on a set of 60 practice trials before completing the real test. The real test had 150 trials broken into 3 blocks and took about 20-30 minutes. To encourage sustained attention, participants were encouraged to respond as quickly and accurately as possible. See Appendix A for an example of a trial in the task.

Story Recall-Delayed. After the AX-CPT, the researcher administered the final cognitive test, Story Recall–Delayed from the Woodcock-Johnson III Tests of Achievement. The test began with the researcher reading the first few words of the stories heard in Story Recall–Immediate (approximately 90 minutes earlier). Participants were instructed to repeat back as much of the rest of the story as they could remember from the point the prompt stopped to the end of the story.

Visit 2

When the participant returned to the lab for their second visit, they started with the visit 2 questionnaire set, which included the current lifestyle factors section of the Neuropsychology, Education, and Lifestyle Status Questionnaire; and the PSS. Then, for the subset of EEG participants, before proceeding with the experiment, the researcher set up the EEG.

EEG recording. For EEG participants, the EEG data were recorded from 32 Ag/Cl lined electrodes in a neoprene cap (Neuroelectrics, Barcelona, Spain) placed in locations corresponding to the 10-10 system nomenclature (Chatrian et al., 1988): P7, P4, Cz, Pz, P3, P8, O1, O2, T8, F8, C4, F4, Fp2, Fz, C3, F3, Fp1, F7, Oz, PO4, FC6, FC2, AF4, CP6, CP2, CP1, CP5, FC1, FC5, AF3, T7, PO3. A clip electrode on the earlobe served as both ground and reference during recording. EEG data were recorded (NIC2

Recording Software) at 500Hz sampling rate. Data and event triggers were transmitted to the recording computer (Macintosh, Cupertino, CA) via a Wi-Fi transmitter attached to the cap. Impedances were kept below 10 kOhms. Participants were seated in a chair with their heads placed on a chinrest, to decrease movement and ensure that they were a consistent distance from the screen. The chinrest was placed 30 inches away from the Dell LCD desktop monitor. The recording computer was equipped with a mouse, keyboard, and speakers in the experiment room, which was kept quiet and dimly lit. During EEG tasks, experimenters continuously monitored the EEG recording from an adjacent room and provided feedback regarding excessive movement to the participants when necessary.

Passage-Listening Task. The participant was prompted to listen to one of three passages while looking at the on-screen fixation cross. There was a 60 second resting period prior to the onset of each passage audio where participants were instructed to remain still and look at the on-screen fixation cross. Participants listened to two out of three possible stories and answered comprehension questions about those stories; all stimuli were presented using PsychoPy software (Peirce, 2007). All participants heard a neutral story, but participants were randomly assigned to listen to either a negative or a positive story. Story order was counter-balanced so that participants had an equal chance of being in the negative or positive story conditions. After the passage, the participants filled out the PPQ for the preceding passage. Participants were then instructed to advance to the next screen for the comprehension questions.

Story Recall-Delayed. After the passage comprehension task, the researcher administered the Story Recall–Delayed from the Woodcock-Johnson III Tests of Achievement again using the same procedure described previously.

Analytic Plan

Behavioral Analyses

ADHD Symptoms (Attention). This predictor was measured using the Barkley Adult ADHD Rating Scale (BAARS). Scores were calculated for each dimension of symptoms endorsed by participants (Inattention, Hyperactivity, Impulsivity) and added to get the total number of ADHD symptoms for each participant. The total number of ADHD symptoms were used for data analysis.

Cognitive Abilities (Executive Function). This predictor was measured using subtests from the Woodcock-Johnson III Tests of Achievement and Cognitive Abilities. All WJ-III raw scores were entered into the WJ-III scoring software and scored using age-based norms to produce standard scores and z-scores for each subtest, as well as combining across subtests to produce the Broad Attention Battery and Working Memory Battery scores. The z-scores for these two batteries were added together to create an overall, standardized composite score for the WJ-III for each participant, which was used for analysis.

Cognitive Control. This predictor was measured using the AX-CPT (Braver et al., 2009, Braver, 2012). The data from the AX-CPT were cleaned in the following way: all non-responses on any trials were removed, as well as any trials with reaction times (RT) below 100 ms or above 3 standard deviations (1,100 ms). All accuracy and error scores for each of the four trial types were calculated as proportions of the number of correct or incorrect responses out of the total number of responses made by each participant. Accuracy and response times were separately averaged for AX, AY, BX, and BY trials for each participant. Two subjects made just one response across all 3 blocks of trials, so their accuracy, error, and RT data were replaced with the group means for each of the four trial types (see Appendix B for report of group means and standard deviations).

Additionally, two behavioral composites were computed: the PBSI (Proactive Behavioral Score Index) and the d'prime context. The first composite, PBSI (Braver et al., 2009; Troller-Renfree et al., 2020), compares performance on AY trials relative to BX trials. Higher scores indicate increased use of proactive control, and lower scores indicate more reactive control. The PBSI was calculated for both errors and RT. A PBSI sum was computed by adding PBSI for errors to PBSI for RT. The PBSIs were calculated using the following equation:

$$PBSI = (\mathrm{AY} - \mathrm{BX}) / (\mathrm{AY} + \mathrm{BX}).$$

Following recommendations for Braver and colleagues (2009), the following correction was made for PBSI accuracy computation to avoid errors equaling to zero:

$$PBSI\ accuracy = (error + 0.5) / (frequency\ of\ trials + 1).$$

The PBSI sum was z-transformed with respect to each subject's grand mean error and RT across all trials to correct for individual differences in overall processing speed and to increase statistical power.

The second composite computed was the d' context, or d'prime interference, (Cohen et al., 1999) which compares the sensitivity to the X probe in the presence and absence of an informative contextual cue, and thus provides a measure of sensitivity to context. To do this, I examined performance on two trial types -- AX and BX. These trial types have the same probe (X) but different cues (A vs B). To calculate the measure, I took the hits (proportion correct) on AX trials and subtracted the false alarms (proportion errors) on BX trials. For instance, if the participant guessed every time they saw an 'X' probe because they did not remember the cue, they would have approximately 50% AX hits and 50% BX false alarms -- a score near 0. The more a participant remembers the cue identity (A vs B) the more accurate they should be on AX and BX trials, which increases the AX hit rate and decreases the BX false alarm rate, thus yielding a higher d' score. The higher the score, the more the cue identity was used to inform the response. The d' context was computed using the following formula:

$$d' = z\text{AX hits} - z\text{BX error}$$

Comprehension. This outcome variable was measured using the comprehension questions described previously. Kuder-Richardson formula 20 (ρ_{KR20}) for reliability of assessments with dichotomous, equal difficulty items indicated reasonable internal reliability of the positive and the neutral story questions. Each set of comprehension questions included 5 sentence level and 10 inference level items, and each participant answered a total of 30 questions; 15 following the neutral story (ρ_{KR20}= -0.88) and 15 following either the positive story (ρ_{KR20}= -0.60) or the negative story (ρ_{KR20}= 0.28) depending on which condition they were randomly assigned. Comprehension data were separated for within-subjects analysis across conditions: total comprehension on all 30 questions, total comprehension on 10 surface questions, and total comprehension on 20 inference questions. Data were also separated for within-subjects analysis by condition, neutral and emotional (positive and negative combined): total comprehension, total surface level comprehension, and total deep level comprehension. Finally, data were separated for between-subjects analysis by total comprehension for positive and negative conditions. All raw comprehension scores were converted to proportions based on correct responses.

EEG Analysis

Data Preprocessing and analysis. EEG data were preprocessed using the EEGlab toolbox (Delorme & Makeig, 2004) in Matlab and customized Matlab scripts (Matlab 2019b, MathWorks, Inc; EEGLAB v.14.1.2). The continuous EEG data were filtered (low-pass 40Hz, high-pass 0.3 Hz). EOG and EMG artifacts (eye and muscle movements) were corrected using independent component analysis (ICA) decompositions with the 'runica' algorithm (Jung et al., 1998). Independent components (ICs) identified as eye movement related (EOG) by visual inspection were manually rejected and interpolated. EEG data were re-referenced to the average reference. After this cleaning procedure, epochs corresponding to the duration of each passage and resting period, respectively, were created.

Frequency analysis. Each epoch was subdivided into a series of 2-second segments. Data for each electrode in each segment were tapered using a Hann window, where *t* is a list of each sample in the segment and *n* is the total number of samples in each segment:

$$w(t) = \frac{1}{2} \times (1 - \cos (\frac{2\pi t}{n - 1})$$

This was done to avoid any artifacts around the segment edges. Power spectra were calculated for each segment by applying a Fast Fourier Transformation (FFT) to the tapered EEG (voltage) data, multiplying the result ($re^{i\phi}$) by the complex conjugate ($re^{-i\phi}$), and dividing the result by the sampling frequency (*fs*), then taking half of the results, as expressed by the following formula, where n is the Nyquist frequency (½ × *fs*):

$$\sum_{1}^{n} \frac{re^{i\phi} \times re^{-i\phi}}{fs}$$

The length of the 2-second segment sampled at 500 Hz meant that there was a frequency resolution of .5 Hz. The mean of the electrode data ($\mu V^2/Hz$) corresponding to each of two frequency bands, alpha (7-12 Hz) and theta (3-6.5 Hz), was taken for each segment, for each passage and resting state block, for each participant.

Chapter 3: Results

Behavioral Results

The data were analyzed in two different ways: behaviorally using a within-subjects and a between-subjects analysis, and neurally using an exploratory EEG correlation analysis.

Descriptive Statistics

The data were screened for sporadic multivariate outliers as recommended by (Hawkins, 1980). Significant outliers were not found after cleaning the data as described in the methods section, however scores across all raw predictor variables were somewhat intercorrelated. Sample demographics are displayed in Table 1, including average age, hours of sleep, diagnoses of depression, anxiety, ADHD, or learning disorder (LD), and GAD-7 scores. Descriptive statistics for raw and composite predictor variables are displayed in Table 2, and sample means for depth of comprehension, both total and by emotion conditions (the emotional variable includes both emotional stories, whether it was a negative or a positive story, as well as the difference between the conditions), as the dependent variables are displayed in Table 3. Average ratings on the PPQ for the positive, negative, and neutral stories from both pilot and study participants can be found in Appendix B.

Table 1

Sample Demographics

	N	M	SD	Minimum	Maximum
Age	44	19.7	1.05	18.00	22.00
Hours of Sleep	44	6.94	1.11	5.00	10.00

Depression[a]	44	0.21	0.41	0.00	1.00
Anxiety[b]	44	0.30	0.46	0.00	1.00
ADHD[c]	44	0.07	0.26	0.00	1.00
LD[d]	44	0.07	0.26	0.00	1.00
GAD-7[e]	44	5.73	3.91	1.00	16.00

Note. [a,b,c,d] 0: no diagnosis, 1: yes for diagnosed disorder

[c] ADHD: Attention Deficit Hyperactivity Disorder (any subtype)

[d] LD: Learning Disorder

[e] GAD-7: Generalized Anxiety Disorder scale. A score of 10 or greater on the GAD-7 is a cutoff point for clinical Generalized Anxiety Disorder. A score of 5, 10, and 15 might represent mild, moderate and severe levels of anxiety respectively

Table 2

Descriptive Statistics for Predictor Variables

	N	M	SD	Skewness	Kurtosis
Raw Scores					
PBSI Accuracy	44	0.03	0.05	-0.34	0.43
PBSI Reaction Time	44	0.22	0.11	-0.81	1.46
D'prime Interference	44	$2.27x10^{-4}$	1.57	-1.33	0.48
BAARS Total ADHD Symptom Count[a]	44	3.61	3.87	1.18	0.63
WJ Working Memory[b]	44	0.61	0.75	-0.15	-0.53
WJ Broad Attention[b]	44	0.20	0.73	-0.14	0.68
Composite Scores					
PBSI Composite[c]	44	$-5.00x10^{-19}$	1.69	-0.52	1.90
WJ Composite[d]	44	0.81	1.44	-0.09	-0.11

Note .[a] BAARS: Barkley Adult ADHD Rating Scale. The BAARS has 3 dimensions characterizing clinical ADHD Symptoms. The Total ADHD Symptom Count is the total number of ADHD symptoms endorsed across all 3 dimensions. A symptom count of 5 or higher is considered clinically significant

[b] WJ: Woodcock-Johnson III, Working Memory and Broad Attention battery z-scores

[c] PBSI Composite: Proactive Behavioral Scale Index, composite is accuracy and reaction time z-scores added together

[d]WJ Composite: Woodcock-Johnson III, Working Memory and Broad Attention battery z-scores added together

Table 3

Descriptive Statistics for Outcome Variables

	N	M	SD	Skewness	Kurtosis
Overall Comprehension					
Total	44	0.74	0.08	-0.11	-0.19
Emotional	44	0.76	0.12	0.24	-0.89
Neutral	44	0.72	0.08	-0.72	-0.02
Emotional - Neutral	44	0.04	0.14	0.01	-0.72
Positive	21	0.69	0.09	0.46	-0.38
Negative	23	0.82	0.11	-0.09	-1.19
Positive - Neutral	21	-0.03	0.11	0.15	0.38
Negative - Neutral	23	0.10	0.14	-0.63	-0.11
Surface Comprehension					
Total	44	0.83	0.13	-0.70	0.12
Emotional	44	0.81	0.19	-0.41	-0.98
Neutral	44	0.86	0.17	-1.012	0.26
Emotional - Neutral	44	-0.05	0.24	-0.06	-0.60
Positive	21	0.71	0.18	0.17	-0.48
Negative	23	0.90	0.15	-1.07	-0.17
Deep Comprehension					
Total	44	0.69	0.09	-0.39	-0.29
Emotional	44	0.73	0.14	0.06	-0.52
Neutral	44	0.65	0.10	-0.30	-0.20
Emotional – Neutral	44	0.08	0.16	0.13	-0.62
Positive	21	0.67	0.11	0.14	-0.50
Negative	23	0.79	0.14	-0.41	0.03

Correlations

Bivariate and partial correlations were conducted on predictor and outcome variables to examine the relationships between predictors and between predictors and outcomes. Intercorrelations between predictors and correlations between predictors and outcomes (i.e., total comprehension, surface comprehension, and deep comprehension across all emotional and neutral story conditions) are displayed in Figures 2 and 3.

Figure 2 displays correlations using the AXCPT PBSI scores. The PBSI Accuracy and Reaction Time scores showed a moderate positive correlation ($r = .43$, $p = .004$). The WJ Working Memory and Broad Attention scales showed a strong positive correlation ($r = .87$, $p < .001$). The WJ Working Memory scale showed a moderate negative correlation with PBSI Accuracy ($r = -.42$, $p = .005$) and the WJ Broad Attention scale showed a moderate negative relationship with PBSI Accuracy ($r = -.39$, $p = .009$). The WJ-III Broad Attention and Working Memory z-scores produced by the WJ-III scoring software (Woodcock, McGrew & Mather, 2001) were used for analysis. A composite score was created by combining these two scales due to their high intercorrelation. A composite score was also created for the PBSI Accuracy and Reaction Time scores due to their high intercorrelations. The PBSI composite score for the AXCPT and the WJ Composite score were both not related to the outcome variables, and were not retained for further analysis.

Figure 3 displays correlations using the AXCPT d'prime interference scores, which is a calculation that indicates sensitivity to context, as described in the Methods section. There was a moderate positive bivariate correlation between the d'prime interference AXCPT score and total comprehension across all conditions ($r = .30$, $p = .043$), and a moderate positive bivariate correlation of d'prime interference with deep comprehension across all conditions (*r* = .39, *p* = .009). Intercorrelations between predictors showed that the BAARS and the AX-CPT d'prime interference were not related to each other, and both were retained for further analysis. See Appendix B for full correlation tables.

The d'prime interference score was retained for further analysis due to its correlations with total and deep comprehension. The BAARS ADHD total symptom count was also retained for further analysis because of my hypothesis that individuals who have higher ADHD symptoms would show differential performance on comprehension measures.

Figure 2

Intercorrelations when including AX-CPT PBSI scores

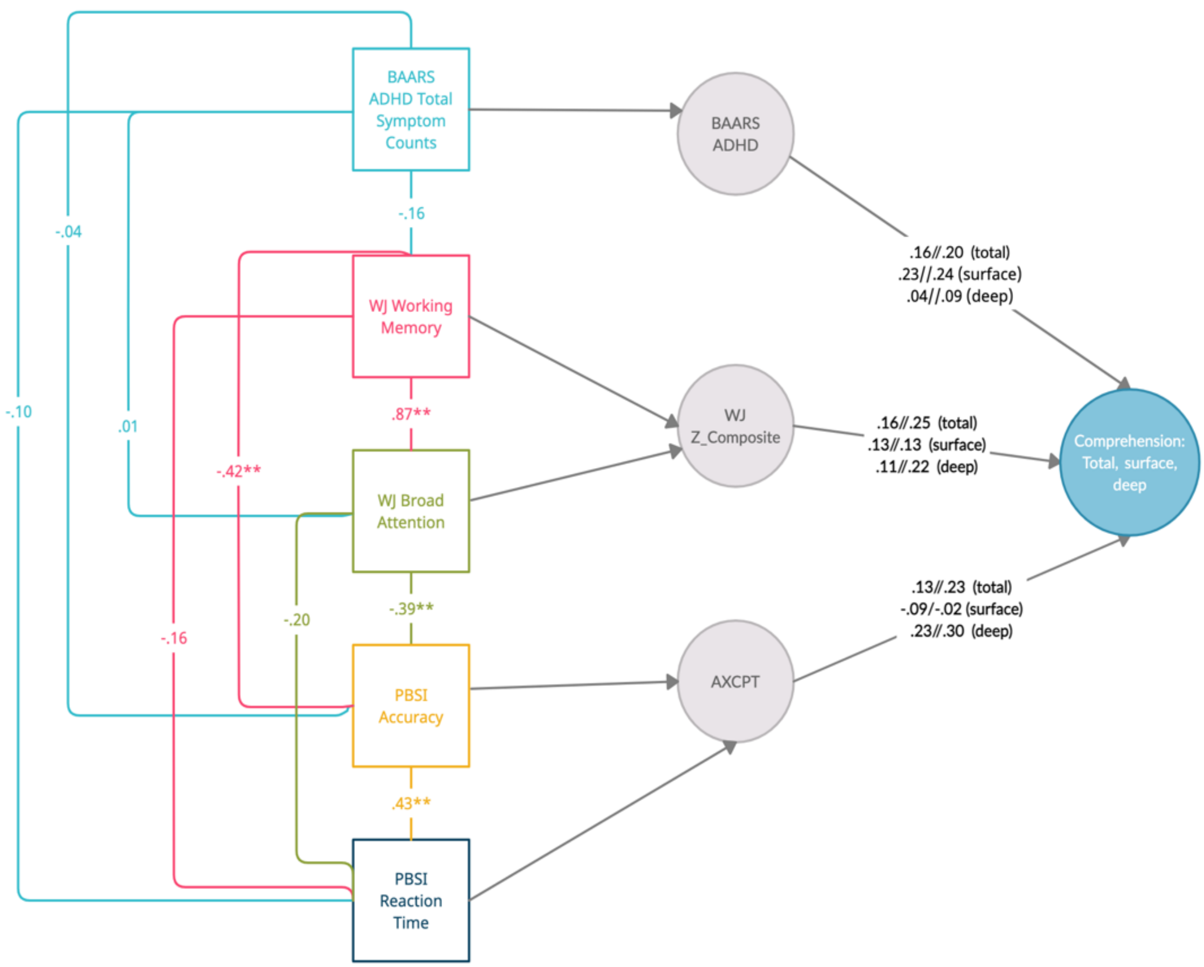
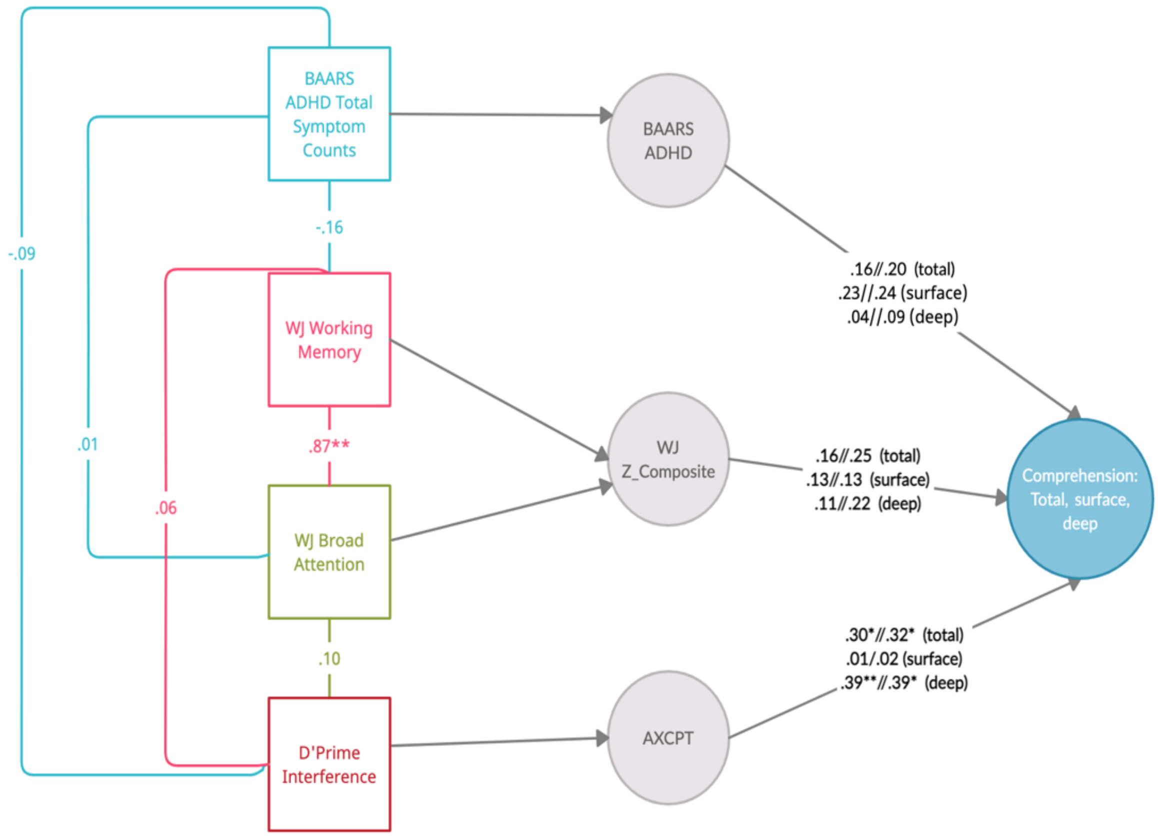


Figure 3

Intercorrelations when including AX-CPT d'prime Interference scores



Analysis of Variance

A within-subjects analysis of variance found that participants' comprehension was influenced by the level of discourse comprehension and the arousal from the story that they heard. The analysis was conducted having two levels of depth of comprehension (surface and deep) and two levels of arousal (emotion and neutral) to examine the differential impacts between these two variables. Effect sizes were calculated according to recommendations from Richardson (2011). ADHD symptoms, executive function, and cognitive control were included as covariates. There was a main effect of depth of processing, F (1, 40) = 9.76, p = .003, η^2_p = .20, with a large effect size, indicating that depth of processing comprehension scores were significantly greater for surface (M = 0.83, SD = 0.13) than for deep (M = 0.69, SD = 0.09) levels of discourse processing in this sample. There was a main effect of arousal, with an F ratio of F (1, 40) = 5.14, p = .029, η^2_p = .11 with a medium effect size, indicating that arousal was greater in the emotional (M = 0.76, SD = 0.12) story than in the neutral (M = 0.72, SD = 0.08) story condition. There was an interaction effect between depth and arousal, though the effect size was small (F (1, 40) = 5.64, p = .022, η^2_p = .02). The covariates did not predict the outcomes, but an interaction between BAARS total ADHD symptom count and arousal was observed with medium effect size, F (1, 40) = 11.66, p = .001, η^2_p = .12. The results are displayed in Table 4.

Table 4

Repeated Measures, Fixed Effects ANOVA using comprehension as the criterion

	df	Mean Square	*F*	*p*	Partial η^2
depth	1	0.22	9.76	.003**	.20
depth* d'prime[a]	1	0.05	1.98	.167	.05
depth*BAARS ADHD[b]	1	0.03	1.12	.297	.03
depth*WJ	1	0.01	0.22	.642	.01
error	40	0.02			
arousal	1	0.10	5.14	.029*	.11
arousal*d'prime	1	0.04	1.79	.188	.04
arousal*BAARS ADHD	1	0.23	11.66	.001**	.23
arousal*WJ[c]	1	0.05	2.46	.124	.06
error	40	0.02			
depth*arousal	1	0.10	5.64	.022*	.12
depth*arousal*d'prime	1	0.05	2.74	.106	.06
depth*arousal*BAARS ADHD	1	3.19×10^{-5}	0.002	.966	< .001
depth*arousal*WJ	1	0.01	0.36	.552	.01
error	40	0.02			

Note. [a] d'prime: AX-CPT scores d'prime interference calculation

[b] BAARS ADHD: Barkley Adult ADHD Rating Scale Total ADHD Symptom Count number

[c] WJ: Woodcock Johnson III Working Memory and Broad Attention Composite Score

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Linear Regressions

A series of linear regressions were conducted to examine the effects of ADHD symptoms and indicators of cognitive control on discourse comprehension. Effect sizes were calculated according to recommendations from Cohen (1988).

Results of the linear regression indicated that ADHD symptoms and cognitive control predicted overall comprehension in the difference between emotional and neutral conditions with a large effect size, accounting for 26% of the variance (F (2, 41) = 7.37, p = .002, R^2 = .26). ADHD symptoms predicted overall comprehension, with a medium effect size and accounting for 21% of variance (F (1, 42) = 11.05, p = .002, R^2 = .21) Also, ADHD symptoms and cognitive control jointly predicted deep level of comprehension with a large effect size, accounting for 33% of the variance (F (2, 41) = 10.13, p < .001, R^2 = .33). ADHD symptoms predicted deep level of comprehension with a medium effect size and accounted for 17% of the variance (F (1, 42) = 8.48, p = .006, R^2 = .17). Cognitive control predicted deep level of comprehension with a medium effect size and accounted for 13% of the variance (F (1, 42) = 6.44, p = .015, R^2 = .13). Results are summarized in Table 5.

Table 5

Linear Regression for Comprehension in the Difference Between Emotion and Neutral Conditions at Overall, Surface, and Deep Levels of Processing

	F	p	R^2
Overall Comprehension			
BAARS ADHD[a]	11.05	.002**	.21
d'prime[b]	1.65	.206	.04
BAARS ADHD, d'prime	7.37	.002**	.26
Surface Comprehension			
BAARS ADHD	3.83	.057	.08
d'prime	0.05	.827	.00
BAARS ADHD, d'prime	1.87	.167	.08
Deep Comprehension			
BAARS ADHD	8.48	.006**	.17
d'prime	6.44	.015*	.13
BAARS ADHD, d'prime	10.13	<.001***	.33

Note. [a] BAARS ADHD: Barkley Adult ADHD Rating Scale Total ADHD Symptom Scores

[b] d'prime: AXCPT d'prime interference calculation

*$p < .05$, **$p < .01$, ***$p < .001$

Finally, a linear regression was conducted to examine whether ADHD symptoms or cognitive control predict comprehension under positive versus negative emotional valence conditions. ADHD symptoms and cognitive control predicted comprehension performance under the difference between negative and neutral conditions with a large effect size, and accounted for 30% of the variance (F (2, 20) = 4.24, p = .029, R^2 = .30). ADHD symptoms alone predicted comprehension performance under the difference between negative and neutral conditions with a large effect size and accounted for 27% of the variance (F (1, 21) = 7.64, p = .012, R^2 = .27). Results are displayed in Table 6. Further analysis of surface versus deep comprehension in the negative and positive story conditions was not pursued due to low sample size for analysis of between groups individual differences (n = 21 in positive condition, n = 23 in negative condition).

Table 6

Linear Regression for Overall Comprehension in the Difference Between Positive, Negative, and Neutral Conditions

	F	p	R^2
Negative - Neutral			
BAARS ADHD[a]	7.64	.012*	.27
d'prime[b]	0.65	.430	.03
BAARS ADHD, d'prime	4.24	.029*	.30
Positive - Neutral			
BAARS ADHD	0.13	.722	.08
d'prime	0.15	.706	.09
BAARS ADHD, d'prime	0.20	.820	.02

Note. [a] BAARS ADHD: Barkley Adult ADHD Rating Scale Total ADHD Symptom Scores

[b] d'prime: AXCPT d'prime interference calculation

*$p < .05$, **$p < .01$, ***$p < .001$

Exploratory EEG Results

Exploratory EEG analyses were conducted with a subset of the sample who volunteered to participate in EEG recording (n = 10). Analyses did not examine participants in the positive condition due to the fact that there were too few individuals who received the positive passage (n = 3), while six (n = 6) participants were in the negative passage condition. EEG analyses included individuals who received the negative passage and the neutral passage (all participants, n = 10). Average values for each subject were created, first by creating an averaged value across frequencies within a band (3-6.5 Hz and 7-12 Hz) at each channel for each 2-second segment (see segmenting procedure, above). Subject averages for each frequency band and channel were created by averaging these (frequency × channel) values across segments.

Behavioral Correlations

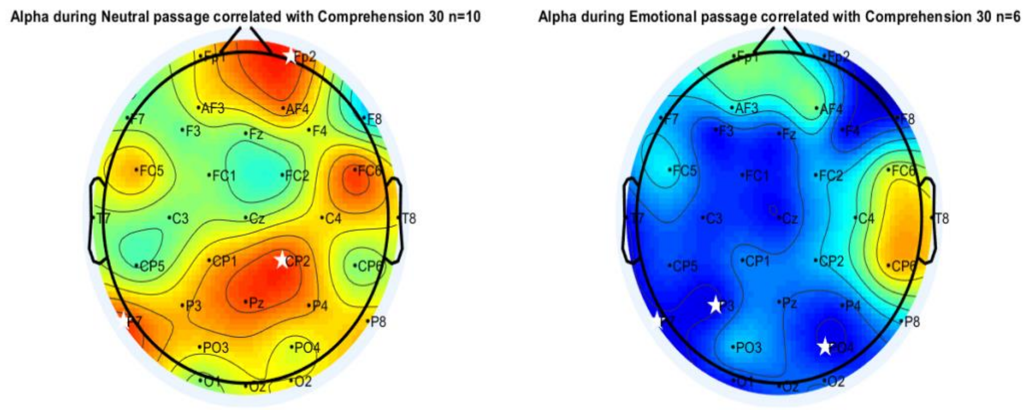
I conducted an exploratory channel-by-channel correlational analysis with each behavioral measure using two-sided Pearson correlations. In figures 4, 5, 6, 7, 8, 9, and 10 below, I used an alpha level for significance of $p < .05$. The results of this exploratory analysis, reported below, are organized by cognitive processes of interest. A correlation table summarizing the results can be found in Appendix C. Interpretation of the results of this analysis should be done with caution due to not controlling for multiple comparisons.

Overall Comprehension. Alpha power during the negative valence emotional passage was negatively correlated with overall comprehension at the following electrodes: P7 ($r = -.84$, $p = .037$), P3 ($r = -.85$ $p = .033$), and PO4 ($r = -.83$, $p = .041$). Alpha power during the neutral passage was positively correlated with overall comprehension at the following electrodes: P7 ($r = .65$, $p = .044$), Cp2 ($r = .67$, $p = .035$) and Fp2 ($r = .69$, $p = .028$). Results are displayed in Figure 3.

Theta power during the negative valence emotional passage was not correlated with overall comprehension at any electrode site. Theta power during the neutral passage was positively correlated with overall comprehension at electrodes P7 ($r = .77$, $p = .009$) and PO4 ($r = .64$, $p = .046$). Results are displayed in Figure 4.

Figure 4

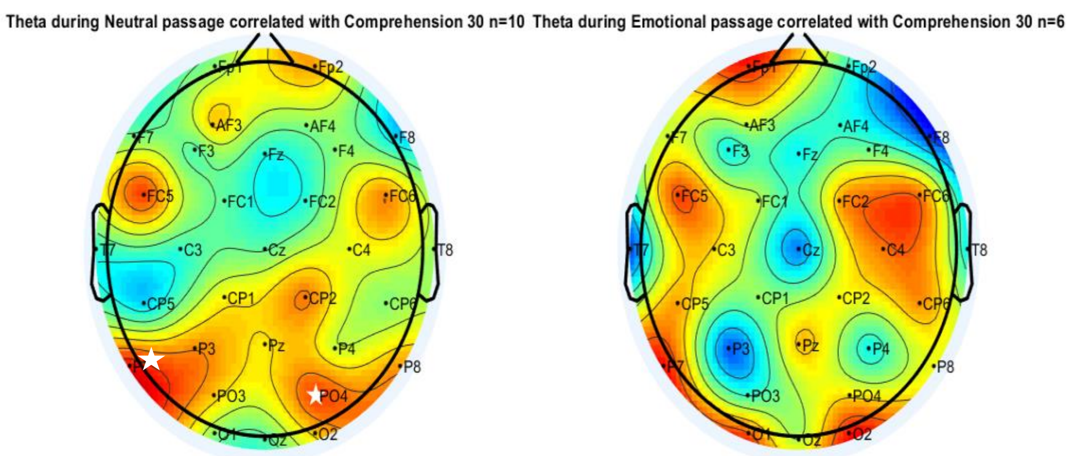
Alpha power during neutral and negative passage listening correlated with total comprehension (150 to 600 $\mu V^2/Hz$)



Note. Electrodes that show significant correlations $p < .05$ are marked with a star

Figure 5

Theta power during neutral and negative passage listening correlated with total comprehension (150 to 600 µV²/Hz)



Note. Electrodes that show significant correlations $p < .05$ are marked with a star

Deep Level Comprehension. Alpha power during the negative valence emotional passage was negatively correlated with deep level of comprehension at FC1 ($r = -.86$, $p = .029$). Alpha power during the neutral passage was not correlated with deep level of comprehension at any electrode.

Theta power during the negative valence emotional passage was negatively correlated with deep level of comprehension at F8 (r = -.89, p = .017). Theta power during the neutral passage was negatively correlated with deep level of comprehension at F8 (r = -.76, p = .011).

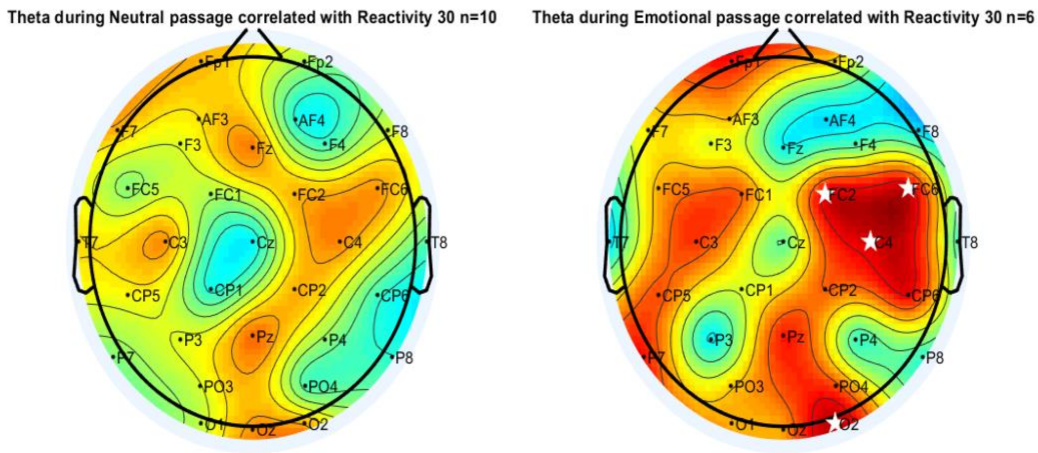
Surface Level Comprehension. Alpha power during the negative valence emotional passage was negatively correlated with surface level comprehension at the following electrodes: P8 (r = -.82, p = .045), F8 (r = -.84, p = .035), and AF4 (r = -.87, p = .024). Alpha power during the neutral passage was negatively correlated with total surface level comprehension at the following electrodes: P8 (r = -.80, p = .006), AF4 (r = -.75, p = .012), and FC5 (r = -.74, p = .015).

Theta power during the negative valence emotional passage was negatively correlated with surface level comprehension at the following electrodes: P4 (r = -.83, p = .040), AF4 (r = -.89, p = .018), and positively correlated with T8 (r = .90, p = .016). Theta power during the neutral passage was positively correlated with surface level comprehension at electrode Cz (r = .66 p = .036). Results are displayed in Figure 5.

AXCPT PBSI Reaction Time. Alpha power during the negative valence emotional passage was negatively correlated with AXCPT PBSI reaction time at electrode P7 (r = -.84, p = .037). Alpha power was not correlated with the neutral passage at any electrode. Theta power during the negative valence emotional passage was positively correlated with AXCPT PBSI reaction time at electrodes O2 (r = .94, p = .005), C4 (r = .85, p = .034), FC6 (r = .85, p = .032), FC2 (r = .82, p = .045). Theta power was not correlated with the neutral passage at any electrode. Results are displayed in Figure 6.

Figure 6

Theta power during neutral and negative passage listening correlated with PBSI Reaction Time (150 to 600 μV²/Hz)



Note. Electrodes that show significant correlations $p < .05$ are marked with a star

AXCPT PBSI Accuracy. Alpha power was not correlated with this behavioral variable.

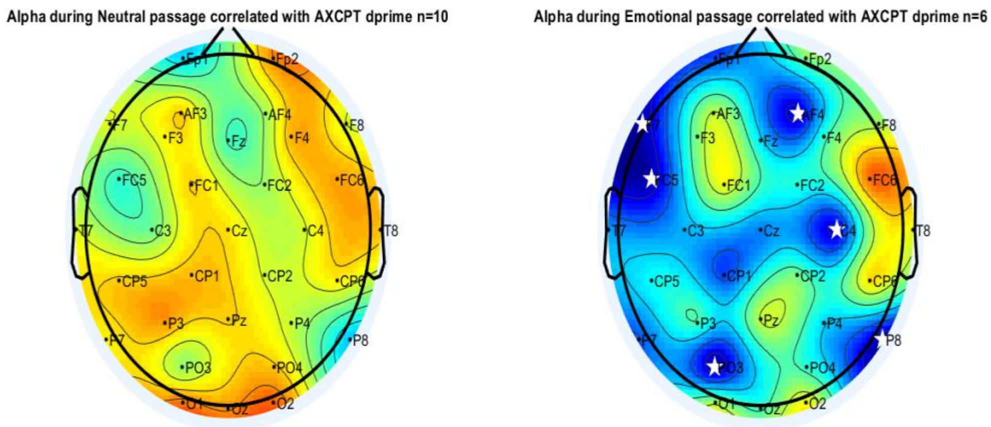
Theta power during the negative valence emotional passage was positively correlated with AXCPT PBSI accuracy at electrodes Fp1 ($r = .85$, $p = .031$) and FC2 ($r = .85$, $p = .033$). Theta power was not correlated with the neutral passage at any electrode.

AXCPT D'Prime Interference. Alpha power during the negative valence emotional passage was negatively correlated with AXCPT d'prime interference at electrodes P8 ($r = -.98$, $p < .001$), C4 ($r = -.86$, $p = .027$), F7 ($r = -.95$, $p = .003$), AF4 ($r = -.89$, $p = .017$), FC5 ($r = -.95$, $p = .003$), and PO3 ($r = -.97$, $p = .001$). Alpha power during the neutral passage was not correlated with AXCPT d'prime interference. Results are displayed in Figure 7.

Theta power during the negative valence emotional passage was negatively correlated with AXCPT d'prime interference at electrodes P4 (*r* = -.90, *p* = .014) and AF4 (*r* = -.98, *p* < .001) and positively correlated at electrode O1 (*r* = .85, *p* = .030). Theta power during the neutral passage was negatively correlated with AXCPT d'prime interference at electrodes P4 (*r* = -.68, *p* = .031), AF4 (*r* = -.69, *p* = .027), and positively correlated with P7 (*r* = .68, *p* = .031). Results are displayed in Figure 8.

Figure 7

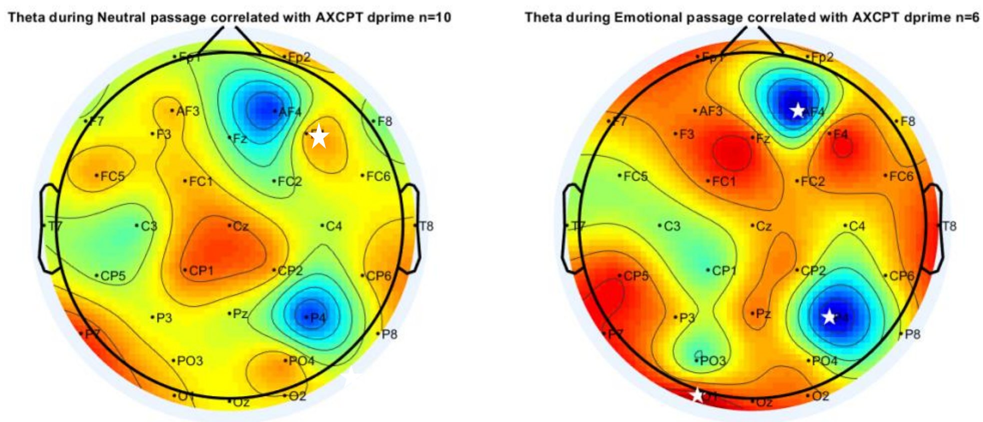
Alpha power during neutral and negative passage listening with AX-CPT d'prime interference (150 to 600 μV²/Hz)



Note. Electrodes that show significant correlations $p < .05$ are marked with a star

Figure 8

Theta power during neutral and negative passage listening correlated with AX-CPT d'prime interference (150 to 600 μV²/Hz)



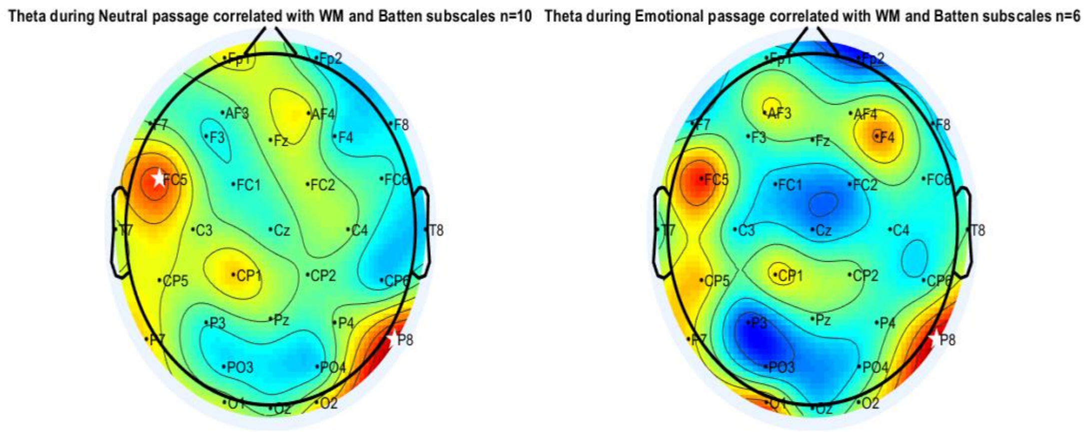
Note. Electrodes that show significant correlations $p < .05$ are marked with a star

Woodcock Johnson Composite of Subscales (WJ). Alpha power during the negative valence emotional passage was not correlated at any electrode. Alpha power during the neutral passage was positively correlated with WJ Scores at electrodes P7 (r = .64, p = .046) and FC5 (r = .68, p = .029).

Theta power during the negative valence emotional passage was positively correlated with WJ Working Memory at electrodes P8 (r = .93, p = .007) and with WJ Broad Attention at electrode P8 (r = .89, p = .016). Theta power during the neutral passage was positively correlated with WJ Working Memory at electrode P8 (r = .88, p = .001) and FC5 (r = .82, p = .003) and with WJ Broad Attention at electrodes P8 (r = .87, p = .001) and FC5 (r = .67, p = .034).

Figure 9

Theta power during neutral and negative passage listening correlated with WJ-III Batteries (150 to 600 $\mu V^2/Hz$)

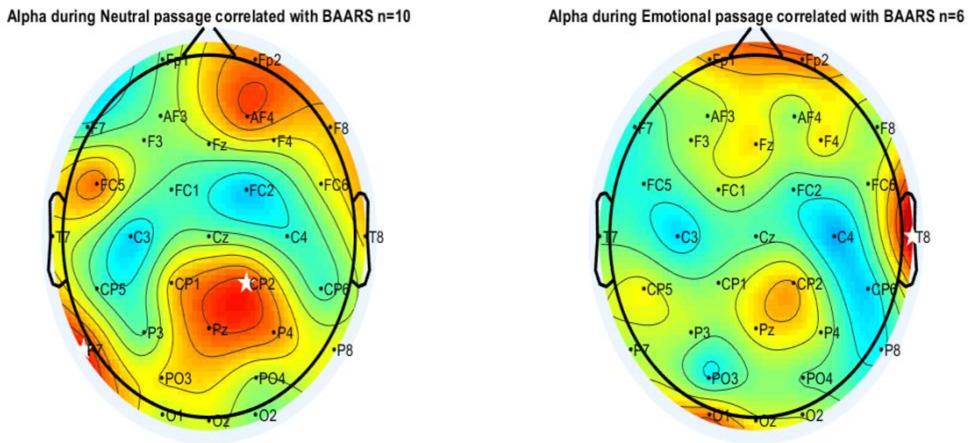


Note. Electrodes that show significant correlations $p < .05$ are marked with a star

Barkley Adult ADHD Rating Scale (BAARS). Alpha power during the negative valence emotional passage was positively correlated with BAARS total ADHD scores at electrode T8 ($r = .93$, $p = .007$). Alpha power during the neutral passage was positively correlated with BAARS total ADHD scores at electrode P7 ($r = .74$, $p = .015$) and CP2 ($r = .65$, $p = .040$). Theta power was not correlated with this behavioral variable.

Figure 10

Alpha power during neutral and negative passage listening correlated with BAARS total ADHD symptoms (150 to 600 μV^2/Hz)



Note. Electrodes that show significant correlations $p < .05$ are marked with a star

Chapter 4: Discussion

Behavioral Findings

The current study presents several findings. The results suggest that the BAARS and the AXCPT have differential and combined effects on discourse comprehension at the overall and deep levels of processing, and that arousal/engagement as emotional valence influences these effects.

First, after examining the correlation matrices and determining that the predictor for executive function/cognitive abilities (WJ Composite) showed no relationship with comprehension across emotional conditions, the analysis proceeded only using cognitive control and ADHD symptoms to measure the relationship between aspects of executive function and discourse comprehension. The within-subjects analysis revealed that there were differential main effects of surface versus deep processing and emotional versus neutral conditions, and that there was an interaction between the two outcomes. It also showed that ADHD symptoms interact with arousal to influence comprehension. However, none of the other predictors (cognitive control and executive function/cognitive abilities) showed any effect when entered as covariates in the model. In order to further investigate the effects of ADHD and cognitive control on levels of processing taking emotional valence into account, I conducted a series of linear regressions, which revealed that ADHD symptoms and cognitive control jointly significantly predicted performance on both overall and deeper levels of comprehension, implying that both play a differential role in comprehension performance in arousing/engaging situations.

The bivariate correlations showed that the AXCPT and BAARS were not associated with WJ-III Working Memory and Broad Attention Batteries, providing support for the idea that performance-based tests and rating metrics do not correspond to each other or pick up on the same components of executive function (Weisman, 2020; Toplak et al., 2013; Barkley & Murphy, 2011). The AX-CPT was also not associated with the BAARS, contradicting my initial expectation for the association between these two predictors. This could be because of the measures used; specifically, ADHD symptoms are not associated with the d'prime interference metric calculated from AX-CPT scores.

Evidence suggests that these constructs are unrelated because worse performance on the AX-CPT over time in populations with ADHD is due to decreased sensitivity to the d'prime interference (sensitivity to context) and slower reaction times overall (Huang-Pollock et al., 2012). It could also be due to differential performance based on ADHD subtype that has been observed on the AX-CPT, such that those with ADHD-Combined type show worse performance on the task over extended periods of time than other subtypes and typical controls (Collings, 2003). Furthermore, the current sample was taken from a large, competitive university where high-performing individuals may be overrepresented, and therefore there may be fewer individuals with diagnosed ADHD represented in the sample (see Results for mean ADHD diagnoses in the sample).

However, as expected, participants showed better surface level processing on average, and better average comprehension performance under the emotional condition than under the neutral condition, suggesting that individuals process surface level details more easily (Kintsch et al., 1988; Royer et al., 1979) and are more aroused by the emotional stories than the neutral stories. This is supported by ratings on the PPQ from both the pilot participants (n= 10, as described in the Methods section) and a subset of the study participants (*n*= 37), with an average arousal rating of 5.5 for positive and negative stories combined versus 2.8 for the neutral story from the sample participants, and 5.4 for positive and negative stories versus 2.7 for the neutral story from the pilot participants (See Appendix B for summary of PPQ ratings).

My initial hypotheses were partially confirmed by results, such that greater attention deficits as shown by higher scores on the total ADHD symptom count dimension of the BAARS would show greater sensitivity to context. The BAARS measures classic, clinical ADHD symptoms such as inattentiveness, hyperactivity/impulsivity, and sluggish cognitive tempo (Barkley, 2011). Results revealed that BAARS total ADHD symptom count predicted comprehension performance at both the overall and deep levels of processing under emotional conditions, suggesting that people with higher numbers of ADHD symptoms were sensitive to the emotional valence of the story, and arousal elicited by the story allowed for deeper level discourse processing and better overall discourse comprehension. Since individuals with ADHD show increased distractibility in the absence of arousing stimuli in the environment (Berger & Cassuto, 2014), as well as perseveration on emotional details and contexts (Lopez-Martin et al., 2013), these findings support the notion that individuals with ADHD rely on the context to provide arousal to stimulate their attention and to engage effortful cognitive processes to perform tasks. In other words, individuals with greater numbers of ADHD symptoms may be more engaged and aroused by emotional contexts due to perseveration on emotional details and increased arousal/engagement with the context, which in turn allows them to process details more deeply.

However, my hypothesis that individuals with reactive cognitive control would be more sensitive to context and show differential comprehension performance based on the emotion of the story was not reflected in the results. The AXCPT measure used for analysis, the d'prime interference, represents sensitivity to context, wherein higher scores indicate better proactive cognitive control (Troller-Renfree et al., 2020). Contrary to my hypothesis, proactive individuals in this sample were more sensitive to emotional relative to neutral stories, and showed significantly better deeper comprehension performance under the emotional condition. Thus, proactive cognitive control allowed for better deeper discourse processing and comprehension. These individuals in my sample may be demonstrating a reward motivation effect, which has been shown to enhance proactive control in previous research using the AXCPT under the dual mechanisms of control (DMC) framework (Chiew & Braver, 2013). Further, some research suggests that positive emotion also influences proactive control alongside reward motivation, albeit a weak effect (Chiew & Braver, 2014). In the current sample, it is unclear whether the effect is due in part to positive emotion, due to insufficient power to examine between subjects effects of positive and negative emotional conditions. This will be an important avenue for further research.

Between subjects analysis of the difference between positive and negative conditions and the influence of ADHD symptoms and cognitive control on performance under these conditions was briefly examined, although I could not run a full analysis due to few subjects in each group. A preliminary test shows that ADHD symptoms predict overall comprehension performance under the negative condition, but not the positive. This is likely due to greater arousal from the negative story than the positive story.

Participants who completed the Post Passage Questionnaire (PPQ; *n*= 37) rated the negative story as more arousing (average rating of 6.18) than the positive story (average rating of 4.80) and the neutral story (average rating of 2.84). Participants also rated the negative story as more negative (average rating of 1.40) than the positive (average rating of 6.07) and neutral (average rating of 3.87) stories. See Appendix B for full table of average ratings for both pilot participants and study participants of the three stories. Furthermore, the poor reliability of the comprehension questions for the negative story may support this finding; individual differences in arousal levels and increased sensitivity to context may be reflected in performance on these questions, and as a result, the reliability metric is poor.

EEG Findings

Overall comprehension and alpha power showed an inverse relationship depending on the emotional valence of the passage, such that the correlation was negative for the negative valence passage, and positive for the neutral passage. This means that alpha increase over posterior channels during listening was detrimental to comprehension during the negative condition, but helped comprehension performance during the neutral condition. Similarly, as theta power in the neutral condition increased, so did comprehension, whereas this relationship was absent in the negative condition.

Furthermore, overall surface level comprehension showed a negative relationship with alpha power during emotional and neutral conditions, such that alpha increasing over posterior channels detrimentally impacted surface comprehension during the both conditions. However, theta power showed an inverse relationship with surface comprehension such that the correlations were negative for the negative valence passage, and positive for the neutral passage, implying that theta increasing over posterior channels during listening was detrimental to comprehension during the negative condition, but helped comprehension performance during the neutral condition.

Finally, overall inference level (deep) comprehension showed a similar negative relationship with alpha power as surface level comprehension, where increasing alpha power negatively impacted deep comprehension under both conditions. Similarly, theta power showed a negative relationship with deep comprehension such that increasing theta power negatively affected comprehension under both neutral and negative emotional conditions.

Regarding cognitive control, alpha power showed an negative relationship with d'prime interference scores under the negative emotional condition, such that decreasing alpha power was associated with increasing d'prime interference scores and vice versa. This suggests that proactive individuals (those who have high d'prime scores) displayed decreased alpha power under emotional conditions because of attention being directed externally in listening to the story. Similarly, theta power showed an negative relationship with d'prime interference scores under the negative and neutral conditions, suggesting that proactive individuals displayed decreased theta power with some amount of effortful processing occurring in these individuals under both conditions.

Regarding ADHD symptoms, alpha power showed a direct relationship with total BAARS ADHD symptoms under both the negative valence and neutral conditions through a positive correlation, suggesting that in individuals with higher ADHD symptoms, alpha power increases across both conditions with attention being directed internally and away from the story listening.

If working memory load is indexed by posterior alpha as suggested by Boudewyn & Carter (2016), among others (Tuladhar et al., 2007; Manza et al., 2014), then this would imply that increasing working memory during the negative valence emotional passage would be detrimental to comprehension performance while working memory load during the neutral passage would be beneficial. However, this effect might also be due to alpha indexing both working memory in one case (neutral) and mind-wandering or decoupling in another (negative valence). This interpretation would be in line with Smallwood, Fishman, & Schooler's (2007) cascade model of inattention, as well as the results of Boudewyn and Carter (2018), which demonstrate that both successful and unsuccessful listening comprehension show posterior alpha increases.

The idea that alpha indexes decoupling rather than WM in the negative valence condition is further suggested by the negative correlation between AX-CPT d'prime context scores and the posterior alpha only in that condition. The premise here, supported by evidence from other tasks requiring visual attention (Boudewyn & Carter, 2016) is that successful AX-CPT performance requires an ability to maintain low alpha, especially over primary sensory areas (temporo-occipital), where alpha indicates lapses of attention (Boudewyn & Carter, 2016).

That theta power, like alpha power, increased with overall comprehension in the neutral condition, might suggest that theta power is going beyond alpha to index working memory load specifically. Studies have suggested that theta and alpha power are inversely related (Popov et al., 2018) and that in situations with auditory and visual distractors, modulation of attention is projected to the frontal lobe when processing auditory information (Do et al., 2020), suggesting that this might be the case.

Study Limitations and Future Directions

This study has limitations that should be considered. First, participation in the study was voluntary through the university Sona system, and participants all received extra credit in their psychology undergraduate courses for participating. This self-selected sampling strategy tends to be biased towards favoring more motivated, highly achieving students looking to boost their grades in their courses. Furthermore, there may be high achieving, high functioning individuals overrepresented in the sample since the study recruited undergraduate participants from a competitive university, and individuals with more reactive cognitive control profiles, lower executive functioning skills, and higher ADHD symptoms may be missing from the sample. This limitation may constrain the generalization and ecological validity of these results to other populations. A future study would draw a larger, more diverse sample from the community so that different levels of executive function and attentional ability would be reflected.

Second, the study lacked sufficient power to investigate levels of processing under positive and negative emotional conditions. The study showed that ADHD symptoms and cognitive control predict performance under emotional conditions to varying degrees. While there was a promising finding that ADHD symptoms may influence comprehension performance under negative emotional contexts, this was not explored further to examine surface and deep levels of processing, and it is unclear whether a larger sample may show an effect under positive emotional contexts. It would be prudent to examine this further in future studies to present a clear picture of how ADHD symptoms and cognitive control influence discourse comprehension under different levels of arousal.

Third, the study did not contain multiple measures of arousal and engagement, but it did measure cognitive and behavioral engagement using arousal patterns in the form of alpha and theta power recorded on EEG. According to Sinatra and colleagues (2015), there are many ways to measure these dimensions of engagement and some dimensions even may blend into others (i.e., measures of behavioral and social engagement may also reflect cognitive engagement and vice versa). However, it is worth noting that in future studies, researchers should use multiple measures of engagement to provide a robust measurement for each dimension, such as observer report or self-report (Sinatra et al., 2015). Future studies containing multiple direct measures of engagement across emotional, behavioral, and cognitive levels of engagement will provide a more specific understanding of its interactions with aspects of executive function and discourse comprehension, and this will allow for more in depth and nuanced comparisons of individual differences with states of arousal and engagement.

Fourth, the study used three auditory stories for comprehension: one positive, one negative, and one neutral, and it included 5 surface level and 10 deep level comprehension questions. While differences in performance across the different levels of processing across emotional and neutral conditions were reflected in this study, future studies would benefit from having participants answer a larger bank of surface and deep comprehension questions across multiple stories that are positive, negative, and neutral valence (i.e., sentence and inference level questions; Royer, 2001). This would provide more data points for analysis and help distinguish and differentiate comprehension from the role of individual differences in arousal levels, ADHD symptoms, and increased sensitivity to context, and provide for better reliability and validity of comprehension questions by measuring consistency in responses across multiple emotional and neutral valence stories.

Finally, the EEG analysis conducted in the study was exploratory due to small sample size. Preliminary exploratory analyses indicate promising results regarding alpha and theta arousal patterns and their relationship to comprehension across emotional contexts. Future studies will have improved study design and greater numbers of EEG participants to examine cognitive and behavioral engagement in the form of arousal measured by EEG, behavioral engagement measured by participant and observer ratings, and emotional engagement in the form of emotional valence influence levels of comprehension processing, and how engagement and arousal interact with individual executive function ability to influence discourse comprehension.

Conclusions

This study presents preliminary findings about the influence of individual EF ability and arousal on discourse comprehension that are promising for pursuit in future studies. ADHD symptoms and proactive control seem to influence overall and deep levels of discourse comprehension, and this relationship is influenced by level of arousal/emotional engagement with the context. My study demonstrates a few important findings. First, performance based measures of cognitive ability and rating scales are not associated with each other and may not measure the same aspects of EF. The sample also showed that individuals with high ADHD symptoms are influenced by arousal in the form of emotional valence of the context in their overall comprehension and deep processing. Further, individuals with proactive control are influenced by the context for deeper levels of comprehension. This carries implications for education and teaching comprehension in classrooms, highlighting the need to closely examine how trait-level executive function abilities and attentional capacities interact with different situational states of arousal and engagement depending on the context in which comprehension occurs. Further research is necessary to tease apart these effects, especially in larger, more diverse populations across different educational settings.

Appendices

Appendix A: Study Questionnaires and Tests

Neuropsychology, Education, and Lifestyle Questionnaire

Please select "yes" if you have a diagnostic history of the following conditions. If yes, please briefly describe your condition (year/age of diagnosis, triggers, subtypes, etc.):

Anxiety: ☐ NO ☐ YES: ______________________________

Depression: ☐ NO ☐ YES: ______________________________

ADHD: ☐ NO ☐ YES:
Subtype: ☐ Inattentive ☐ Hyperactive ☐ Combined

Other Psychological/Emotional Disorder: ☐ NO ☐ YES: ______________________________

Stroke: ☐ NO ☐ YES:
Concussion: ☐ NO ☐ YES:
Headaches: ☐ NO ☐ YES:
Seizures/Epilepsy: ☐ NO ☐ YES:
Other Neurological Condition: ☐ NO ☐ YES: ______________________________

Diagnosed Learning Disabilities: ☐ NO ☐ YES: ______________________________

Do you take medication for any of these conditions? ☐ NO ☐ YES: if yes, please list below:____

Educational History:

Class Status at UMD: ☐ Freshmen ☐ Sophomore ☐ Junior ☐ Senior
Major: ______________________________ Estimated GPA: ____________

Current Lifestyle Choices:

ON AN AVERAGE SCHOOL DAY:

How much sleep do you get? ___________ Hours
Do you eat breakfast? ☐ NO ☐ YES
Do you exercise? ☐ NO ☐ YES: How long? __________ Hours
Do you: Smoke Cigarettes ☐ NO ☐ YES
Smoke Marijuana ☐ NO ☐ YES
Do Other Drugs ☐ NO ☐ YES
Consume Alcohol ☐ NO ☐ YES: How much? ___________ Drinks
Take prescription medications that alter brain function
(Stimulants, Antidepressants, Anti-anxiety, Anti-Seizure, etc.) ☐ NO ☐ YES: ______________________________

TODAY/LAST NIGHT:

How much sleep did you get? ___________ Hours
Did you eat breakfast? ☐ NO ☐ YES

Did you exercise? ☐ NO ☐ YES: How long? ___________ Hours
Have you:
Smoked Cigarettes ☐ NO ☐ YES
Smoked Marijuana ☐ NO ☐ YES
Done Other Drugs ☐ NO ☐ YES
Consumed Alcohol ☐ NO ☐ YES: How much? ____________ Drinks
Take prescription medications that alter brain function
(Stimulants, Antidepressants, Anti-anxiety, Anti-Seizure, etc.) ☐ NO ☐ YES: ______

GAD-7 Anxiety Scale

Over the last 2 weeks, how often have you been bothered by the following problems? (Numbered items were 0 - "Not at all sure," 1 - "Several days," 2 - "Over half the days," and 3 - "Nearly every day")
1. Feeling nervous, anxious or on edge
2. Not being able to stop or control worrying
3. Worrying too much about different things
4. Trouble relaxing
5. Being so restless that it's hard to sit still
6. Becoming easily annoyed or irritable
7. Feeling afraid as if something awful might happen

If you checked off any problems, how difficult have these made it for you to do your work, take care of things at home, or get along with other people?
Not difficult at all, somewhat difficult, very difficult, or extremely difficult

Barkley Adult ADHD Rating Scale-IV: Self-Report

For the first 27 items, please indicate the number next to each item that best describes your behavior during the past 6 months. Then answer the remaining questions. (Numbered items were 1 - "Never or rarely," 2 - "Sometimes," 3 - "Often," and 4 - "Very Often")

Inattention
1. Fail to give close attention to details or make careless mistakes in my work or other activities
2. Difficulty sustaining my attention in tasks or fun activities
3. Don't listen when spoken to directly
4. Don't follow through on instructions and fail to finish work or chores
5. Have difficulty organizing tasks and activities
6. Avoid, dislike, or am reluctant to engage in tasks that require sustained mental effort
7. Lose things necessary for tasks or activities
8. Easily distracted by extraneous stimuli or irrelevant thoughts
9. Forgetful in daily activities

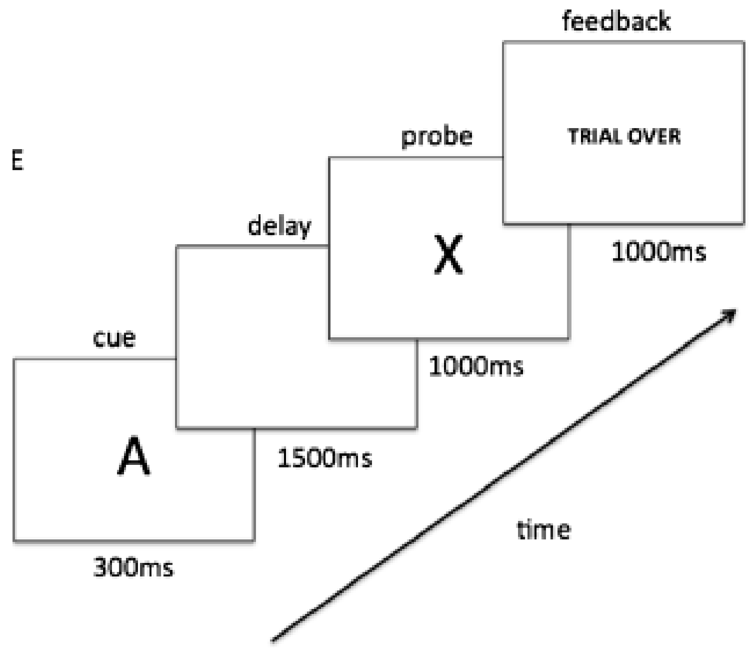
Hyperactivity/Impulsivity

10. Fidget with hands or feet or squirm in seat
11. Leave my seat in classrooms or in other situations in which remaining seating is expected
12. Shift around excessively or feel restless or hemmed in
13. Have difficulty engaging in leisure activities quietly (feel uncomfortable, or am loud or noisy)
14. I am “on the go” or act as if “driven by a motor” (or I feel like I have to be busy or always doing something)
15. Talk excessively (in social situations)
16. Blurt out answers before questions have been completed, complete others’ sentences, or jump the gun
17. Have difficulty awaiting my turn
18. Interrupt or intrude on others (butt into conversations or activities without permission or take over what others are doing)

Sluggish Cognitive Tempo
19. Prone to daydreaming when I should be concentrating on something or working
20. Have trouble staying alert or awake in boring situations
21. Easily confused
22. Easily bored
23. Spacey or “in a fog”
24. Lethargic, more tired than others
25. Underactive or have less energy than others
26. Slow moving
27. I don’t seem to process information as quickly or as accurately as others

Did you experience any of these 27 symptoms at least “Often” or more frequently (Did you circle a 3 or a 4 above)? NO or YES
If so, how old were you when those symptoms began?
If so, in which of these settings did those symptoms impair your functioning? Please check next to the areas that apply to you: school, home, work, social relationships

AX-CPT Trial Example



Post Passage Questionnaire (PPQ)

Please rate the following by circling a number on the scale provided for you:

Arousal --

Completely Unarousing	Mostly Unarousing	Somewhat Arousing	Neither Arousing/ Unarousing	Somewhat Arousing	Mostly Arousing

1 2 3 4 5 6 7

Positive vs. Negative --

Completely Negative	Mostly Negative	Somewhat Negative	Neither Positive/ Negative	Somewhat Positive	Mostly Positive

1 2 3 4 5 6 7

Relatability --

Completely Unrelatable	Mostly Unrelatable	Somewhat Unrelatable	Neither Relatable/ Unrelatable	Somewhat Relatable	Mostly Relatable

1 2 3 4 5 6 7

Briefly summarize the passage you just heard/read:

In a few words or sentences, please describe how this story made you feel:

List any emotions are you feeling after reading this passage:

Did this passage evoke any positive or negative memories from your life?
Circle one:

Yes, a positive memory | Yes, a negative memory | No memory

Passages and Comprehension Questions

Passage D (Neutral)
Excerpt from "Differential Effects of Various Drug Treatments on Daphnia Heart Rates," a Lab Report for a Cell Biology and Physiology Course by Hannah Weisman, November 2018

First, 200 microliters of nicotine, acetylcholine, caffeine, and lidocaine were transferred into 4 labeled tubes and were then put aside until they were needed later. The following basic procedure was used repeatedly on three replicates of four different drug-treatment trials.

A single Daphnia was collected with a transfer pipette. Excess water was squeezed out of the pipette with care taken to ensure that the Daphnia remained within the pipette. The Daphnia was then deposited into a well of a depression slide. Immediately following, a drop of detain solution was placed over the Daphnia to keep it from moving and allow for the student to focus a microscope over it. The light of the microscope was then turned on – making sure it was not overly bright as that would damage or even kill the Daphnia – and the student adjusted the stage under the 10X objective until the Daphnia was in focus. The student working with the microscope then identified the dorsal heart and indicated that she was ready to start counting the basal heart rate.

As soon as she was ready to start counting heartbeats, the student not looking through the microscope started the timer and the student looking through the microscope began counting each time the dorsal heart expanded – indicating a heartbeat. This heartbeat tracking was done by counting to 10 repeatedly and putting up a finger for every 10 beats counted. After 15 seconds, the lab partner announced the end of the counting period and the student who was counting reported the number of heartbeats she observed by multiplying the number of fingers she had up by 10 and then adding in the number that she stopped counting at.

For example, if the student stopped counting on the number 3 and had 7 fingers up, then she would multiply 7 times 10 (equaling 70), and ten adding 3 to account for the 3 seconds left over.

As soon as the data had been recorded in the lab notebook, the microscope light was turned off to cool down the depression slide holding the Daphnia. While the Daphnia slide was cooling, the number of observed heartbeats was multiplied by 4 to normalize the data to be in terms of beats per minute.

Once the slide was cool, one drop of a drug treatment (acetylcholine, caffeine, nicotine, or lidocaine) was placed right over the Daphnia on the slide. After a minute of letting the drug take effect, another drop of detain solution was dropped overtop of the Daphnia, and the slide was placed back under the light of the microscope for the student to focus the 10X objective over the Daphnia to relocate the dorsal heart. Once located, the students proceeded to conduct the same counting procedure as written before. When the counting process was finished, the microscope light was turned off, the data was normalized using the same procedures as listed above, and the Daphnia was discarded into either the recovery (for living Daphnia) or waste (for dead Daphnia) containers. The depression slide was then washed with water and dried in preparation for the next trial. The entire protocol was repeated to equal a total of 3 replicates for each of the four drug treatments.

Were the following statements present in the passage?
1. This heartbeat tracking was done by counting to 10 repeatedly and putting up a finger for every 10 beats counted.
2. The following basic procedure was used repeatedly on three replicates of four different drug-treatment trials.
3. The E.coli strain was then deposited into a petri dish.
4. The student working with the microscope then identified the dorsal heart and indicated that she was ready to start counting the basal heart rate.
5. Once the slide was cool, one drop of a drug treatment (adrenaline, noradrenaline, naproxen sodium, and caffeine) was swirled around in a beaker until it dissolved.
Answer the following questions yes or no.
6. Does this passage mention acetylcholine as one of the drug treatment for testing on the Daphnia?
7. Do the students count the heartbeat of the Daphnia during a period of 15 seconds?
8. Is this experiment done on multiple Daphnia?
9. Is the Daphnia on the slide examined under light microscope?
10. Is the data recorded in a lab computer?
11. Is this passage detailing the procedure of a drug experiment?
12. Are there professional researchers conducting this experiment?
13. Does the passage specify the amounts and types of drugs used for drug treatment of Daphnia?
14. Do student count the heartbeat of the Daphnia during the experiment?
15. Is this experiment examining the effects of certain drugs on heart rate?

Passage B (Negative)
Excerpts from “Sandy Hook Elementary shooting leaves 28 dead, law enforcement sources say,” a Washington Post article by Steve Vogel, Sari Horwitz, and David A. Fahrenthold – December 14, 2012 (Vogel, Horwitz, & Fahrenthold, 2012)

NEWTOWN, Conn.–A shooting rampage in this small Connecticut town on Friday morning left 28 people dead, including 20 children killed inside their elementary school, authorities said.

Police described the school itself as one of the most horrific crime scenes that many had ever encountered, and officials said the first-arriving responders would be given counseling. Children who were evacuated from the school said later that they had been told to keep their eyes closed until they were outside.

Police said that as the day went on, they had accounted for every child who attended the school, tracking down even those who were absent because of illness.

All had been accounted for, they said.

Police said they were summoned to the school by a number of 911 calls. Both state and local police converged on the school, according to Connecticut State Police Lt. L. Paul Vance, and "began a complete active shooter search of the building."

Meredith Artley, managing editor of CNN.com, described interviewing a woman who was at the school about 9:30 or 9:35 a.m. The woman was in a meeting with the principal, vice principal and school psychologist when they heard shots from the hall. The three school officials went into the hallway, and the vice principal came crawling back, shot in the foot, Artley said.

The witness, who was not identified but has a 7-year-old at the school, told Artley that she later passed the principal and the psychologist lying in the hallway, surrounded by pools of blood.

In this small town near the New York border, police cars began screaming toward the school. At Berkshire Motors, owner Jim Marcucilli thought he saw 40 police cruisers. He had been working on a car, but its owner, frantic, demanded back back the keys. "Oh my God," she said, according to Marcucilli. "I have to get my kid!"

Students inside the school were evacuated to a nearby firehouse, where television reporters saw parents tearfully reuniting with their children.

Students recounted hearing police officers on the roof, and classmates so frightened they became sick to their stomachs. In interview with New York's WABC television, student Brendan Murray said he was in the gym when he heard a banging sound. Students at first thought a custodian had knocked something over, but then they heard a scream.

"Then a police came in and was like, 'Is he in here?' Then he ran out," Murray said. "And then somebody yelled, 'Get to a safe place!' So we went to the closet in the gym."

Eventually, he said, police escorted the students out of the school and to the firehouse, where they reunited with their classmates.

"We sat in our classes," he said. "And were all really happy that we were all alive."

Parent Stephen Delgiadice told the AP that his 8-year-old daughter heard two big bangs and teachers told her to get in a corner. His daughter was fine.

A photo posted by The Newtown Bee newspaper showed a group of young students— some crying, others looking visibly frightened — being escorted by adults through a parking lot in a line, hands on each other's shoulders. Mergim Bajraliu, 17, heard the gunshots echo from his home and raced to check on his 9-year-old sister at the school. He told the AP his sister, who was fine, heard scream come over the intercom at one point. He said teachers were shaking and

crying as they came out of the building.
“Everyone was just traumatized,” he said.

Were the following sentences present in the passage? Yes or no.
1. At Berkshire Motors, owner Jim Marcucilli thought he saw 40 police cruisers.
2. Students at first thought a custodian had knocked something over, but then they heard a scream.
3. Children were interrupted in the middle of class by a fire drill.
4. Teachers were not aware of the school’s emergency protocols.
5. Officials said the first-arriving responders would be given counseling.
Answer the following questions yes or no.
6. Did 28 people die in the Newtown, CT incident?
7. Were there any teachers or staff injured during the incident?
8. Did the incident occur at a high school?
9. Did some students hide in the bathroom when told to get to a safe place?
10. Was there a picture published in a local newspaper of the students as they exited their school?
Answer the following questions yes or no.
11. Was this passage about a shooting at an elementary school?
12. Did the passage include quotes from people affected by the incident?
13. Did state and local police respond to reports of an active shooter at the school?
14. Did the passage mention any details about the shooter?
15. Did the passage provide information about the date and time of the incident?

Passage G (Positive)
“You Found These Words When You Needed To,” a blog-style post by
Jacqueline Whitney on Thoughtcatalog.com, August 2019 (Whitney, 2019)

Lean in closely to the words you are about to read. It is highly possible at least one sentence you need to see.
Your heart will feel lighter, your lungs will ease and clarity for what your future holds will come.
Light is coming. You are safe. Love has got you.
Everything is falling into pieces and those pieces are fitting into the exact places they need to.
It’s completely okay to not be able to explain what you feel or not know what to do next.
You don’t need to have all the answers. Follow your heart’s instincts and let universal fate do the rest.
It’s normal to be scared. Life is scary, but not as scary as it seems.
Vulnerability might be the most gentle, intense strength you can obtain. Don’t let it contain you.
If speaking your truth feels terrifying, dance through fear. Someone needs to hear what you have to say. You deserve to say what you want to say.
You are good enough for people the way you are. You are imperfectly, perfect.
You are loved and worthy of being loved closely. You are loved closely.

You don’t need a lover to survive. You won’t be lonely forever. Someone out there needs your heart to hold forever. You are good enough to be wanted in every way. You are wanted.
You don’t have to be society’s ‘ideal look’ or have a certain body to be loved. I am not saying this because I have to. I mean it, you are beautiful. You are beautiful because you have a soul no other has. Your soul has purpose no other has.
Take care of yourself where you are right now.
This season of waiting is just that, a season. May you be patient in all things. When your soul feels heavy and your life feels difficult, know that your soul will feel lighter soon. Beyond this darkness there will be light.
You are not your mistakes. You are the lesson you choose to learn through them. Keyword: choose. It is a choice to look for a lesson within every mistake. There is always one or a ton.
Everything is going to be fine. You will find happiness, comfort, and contentment in your life. I know you’re looking, but keep looking.
If they are continuously hurting you, it is time to walk away.
The pain of grief will go away. Your loved one is with you in spirit.
Don’t try to heal your bleeding hands before they’re ready. You will know when it’s time to begin healing. You will know when you have healed.
Don’t give up. The space you hold wouldn’t be the same without you. This is a truth. You are desperately needed.
I don’t think you’re numbing or hiding from your past when emotionally you need a break from it. Trust your heart’s timing. Trust.
You are not alone. You can do it. You are strong and you are capable. Be brave and be bold. You’re going to figure your life out. You don’t have to figure your life out now.
Rest up.
You are not broken even when you feel you’re breaking. You’re coming together, into all of who you’ve been made to be.
If you’re too hard on yourself, be more gentle. Start with, “I’m sorry.”
At the end of the day you are a human being and no human being has it all together. You really are doing better than you may feel you are.
I don’t know you, but I am so proud of you.
Above all, hold hope. Hope is evident everywhere.
You found these words when you needed to.

Were the following sentences present in the passage?
1. You found these words when you needed to.
2. This season of waiting is just that, a season.
3. The discomfort of regret will go away.
4. You’re coming together, into all of who you’ve been made to be.
5. Don’t try to heal your bleeding hands before they’re ready.
Answer the following questions yes or no.
6. Does the subject of the passage think it is okay to follow your instincts and let the rest fall into place?
7. Does the subject of the passage think that vulnerability is a weakness?

8. Does the subject believe that people should speak their truth without fear of others' opinions?
9. Does the subject believe that humans should have it all together and figured out?
10. Is it stated in the passage that each person has a unique soul with a purpose?
11. Does the passage assume that it applies to and will be helpful to everyone?
12. Is the passage written entirely in the second person point of view?
13. Does the passage give the reader any positive affirmations?
14. Does the passage mention the concept of hatred?
15. Does the passage mention the concept of grief?

Appendix B: Behavioral Analyses

Descriptive Group Averages

Table B1

AX-CPT Group Means by Trial

Trial Type	*M* RT	*SD* RT	*M* Acc	*SD* Acc	*M* Err	*SD* Err
AX	475.90	91.44	0.92	0.11	1.58	0.11
AY	659.75	134.63	0.79	0.17	1.71	0.17
BX	438.34	163.80	0.91	0.13	1.59	0.13
BY	432.77	118.87	0.98	0.05	1.52	0.05

Note. RT: Reaction time, Acc: Accuracy/correct trials, Err: error/incorrect trials

Table B2

Average PPQ Ratings for Neutral, Positive, and Negative Stories

Pilot Participants				
	Passage	Arousal	Positive/Negative	Relatability
	Negative	5.4	1.4	4.7
	Neutral	2.7	4.5	4.2
	Positive	5.4	6.1	5.5
Study Participants				
	Passage	Arousal	Positive/Negative	Relatability
	Negative	6.2	1.5	3.7
	Neutral	2.8	3.9	3.7
	Positive	4.8	6.1	5.4

Note. Responses are based on a Likert scale rating of 1 to 7, with 1 being the least and 7 being the most.

Correlation Tables

Table B3

Bivariate Correlation Table of Predictors and Outcomes (Raw Scores)

Variable		BAARS ADHD	AXCPT PBSI Acc	AXCPT PBSI RT	WJ WM	WJ BA	Total Comp	Total Surface	Total Deep
BAARS Total ADHD	r	__							
	p	__							
AXCPT PBSI Acc	r	-.04	__						
	p	.789	__						
AXCPT PBSI RT	r	-.10	.43**	__					
	p	.542	.004	__					
WJ WM	r	-.16	-.42**	-.16	__				
	p	.310	.005	.313	__				
WJ BA	r	.01	-.39**	-.20	.87***	__			
	p	.945	.009	.205	<.001	__			
Total Comprehension	r	.16	.12	.11	.17	.14	__		
	p	.304	.445	.476	.274	.373	__		
Total Surface	r	.228	-.10	-.04	.14	.10	.64***	__	
	p	.137	.533	.794	.367	.508	<.001	__	
Total Deep	r	.04	.23	.173	.12	.10	.83***	.10	__
	p	.807	.142	.260	.453	.504	<.001	.523	__

Note. Predictor scores in this table are raw scores.

BAARS ADHD: Total ADHD symptom count from BAARS, WJ WM: Woodcock Johnson-III Working Memory Battery Z-scores, WJ BA: Woodcock Johnson Broad Attention Battery Z-scores, Total Comp: total overall comprehension, Total Surface: surface level comprehension across emotional and neutral conditions, Total Deep: deep level comprehension across emotional and neutral conditions

* *p* < .05 ***p* .01 ****p* < .001

Table B4

Bivariate Correlation Table of Predictors and Outcomes (Composite Scores)

Variable		BAARS ADHD	AXCPT PBSI Acc	AXCPT PBSI RT	WJ WM	WJ BA	Total Comp	Total Surface
BAARS Total ADHD	r	__						
	p	__						
AXCPT d'prime	r	-.90	__					
	p	.558	__					
PBSI Composite[a]	r	-.08	.41**	__				
	p	.610	.006	__				
WJ Composite[b]	r	-.08	.08	-.35*	__			
	p	.622	.607	.019	__			
Total Comp	r	.16	.30	.13	.16	__		
	p	.304	.046	.393	.304	__		
Total Surface[c]	r	.23	.01	-.09	.13	.64***	__	
	p	.137	.970	.584	.418	<.001	__	
Total Deep[d]	r	.04	.39**	.23	.11	.83***	.10	__
	p	.807	.009	.126	.463	<.001	.523	__

Note. Predictor scores in this table are standard or composite scores.

[a]PBSI Composite: PBSI Accuracy and RT z-scores added together

[b]WJ Composite: Woodcock Johnson-III Working Memory Battery Z-scores and Woodcock Johnson Broad Attention Battery Z-scores added together

[c]Total Surface: surface level comprehension across emotional and neutral conditions, dTotal Deep: deep level comprehension across emotional and neutral conditions

* $p < .05$ ** p .01 *** $p < .001$

Table B5

Partial Correlation Table of Predictors and Outcomes

Variable		BAARS Total ADHD	AXCPT d'prime	PBSI Composite[a]	WJ Composite[b]
Total Comprehension	r	.21	.32	.23	.25
	p	.193	.042*	.145	.114
Total Surface[c]	r	.24	.02	-.02	.13
	p	.131	.916	.914	.407
Total Deep[d]	r	.09	.39*	.30	.22
	p	.593	.011	.051	.154

Note. Predictor scores in this table are standard or composite scores

[a]PBSI Composite: PBSI Accuracy and RT z-scores added together

[b]WJ Composite: Woodcock Johnson-III Working Memory Battery Z-scores and Woodcock Johnson Broad Attention Battery Z-scores added together

[c]Total Surface: surface level comprehension across emotional and neutral conditions, dTotal Deep: deep level comprehension across emotional and neutral conditions

*$p < .05$, **$p < .01$, ***$p < .001$

Appendix C: EEG Analyses

Correlation Tables

Table C1

Alpha Power Correlations with Variables for Negative and Neutral Conditions

Negative Condition				
	Electrode Channel	Measure	*r*	*p*
	P7	AXCPT PBSI Reaction Time	-.84	.037
	P7	Total Comprehension	-.84	.037
	P3	Total Comprehension	-.85	.033
	P8	AXCPT d'prime interference	-.98	.000
	P8	Total Surface Comprehension	-.82	.045
	O1	Total Neutral Condition Comprehension	-.84	.038
	T8	BAARS Total ADHD Symptoms	.93	.007
	F8	Total Surface Comprehension	-.84	.035
	C4	AXCPT d'prime interference	-.86	.027
	C3	Total Emotion Condition Comprehension	-.82	.044
	Fp1	Surface Comprehension Neutral Condition	-.91	.011
	F7	AXCPT d'prime interference	-.95	.003
	PO4	Total Comprehension	-.83	.041
	AF4	AXCPT d'prime interference	-.89	.017
	AF4	Total Surface Comprehension	-.87	.024
	AF4	Total Neutral Condition Comprehension	-.87	.023
	FC1	Total Deep Comprehension	-.86	.029
	FC5	AXCPT d'prime interference	-.95	.003
	PO3	AXCPT d'prime interference	-.97	.001
Neutral Condition				
	Electrode Channel	Measure	*r*	*p*
	P7	BAARS Total ADHD Symptoms	.74	.015
	P7	WJ Broad Attention Battery ZScore	.64	.046
	P7	Total Comprehension	.65	.044
	P7	Total Emotion Condition Comprehension	.77	.010
	P7	Total Emotion-Neutral Comprehension	.75	.012

Pz	Total Emotion Condition Comprehension	.74	.015
Pz	Total Emotion-Neutral Comprehension	.72	.020
P8	Surface Comprehension Neutral Condition	-.80	.006
Fp2	Total Comprehension	.69	.028
Fp2	Total Emotion Condition Comprehension	.70	.023
Fp2	Total Emotion-Neutral Comprehension	.63	.049
AF4	Surface Comprehension Neutral Condition	-.75	.012
CP2	BAARS Total ADHD Symptoms	.65	.040
CP2	Total Comprehension	.67	.035
CP2	Total Emotion Condition Comprehension	.65	.042
FC5	WJ Working Memory Battery ZScore	.68	.029
FC5	Surface Comprehension Neutral Condition	-.74	.015

Note. All reported statistics are significant at either $p < .05$, $p < .01$, or $p < .001$ levels

Table C2

Theta Power Correlations with Variables for Negative and Neutral Conditions

Negative Condition				
	Electrode Channel	Measure	*r*	*p*
	P7	Total Emotion Condition Comprehension	.94	.005
	P7	Total Emotion-Neutral Comprehension	.84	.036
	P4	AXCPT d'prime interference	-.90	.014
	P4	Total Surface Comprehension	-.83	.040
	P8	WJ Working Memory Battery ZScore	.93	.007
	P8	WJ Broad Attention Battery ZScore	.89	.016
	O1	AXCPT d'prime interference	.85	.030
	O2	AXCPT PBSI Reaction Time	.94	.005
	O2	AXCPT PBSI Sum	.88	.022
	T8	Total Surface Comprehension	.93	.008
	T8	Surface Comprehension Neutral Condition	.90	.016
	F8	Total Deep Comprehension	-.89	.017
	C4	AXCPT PBSI Reaction Time	.85	.034
	F4	Surface Comprehension Emotion Condition	.95	.003
	Fz	Total Neutral Condition Comprehension	-.98	.000
	Fp1	AXCPT PBSI Accuracy	.85	.031
	Fp1	AXCPT PBSI Sum	.85	.034
	FC6	AXCPT PBSI Reaction Time	.85	.032
	FC6	AXCPT PBSI Sum	.82	.045

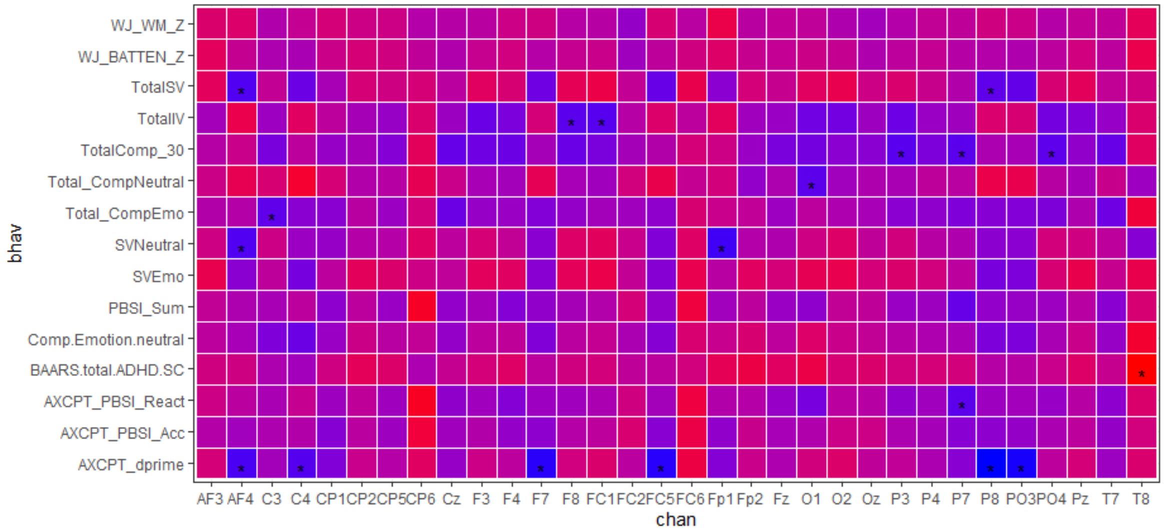
	Electrode Channel	Measure	*r*	*p*
	FC2	AXCPT PBSI Accuracy	.85	.033
	FC2	AXCPT PBSI Reaction Time	.82	.045
	FC2	AXCPT PBSI Sum	.89	.016
	AF4	AXCPT d'prime interference	-.98	.000
	AF4	Total Surface Comprehension	-.89	.018
Neutral Condition				
	Electrode Channel	Measure	*r*	*p*
	P7	AXCPT d'prime interference	.68	.031
	P7	Total Comprehension	.77	.009
	P7	Total Emotion Condition Comprehension	.71	.021
	P4	AXCPT d'prime interference	-.68	.031
	Cz	Total Surface Comprehension	.66	.036
	P8	WJ Working Memory Battery ZScore	.88	.001
	P8	WJ Broad Attention Battery ZScore	.87	.001
	F8	Total Deep Comprehension	-.76	.011
	PO4	Total Comprehension	.64	.046
	PO4	Total Emotion Condition Comprehension	.65	.041
	AF4	AXCPT d'prime interference	-.69	.027
	FC5	WJ Broad Attention Battery ZScore	.67	.034
	FC5	WJ Working Memory Battery ZScore	.82	.003
	FC5	Surface Comprehension Emotion Condition	.63	.049

Note. All reported statistics are significant at either $p < .05$, $p < .01$, or $p < .001$ levels

Correlation Maps

Figure C1

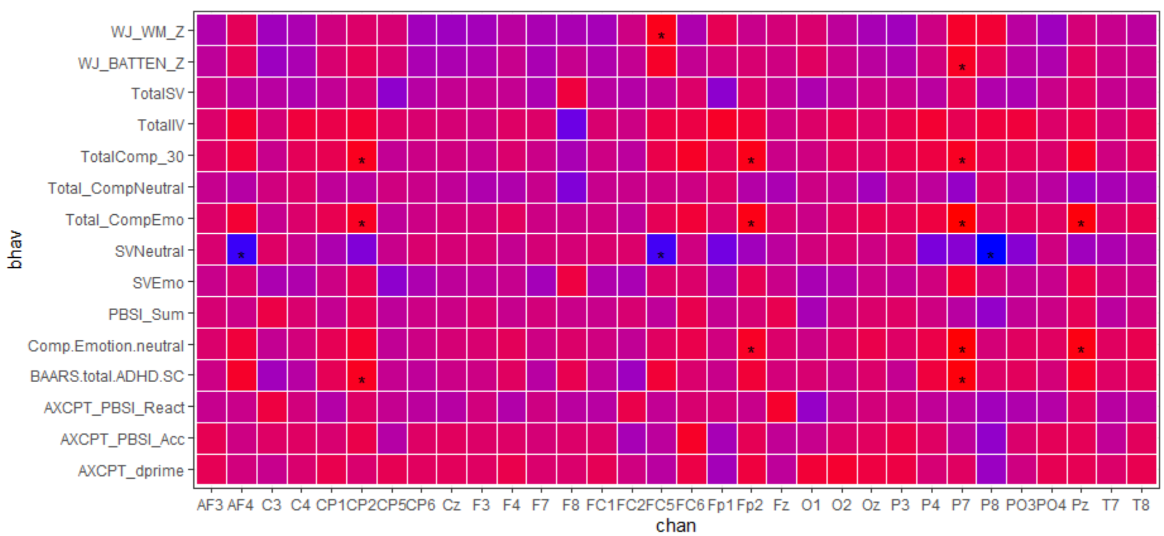
Alpha power electrode correlation map for negative valence condition



Note. All significant electrodes at either $p < .05$, $p < .01$, or $p < .001$ levels are marked with an asterisk

Figure C2

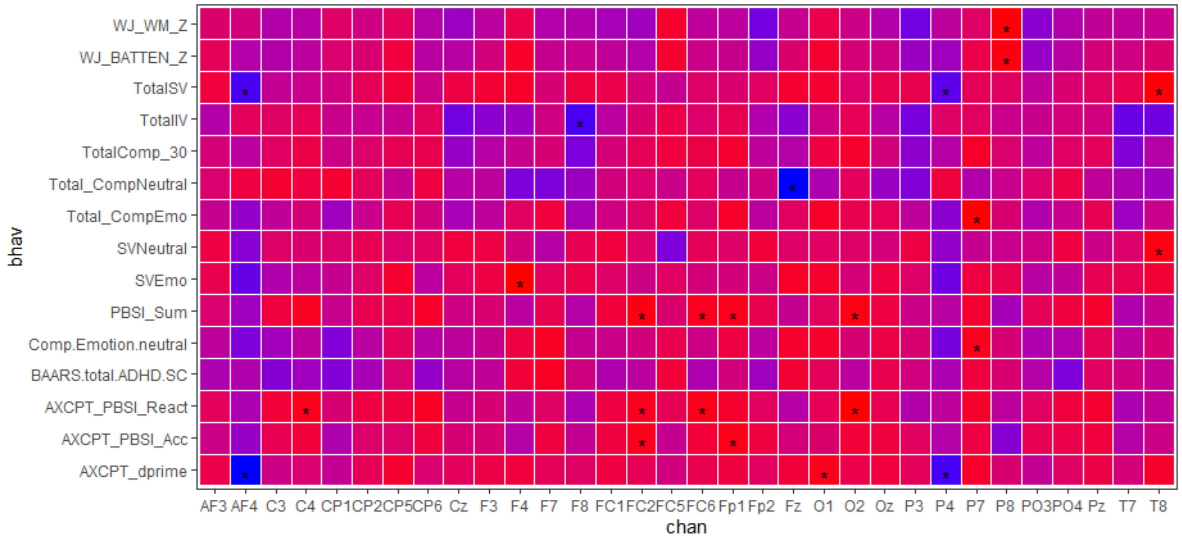
Alpha power electrode correlation map for neutral valence condition



Note. All significant electrodes at either $p < .05$, $p < .01$, or $p < .001$ levels are marked with an asterisk

Figure C3

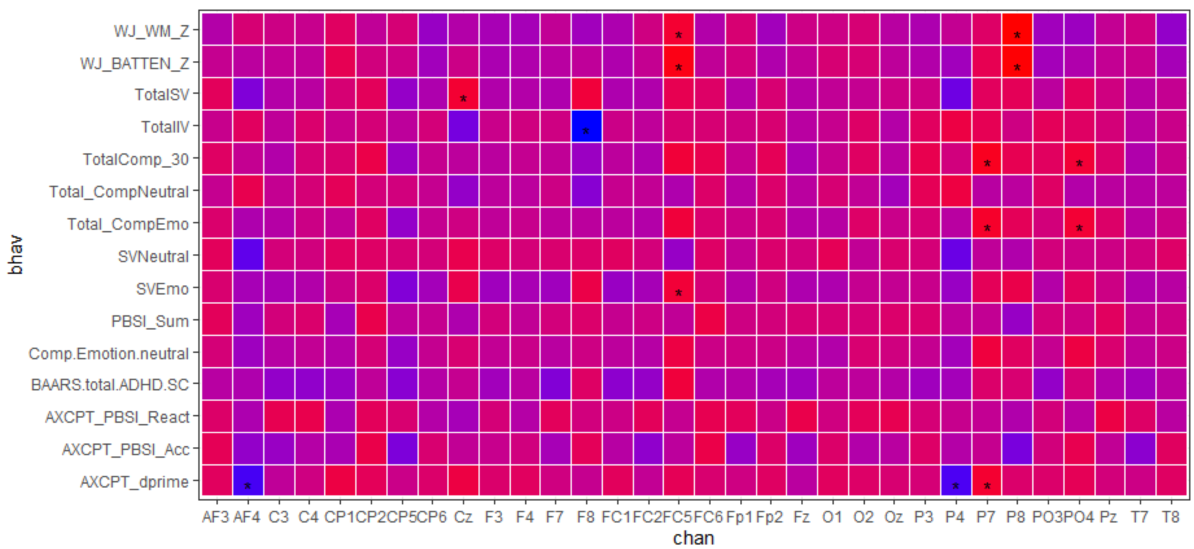
Theta power electrode correlation map for negative valence condition



Note. All significant electrodes at either $p < .05$, $p < .01$, or $p < .001$ levels are marked with an asterisk

Figure C4

Theta power electrode correlation map for negative valence condition



Note. All significant electrodes at either $p < .05$, $p < .01$, or $p < .001$ levels are marked with an asterisk

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