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## Abstract

Evidence suggests that Attention-deficit/hyperactivity disorder (ADHD) negatively affects verbal and reading comprehension in children, although the effect of ADHD on reading comprehension is partially mediated by the initial reading level of the participant. Additional research suggests that children and adults with ADHD tend to demonstrate a reduced working memory capacity, when compared to their non-ADHD peers, which may also affect the relationship between ADHD and reading comprehension. However, the current literature consists primarily of studies performed with children, and there has been little investigation into the biological factors of reading comprehension in ADHD populations. The current study sought to expand the current research regarding ADHD and reading comprehension in young adults enrolled in undergraduate psychology classes at a southeastern university. The current study also explored biological determinants of reading comprehension though electrooculogram analysis. It was found that, in this sample, individuals with more ADHD symptoms showed similar to improved reading comprehension when compared to individuals with fewer ADHD symptoms. This represents a reversal of trends found in the previous literature.

# Exploring Reading Comprehension in Undergraduate Students with ADHD Symptoms

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder affecting millions of individuals in the United States and around the world (Barkley, 2006). According to the American Psychiatric Association (APA) Diagnostic Statistical Manual of Mental Disorders Fourth Edition (DSM-IV-TR), 3-7% of children 6-7 years of age have ADHD (APA, 2000). Recent community studies report that 8.7% to 9.5% of children (5.4 million) between the ages 4-17 years are affected by ADHD (Froehlich et al., 2007; Visser, Bitsko, Danielson, Perou, & Blumberg, 2010). Once thought to be a disorder of childhood, longitudinal studies show that up to 50-80% of children clinically diagnosed with the disorder show persistent, chronic ADHD into adolescence; up to 50-70% still have symptoms into adulthood (Barkley, 2006). Current prevalence rates of adult ADHD are estimated to be 4.4% in the US (Kessler et al., 2006).

ADHD is a heterogeneous disorder characterized by three core symptoms: (1) an inability to control or inhibit behaviors and/or to resist distractions (impulsivity): (2) excessive activity levels (hyperactivity); and, (3) poor sustained attention and persistence especially when tasks are repetitive, routine, and/or when concentration is required (Barkley, 2005, 2006). According to the DSM IV-TR, an individual must exhibit six or more symptoms of hyperactivity, impulsivity, and/or inattention, consistently for at least six months (American Psychiatric Association, 2000). To meet diagnostic criteria, symptoms must be present prior to the age of seven, and impairment must exist across multiple settings (i.e., school and home). There must be clear evidence of impairment in social, academic and/or occupational functioning (APA, 2000). The symptoms of hyperactivity, impulsivity, and/or inattention must be maladaptive and inappropriate for the individual's developmental level, and may not be better explained by other disorders (e.g., Anxiety, Mood, Personality, or Pervasive Developmental Disorders). Depending on the predominance of symptoms, individuals may be categorized to three types of ADHD - inattentive type, hyperactive-impulsive type, or the combined type (APA, 2000).

The fifth edition of the Diagnostic and Statistical Manual, the DSM-5, retained the same 18 symptoms from the DSM-IV-TR across the domains of inattention and hyperactivity and impulsivity, and specifies that ADHD should not be diagnosed when symptoms are better explained by other disorders (APA, 2013). Other changes have been made to reflect the life-span nature of the disorder, including the following: the onset of symptoms that cause impairment has been raised from 7 to 12 years old, and, fewer symptoms are required to diagnose adults. Additionally, ADHD is now listed under neurodevelopmental disorders to highlight the neurobiological and brain-related differences found in individuals with ADHD.

While both children and adults with ADHD have high rates of comorbidity for a variety of psychiatric disorders, this study is primarily interested in rates of reading disabilities (RD) and/or learning disabilities (LD). A recent review of the literature shows that studies conducted from 2001 to 2011, report rates of ADHD and LD at 45.1% for children (DuPaul, Gormely, & Laracy, 2011). Depending on the study, rates of ADHD plus RD ranged from 11-52% and varied primarily as a function of how each disorder was diagnosed. In general children with ADHD are 3 times more likely to have a learning disability; while, children with LD are 7 times more likely to have ADHD compared to typically developing peers. A number of studies have explored reasons for these high rates of comorbidity and will be briefly reviewed in subsequent sections. At this time, most researchers suggest that individuals with ADHD and LD share common neurocognitive dysfunctions related to deficits in working memory and processing speed (Swanson, Mink, & Bocain, 1999; Willcut et al., 2011). Prevalence rates of learning disabilities in adults are harder to verify which may in part be related to the significant adverse effects that ADHD has on academic outcomes over the lifespan including high drop-out rates and academic underachievement (see Barkley, Murphy & Fischer, 2010 for an in-depth review of adult ADHD outcomes).

The next portion of the paper provides a brief review of the literature exploring deficits in executive functions including working memory and disinhibition in an effort to provide a framework for a neurocognitive model of ADHD. This section also highlights developmental factors related to these functions. The relationship between specific neurocognitive deficits related to ADHD (i.e., working memory, processing speed, and focused attention), academic functioning, and reading comprehension are also reviewed. Finally, methods that have been found useful for measuring physiological differences during reading particularly related to the visual attention processes and focused attention are presented.

## Deficits in Executive Functions and Working Memory: A Neurocognitve Model of ADHD

Executive functions refer to higher-order cognitive processes including working memory and inhibitory control which are primarily mediated by the frontal lobes (Rommelse et al., 2008). Studies investigating the neurobiological substrates of ADHD in children and adults have found anatomical and functional differences in the prefrontal cortex (PFC) compared to non-ADHD individuals (Barkley, 1997; Nigg, 2006). The PFC receives incoming information/stimuli from various brain regions, sustains attention, inhibits distractions, and governs emotions and impulses involved with regulating complex behaviors; and, serves as the top-down control system regulating executive functions including planning, inhibitory control of behavior, and working memory. The PFC is slow to develop and may be responsible for some of the characteristic neurocognitive and behavioral deficits that differentiate individuals with and without ADHD. A longitudinal study investigating the developmental trajectory and brain growth patterns of children with ADHD, using repeated MRI scans, revealed marked delays in cortical maturation, most prominently in the PFC regions that are critical for regulating attention, emotions and behaviors (Giedd, Blumenthal, Molloy, & Castellanos, 2006; Shaw et al., 2007). Both structural and functional anomalies in the PFC have been "implicated in the pathogenesis of ADHD;" these are the latest regions to develop; and, approach normal cortical thickness in late adolescence 5 years after their control peers (Shaw et al., 2007, p. 19651). Coupled with delays in brain growth in temporal into occipital regions (3-4 year delay), and early peak thickness in the primary motor cortex these structural differences correspond to the functional impairments found in children and persist in adults with ADHD. The five year delay in the PFC's development, coupled with general under-activation of the frontal lobes in individuals with ADHD, indicates that the neurological differences between individuals with ADHD and their neurotypical peers encompass both developmental and functional differences. These differences may help explain the behavioral symptoms of ADHD, such as an inability to inhibit movement due to the under-activation of the PFC, which is partly responsible for inhibitor control of behaviors.

Neurocognitive deficits have been the focus of new explanatory models of ADHD, and a number of studies have investigated the relationship between neurobiological substrates or pathways that play a role in executive function (EF) deficits including problems with organization, planning, decision-making, shifting mental sets, response-inhibition and working memory (Barkley, 1997; Nigg, 2006; Pennington & Ozonoff, 1996). For purposes of this study, we are focusing on specific aspects of executive functions, particularly deficits in working memory and inhibitory control because these are core features of ADHD, and may partially explain the associated reading problems commonly found in both children and adults with ADHD.

Working memory (WM) is generally defined as the ability to selectively attend, to simultaneously hold and process information, and, to concentrate so that information can be encoded into long-term memory (Posner, 2004). Baddeley (2003) describes WM as a limited-capacity system, responsible for producing, maintaining and manipulating stimuli; whereby the cognitive representations of incoming stimuli are rehearsed and independently stored in subsystems depending on the phonological or visual-spatial characteristics of the task. Baddeley (2007) suggests that the WM system is comprised of a “central executive” (CE) responsible for two major processes: focusing and dividing attention particularly in the face of competing stimuli or concurrent tasks (dual processing); and, rehearsal/storage in phonological (PH) and visual-spatial (VS) subsystems.

Given the complexity of this system and its relationship to core features of ADHD, there has been a great deal of interest in exploring WM deficits as a potential endophenotype or more objective neurocognitive measure of ADHD (Kasper, Alderson, & Hudec, 2012). In a meta-analysis of 45 studies, Kasper et al. (2012) reported large effect sizes on phonological (PH = .69 effect size) and visuospatial aspects of WM (VS = .74 effect size), which suggests that children with ADHD consistently perform more poorly than typically developing children. There were a number of methodological variables associated with large between group WM differences (i.e., greater number of trials, fewer females, greater CE demands, recall vs. recognition task); while other variables, decreased between group differences (i.e., fewer number of trials, more females, lower CE demands, recognition vs. recall tasks). A better understanding of variations in these specific methodological variables provides insight into and ways for explaining differences across studies when they do appear.

Another study showed clear differences in working memory skills between ADHD and non-ADHD children while performing math tasks (Huang-Pollock & Karalunas, 2010). Pre-school children with and without ADHD were taught two cognitive tasks requiring varying degrees of working memory (WM): Task (1) consisted of arithmetic problems, where numbers were replaced by letters so that mathematical operations could be performed using a simple alphabetic code (high WM load), and Task (2) consisted of math problems that could be solved by using fingers (low WM load). The alphabet arithmetic and finger math tasks were matched for item difficulty so that any differences in performance would be accounted for by deficits in WM. Children with ADHD made more errors and were slower to solve problems than their non-ADHD counterparts; and, error rates and response times increased as the WM demands of the task increased. As predicted, it took children with ADHD longer to develop automaticity when learning new tasks with high WM demands (Huang-Pollock & Karalunas, 2010).

While current research shows promise for describing how children with ADHD differ from typically developing peers, future studies need to explore whether working memory deficits are unique to ADHD or are symptomatic of other learning and/or reading disorders. With this in mind, Swanson, et al. (1999) examined the relationship between phonological processing and

WM deficits in children with varying levels of reading problems with and without ADHD, including: children with reading disabilities (RD), slow learners without a formal learning disability diagnosis (SL), children with ADHD alone (ADHD), and children with combined ADHD and reading disabilities (ADHD + RD) or ADHD + SL. Phonological processing deficits were found in all children with reading difficulties regardless of their diagnostic group status, while core symptoms of ADHD (i.e., inattention and hyperactivity) did not predict poor reading performance. Children in the ADHD+ SL or the SL (alone) groups also obtained higher scores than children in the RD and RD+ADHD groups on visual-spatial working memory tasks. Finally, participants with RD alone had the lowest scores on verbal working memory tasks than did the other groups (Swanson et al., 1999). In this study, children with ADHD did not demonstrate significantly weaker working memory abilities when compared to children with specific reading disabilities or general learning delays.

In an effort to further explore unique or shared neurocognitive and EF deficits, Willcutt, et al. (2001), found that reading disabilities, rather than ADHD, were associated with deficits in phonemic awareness and poor verbal working memory; while, children with ADHD displayed greater deficits in executive functions primarily impaired inhibition. Although WM deficits were not consistently found in all participants with ADHD, this may be due to the types of working memory that were investigated. Specifically, Willcutt et al. (2001) did not include tasks that measured visuospatial working memory, which may have suppressed or underestimated WM deficits reported in that have been shown to be related to ADHD. There was a cumulative adverse effect on performance when participants had both ADHD and reading disabilities. Given that ADHD is often comorbid with reading disabilities (Barkley, 1997; DuPaul et al.

2013), it is important to measure the additive effects, particularly when individuals with multiple diagnoses are included.

In a large scale twin study of 614 children investigating the etiology and comorbidity of RD and ADHD, McGrath et al. (2011) utilized a multiple model of cognitive deficits to determine shared and unique cognitive deficits among these groups. Using hierarchical structural equation modeling, the following results were reported: (1) phonological awareness and naming speed deficits were unique predictors of RD; (2) response inhibition was the single unique predictor for ADHD; while, (3) deficits in processing speed predicted both the RD and ADHD groups. The three predictor variables explained 75% of the variance of the RD symptom dimension; while the two predictor variables accounted for 35% of the variance in the inattention symptom dimension and only 16% of the hyperactive-impulsive symptom dimension. Although verbal working memory was also considered, it did not significantly predict RD or ADHD symptom dimensions after the effects of other cognitive variables were controlled (i.e., processing speed, naming speed, etc.) (McGrath et al., 2011). It is important to note that the comorbidity between RD and ADHD, particularly inattention, appeared to be a function of shared deficits in processing speed. This study highlights the importance of investigating multiple predictor variables so that the variance that is shared with an omitted factor is not attributed to one that has been included.

Response inhibition, or the ability to regulate or control behaviors in response to environmental cues, has been the focus of a number of studies. Castellanos, Sonuga-Barke, Milham, and Tannock (2006) investigated the differential effects of inhibitory control and delay aversion in children with ADHD while completing tasks requiring executive functioning.

Children in the study were given a stop-go task which is a timed forced-choice task. The child is asked to respond (usually by key-press) in the presence of a stimulus called the “go signal,” except if the “stop signal” is also present. This is considered to be a test of inhibitory control because the participant must inhibit the urge to respond when the “stop signal” is present (Castellanos et al., 2006). In addition to the stop-go task, the participants performed a delay discounting task. In this task, children were allowed to choose freely between a small immediate reward and a larger reward after a variable delay. As expected, children with ADHD showed slower response times than did their typically developing peers in response to stop signals, and delay conditions were more aversive because they preferred smaller but more immediate rewards (Castellanos et al., 2006). Although scores on the stop-go and delay tasks were not highly correlated, when considered together the majority of children in the study were correctly classified as ADHD or non-ADHD based on their performance. This study suggests that a combination of EF tasks may be better predictors of ADHD than measures of single delay or inhibitory deficits. For this reason, a more global measure of executive dysfunction, such as the BDEFS, may be more useful than individual measures of certain aspects of executive functioning.

Differences in verbal working memory, inhibitory control, and sustained attention appear to differentiate children with and without ADHD, and may be potential mediating variables explaining the relationship between ADHD and reading difficulties. However, the individual impact of ADHD as a disorder on working memory is more complex, particularly when comorbid disorders such as learning disabilities are considered. It is thus important to consider various aspects of executive functioning in relation to ADHD, in order to determine any true differences in functioning which may exist. Most academic tasks require an ability to focus attention sufficiently to understand and perform the task, while remembering the instructions needed to do so. Reading and understanding a story, in particular, requires the ability to retain information long enough to understand the plot and accommodate the introduction of new characters and events. The literature reviewed to this point suggests that executive functions including working memory and response inhibition are compromised in children with ADHD, and may partially explain difficulties in reading difficulties. A more in-depth review of the literature exploring the relationship between ADHD and academic functioning will be presented in the following sections.

## The Relationship Between ADHD and Academic Functioning

Although the current DSM-IV-TR diagnostic criteria require evidence of ADHD symptoms before the age of 7 and before the age of 11 in DSM-5, many children with ADHD are first diagnosed due to school difficulties (Faraone et al., 1993). According to Faraone et al. (1993), grade failure and lower overall scholastic performance are common among children with ADHD, regardless of comorbidities. Although the study included only white, non-Hispanic, males, two comparison groups were also examined – male and female siblings of the ADHD participants and a control group of typically developing children and their siblings. Children with ADHD performed more poorly on the Wechsler Intelligence Scale for Children-Revised (WISC-R), were more likely to repeat a grade in school, and used more tutoring services compared to their siblings, who were not diagnosed with any psychological disorder (Faraone et al., 1993). Siblings of children with ADHD scored slightly lower than did siblings of the typically developing controls suggesting possible familial or genetic factors. Comorbid conduct and learning disorders did contribute to the negative scholastic outcomes among participants with ADHD, but the findings remained significant even among participants with ADHD who had no comorbid disorders (Faraone et al., 1993).

**Factors Affecting Reading Comprehension**

Reading comprehension requires complex cognitive processes, including word recognition, vocabulary knowledge, and sentence comprehension or understanding. Klauda and Guthrie (2008) examined the relationship between the speed of word recognition and semantic processing in fifth graders. Word recognition speed and semantic processing are important aspects of reading comprehension that are known to vary between individuals and groups. In the 2008 study, 278 fifth graders were asked to participate in several assessments of word recognition, reading comprehension, and reading fluency measures (Klauda & Guthrie, 2008). Experimenters scored these measures after each individual's performance, and recordings of the interviews were scored in order to establish inter-rater reliability (Klauda & Guthrie, 2008). Students who tested below average in reading, as well as certain selected students at and above grade level, were exposed to additional tests of word recognition and oral reading skills (Klauda & Guthrie, 2008).

Results from multiple regression analyses indicated that word recognition, syntactic processing, ability to make inferences, and background knowledge (including vocabulary) were all related to reading comprehension, and that higher scores on these measures predicted higher scores on other measures of reading comprehension (Klauda & Guthrie, 2008). Although the relationship between semantic processing and reading comprehension has been studied in readers with below-average skills, reading comprehension research in individuals with ADHD and other disorders is not extensive. In addition to lower reading comprehension skills, emerging research on children with ADHD show that they have slower and more variable reading rates compared to typically developing peers (Zentall, Tom-Wright, & Lee, 2013). While this latest study did not specifically analyze the effects of learning disorders or ADHD on the relationship between word recognition, processing speed, and background knowledge on reading comprehension, it does provide a clear direction for future study by demonstrating a possible area of deficit. The findings of Klauda and Guthrie (2008) and Zentall et al. (2013) informed the design and essential question of the current study.

**Working memory deficits relate to reading comprehension.** Working memory, one aspect of executive functioning, involves the ability to direct mental energies and to control one's attention for the completion of a task. McVay and Kane (2012) examined the role of mind-wandering as a potential mediating variable in the relationship between working memory and reading comprehension. They found that among skilled adult readers in a sample of undergraduates, mind-wandering across four reading tasks loaded onto an individual variable, which seemed to vary among the participants. Factor analysis results revealed that a mind-wandering factor partially explained the relationship between working memory and reading comprehension. Participants with high working memory ability were better able to sustain attention on the reading tasks, and were less likely to report mind-wandering than were participants with lower working memory capacities (McVay & Kane, 2012). However, mind-wandering did not fully explain the relationship between working memory and reading comprehension, indicating that working memory is likely to have its own direct relationship to reading comprehension. Unsworth and McMillan (2013) confirmed the relationship between working memory capacity and mind-wandering, and indicated that both factors showed individual differences that were related to individual performance on reading comprehension tasks. Motivation and topic interest were also noted to relate to both mind-wandering and reading comprehension, while prior experience with a topic also partially-predicted reading comprehension (Unsworth & McMillan, 2013). These findings suggest that it may be useful to control for topic familiarity in order to accurately assess reading comprehension.

Reading requires that a person be able to hold important points in working memory (WM) as they decode and process words and sentences for meaning, and as they gather new information. All of these processes occur while reading a story, novel, or even a textbook. The ability to maintain and use important information is part of working memory. Caplan, DeDe, Waters, Michaud, and Tripodis (2011) assessed the relationship between working memory, processing speed, and reading comprehension for simple and complex sentences. Participants read sentences that were either possible or impossible based on changing one word. In the first experiment, the sentences were either cleft object (e.g., “to the boy, who was Joe’s friend”) or cleft subject (e.g., “the ball, which Joe was holding”). In the second experiment, all sentences included relative clauses imbedded in double parenthetical phrases or a complex sentence structure. Although working memory did not predict sentence comprehension in the first experiment, lower working memory load was associated with increased processing times in the second experiment (Caplan et al., 2011). Although overall comprehension accuracy was similar in both groups, in determining the realistic versus impossible nature of the sentences, participants with lower working memory tended to take longer to make judgments about sentences at the same level of difficulty.

Working memory capacity seems to affect not only reading comprehension itself, but also the selection of reading comprehension strategies depending on the reason for reading a passage. Linderholm and van den Broek (2002) examined the extent to which college students with different working memory capacities altered their cognitive strategies in order to accommodate their purpose for reading a selected text. Participants completed reading span tasks to determine their working memory capacity, which split them into high working memory capacity and low working memory capacity groups. Individuals in both groups were randomly assigned to one of two texts. The texts “Origins of the Moon” and “Why American Songbirds are Vanishing” were modified versions of Scientific American magazine articles, and were chosen for interest value and educational quality. Both articles shared a similar structure and format. Once participants received their article, they were told either to read the article as though they were browsing a magazine and had come across it (entertainment condition) or to imagine that they were reading the text for an exam in class (study condition).

As they read the article aloud, participants were asked to state their reactions to the article aloud; responses, including simple repetitions, predictions, and other reactions, were recorded and categorized. These responses were coded as being evaluative, associations, connections intended to deepen understanding, and inferences about the content of the articles. Overall, inferences were more common during reading for the study condition, for both working memory groups, as were paraphrasing statements. However, participants with lower working memory capacities made fewer predictive inferences in both reading conditions, and repeated more of the text aloud when reading for study. During a free recall task, differences between working memory groups were seen only for the study condition. As predicted, participants with lower working memory capacity remembered less about the articles than did the higher working memory capacity comparison group. This study suggests that the relationship between weaknesses in working memory and reading comprehension are not limited to childhood but continue into young adulthood.

Christopher et al. (2012) examined the differential effects of working memory, processing speed, and naming speed on word reading and reading comprehension to determine if they served as unique predictors of reading ability. Children and adolescents between the ages of 8 and 16 years old were divided into two groups (8 to 10 years, and 11 to 16 years). The relationship between word reading and reading comprehension was tested across groups in order to understand whether reading experience may help explain the relationship between these two skills. There were no significant age related differences between groups, supporting the important relationship between word reading and reading comprehension regardless of age and reading experience. Working memory and processing speed were significant and unique predictors of both reading comprehension and word reading ability, while processing speed was somewhat more predictive of word reading ability than of reading comprehension. The speed with which participants were able to name pictures was not predictive of reading ability or comprehension. These findings suggest that, while working memory and processing speed are both general constructs of executive functioning, they appear to have individual predictive patterns for reading ability and may have differential effects on global cognitive functioning.

In a longitudinal study, Cain, Oakhill, and Bryant (2004) examined the relationship between working memory capacity and reading comprehension skills in children. Children were tested on three occasions, at ages 8, 9, and 11, and were given a battery of tests to measure reading ability, vocabulary, comprehension skills (such as inference making), and working memory (operationally defined as performance on sentence span and a digit span-type task). All of the children were considered to be average or mid-level readers, as very good or very poor readers were excluded from the study. At each time point, working memory and comprehension skills were predictive of reading comprehension abilities, even after controlling for the effects of word reading ability and vocabulary. The effects of comprehension skills on reading comprehension were not fully mediated by working memory; although working memory was predictive of reading comprehension abilities in the children studied, the differences among individuals in terms of their working memory abilities could not sufficiently explain the differences in reading comprehension observed. Other factors such as basic comprehension skills provided unique predictive value for reading comprehension at each time point of the study. This study provides more evidence about the relationship between working memory and reading comprehension in non-ADHD populations.

**Verbal Comprehension Deficits in Children with ADHD Relate to Reading Comprehension**

Although the nature of the underlying cognitive deficits associated with reading comprehension deficits is not fully understood, studies comparing children with ADHD to typically developing peers show a relationship between deficits in story comprehension and verbal processing (Lorch, et al., 1999). This study examined the relationship between story structure and comprehension in 7- to 11-year-old boys and girls, both with and without ADHD. Children listened to audiotapes of two folk tales that were roughly 4 minutes long. Each passage was too complicated to be recalled by simple memorization. The children were then asked to retell the story while being audio recorded, so that the next child in the study could hear about the stories (Lorch et al, 1999). The children's retellings of the folk stories were analyzed for completeness, and for their adherence to cause and effect relationships developed by the experimenters.

It was determined that typically developing children recalled more of the story units (i.e., events and people) than did children with ADHD. Additionally, typically developing children seemed more influenced by the story structure, such that story units with more causal connections (i.e., more relationship to previous and later events in the story) were recalled with greater frequency (Lorch et al., 1999). Although children with ADHD also tended to remember more causally linked story units, the relationship between causal linkage and recall was not as strong compared to typically developing children (Lorch, 1999). In 2009, Leonard, Lorch, Milich, and Hagans found similar results with early elementary school-age children. In this experiment, parents told their children a story using a standardized wordless picture book. The parents then left the room, and an experimenter asked the child to retell the story. Each child's retelling was scored based on the number of goal-based events, which moved the story towards its conclusion, non-goal-based events, and other details that were remembered. Children with ADHD showed less ability to remember goal-based events in a story, and retold the story with fewer details (Leonard et al., 2009). It was clear that events and characters with clear causal links were recalled more easily and accurately than those that have fewer relationships to other characters and events, or those that have relationships that are less clear. This might provide insight for designing interventions for children with ADHD and poor reading comprehension. Charts, family trees, and other tactics to clarify the relationships between events and characters in complex stories may aid children with ADHD in achieving better recall and comprehension.

Academic difficulties have lifelong negative outcomes for individuals with ADHD, particularly if they fail to complete secondary school. According to a 2009 study, students who do not complete high school are expected to earn between 65 and 70 percent less than their peers who do graduate (Tyler & Lofstrom, 2009). Income differences increase for those who do not earn a college degree. Other costs associated with school failure and dropping out include a greater potential for multiple early pregnancies, unemployment, and incarceration (Tyler & Lofstrom, 2009). Although there appears to be a strong relationship between these outcomes and school failure, the studies performed to date have been correlational, so it is not possible to determine the directionality of this relationship. Despite the shortcomings of correlational studies, it is clear that failure to complete high school has negative economic and social outcomes for both individuals and the community in which they live.

The nature of neurocognitive deficits in adults with ADHD are reviewed next. Studies addressing the relationship between adult ADHD and reading difficulties will be highlighted. It is important to note that the literature on adult ADHD and its relationship with reading and academic difficulties are less extensive than studies on children. This relative paucity provides a strong rationale for exploring these relationships in the present study.

## Neurocognitve Deficits in Adults with ADHD

The need to investigate the relationship between working memory, attention, and reading comprehension problems in undergraduate student populations is important because estimates suggest that 2-7% of college students in the United States have ADHD (Wyeandt & DuPaul, 2008). The degree to which neurocognitive deficits associated with ADHD affect reading comprehension, reading speed, and fluency in young adults is of interest to clinical psychologists who diagnose attention and learning disorders, and to university staff who are eager to effectively accommodate the needs of students in rigorous, demanding classes.

Roberts, Milich, and Fillmore (2012) examined the effects of ADHD on response times and accuracy rates on dual tasks and tests of working memory load in a sample of adults with ADHD between the ages of 19 and 30 years of age. Participants performed almost identically on the visual section of a dual task, in which they were instructed to press the corresponding number key in response to the presentation on screen of either a one (1) or a two (2). However, despite similar scores in the visual portion of the dual task, participants with ADHD showed slower response times on the auditory dual task, in which they were required to press keys in response to either a high or low tone, when compared to adults without ADHD (Roberts et al., 2012). Working memory differences between the groups were greater on the “N-back” cognitive task, in which participants were shown a letter, instructed to remember that letter for a certain number of trials. In each trial, participants were shown a series of letters. At the end of the series, participants were asked to determine if the letter from a certain number of trials (N) previous to the current trial had been presented. The majority of trials did not include the target letter.

Participants with ADHD were significantly less accurate at each level of the task (1, 2, and 3-back) than were participants without ADHD. However, performance differences became greater as memory load increased, and individuals had to perform more difficult tasks. An additional trend was found in reaction times, such that participants with ADHD took longer to respond in both the one and two-back tasks (Roberts et al., 2012). These data suggest that adults with ADHD have WM weaknesses which appear to be more pronounced on tasks where memory load is high. Furthermore these deficits appear to be related to a reduced maximum cognitive load, as demonstrated by poorer performance in the N-back test, rather than an inability to split attention between two stimuli.

Engelhardt, Nigg, Carr, and Ferreira (2008) examined the performance of adults with and without ADHD on a sentence processing task and on tasks of working memory. Participants were asked to read a sentence that led to an initial, misleading interpretation. Careful reading of the sentence resulted in a more accurate interpretation, and required sufficient inhibition of the initial "misleading" interpretation. There was no evidence of cognitive inhibition problems, as adults with ADHD in this sample were able to suppress or inhibit misleading information while reading a sentence; however, they did have problems reanalyzing sentences for their meaning when working memory was required (Engelhardt et al., 2008). This study suggests that cognitive inhibition problems that contributed to reading problems in children with ADHD are not present in adults with ADHD. However, deficits in WM, particularly the inability to simultaneously hold and reanalyze was impaired in adults with ADHD. Baddeley's (2003, 2007) working memory model may be useful for explaining these findings – that is, the task of reanalyzing sentences may have had higher "central executive" (CE) demands on the WM system particularly when one had to simultaneously process and retrieve information from verbal/phonological WM subsystems. It is also possible that adults with ADHD who have managed to be successful in school have learned coping skills to mask or accommodate for inhibitory weaknesses but these compensatory efforts may come at the expense of WM.

Marchetta, Hurks, Krabbendam, and Jolles (2008) also examined executive functioning deficits, including working memory in three groups: adults with ADHD, adults with ADHD with at least one comorbid disorder, and healthy control adults. Marchetta et al. (2008) found that deficits were present on tasks requiring concept shifting and verbal WM in adults with ADHD, with or without a comorbid disorder. The presence of verbal WM deficits in adults is consistent with studies of children with ADHD. These results highlight specific working memory deficits in adults with ADHD and provide a rationale for controlling this variable in the current study. This will allow for interpretation of the effects of ADHD on reading comprehension, regardless of participants' working memory functions.

Miller, Ho, and Hinshaw (2012) examined executive function deficits in young adult women diagnosed with ADHD in childhood. Women with a childhood diagnosis of ADHD performed more poorly on measures of executive functioning, including tests of working memory (digit span and letter number sequencing from the WAIS-III) compared to typically developing controls. Women with a childhood diagnosis, but whose ADHD symptoms were no longer diagnostically significant, did not differ from women with persistent ADHD symptoms (Miller et al., 2012). It is important to note that these differences in executive functioning between women with ADHD and controls were similar to those noted for men with ADHD.

The research reviewed to this point has focused on measuring aspects of ADHD, WM and attention using neurocognitive tasks. Researchers are interested in identifying more direct, physiological measures of how biological systems are activated or engaged during reading and reading comprehension tasks. The next section provides a brief review of studies investigating visual attention, using electrooculogram data.

## Biological Markers or Determinants of Focused Attention

Visual attention is a necessary factor for fluent reading, and one that can be objectively measured using electrooculogram (EOG) data. Electrooculograms measure the changes in electrical impulses that result from eye movement, and are especially useful for studying saccades. Saccades are large eye movements that allow the eyes to shift focus to different words during reading (Pittman, 2011). Eye movement differences have been related to visual-spatial memory and to inhibitory processes by Rommelse et al. (2008). Participants with a lower working memory capacity were found to have greater numbers of anticipatory glances to the section of the computer screen upon which a stimulus was expected to appear (Rommelse et al., 2008). Although this study did not examine ADHD, this may be an avenue to pursue to determine if working memory problems extend to visual-processing difficulties while reading.

Munoz, Armstrong, Hampton, and Moore (2003) examined the saccadic eye movements of individuals with and without ADHD during several non-reading tasks. In one task, participants were instructed to maintain visual attention on a central focus point until a stimulus appeared on the borders of the screen, at which point, individuals were instructed to bring their attention to the stimulus. In this task, individuals with ADHD tended to show slightly longer delays to focusing on the stimulus, and tended to maintain visual attention on the area where the stimulus appeared for longer than did individuals without ADHD, indicating differences in quick changes of attentional focus. In a second task in the same experiment, individuals were instructed to maintain focus on a central point, as before. However, during this task, the participants were to look to the opposite side of the screen from the stimulus when it appeared. In this task, individuals with ADHD demonstrated more saccades towards the stimulus, as well as a continued trend of slowed reaction time. Finally, in a task where participants were asked to maintain focus on stimuli when they appeared, individuals with ADHD again demonstrated more inappropriate saccades away from the target than did participants without ADHD (Munoz et al., 2003). Taken together the results of these experiments indicate that individuals with ADHD may have slower reaction times during tasks which require attention, in addition to the known difficulties in maintaining attention. Additionally, the inappropriate saccades away from the focal target may be a biological marker of distraction.

Kaakinen and Hyönä (2010) documented the utility of oculomotor tracking systems to investigate various aspects of reading. The study specifically measured the effect of word length and word commonness on length of fixation, the average length of saccadic eye movements, and the probability of repeating words. Differences in eye movement were measured during a reading comprehension task and were contrasted to a proofreading task. Longer, less common words require longer fixation times, and therefore are read more slowly than shorter and more common words (Kaakinen & Hyönä, 2010). The effects of word length and commonness on the length of eye saccades within words were not consistent, but both word length and word commonness predicted a greater probability of rereading the word, such that common short words were least likely to be repeated, and uncommon long words the most likely to be reread (Kaakinen & Hyönä, 2010). These findings indicate that the reading level of the selected narrative (and the level of vocabulary in particular) has an effect on reading, and that biological indicators of reading can be used to determine, to a certain extent, the amount of focus placed on reading tasks.

Data regarding fixation times, average length of eye saccades, and the re-reading of words or phrases (backwards eye saccades) can be obtained using BIOPAC Student Lab software, which can reliably replace expensive stand-alone eye-tracking equipment (Pittman, 2011). BIOPAC EOG recordings function by magnifying and recording the minute electrical impulses released during muscular functioning. These impulses are detectable at the skin's surface, and, in the case of eye tracking, can determine whether an individual's eye moved horizontally or vertically based on minute muscular activation at the temple, and directly above and below the eye (Pittman, 2011). Because EOGs record time data as well as data on eye movement, the data obtained can also be used to calculate reading speed. Backwards eye saccades will be examined in terms of saccades in one minute, rather than a total count for each participant, in order to ameliorate the effects of different reading times among different individuals. The possibility of unique biological markers of reading comprehension in individuals with ADHD is supported by the general consensus of neurological differences between individuals (children and adults) with and without ADHD (Giedd, Blumenthal, Molloy, & Castellanos, 2006; Pennington, & Ozonff, 1996).

**The Present Study**

As previously reviewed, individuals with ADHD often experience deficits in working memory, response inhibition, and other executive functions, which appear related to the core symptoms of the disorder. Deficits in working memory, sustained attention, and response inhibition may partially account for the higher rates of academic difficulties found in children with ADHD, and may be related to higher rates of college failure among the population. The current study explored the relationships between ADHD symptoms and various other concepts, including reading comprehension, working memory, executive dysfunction, and physiological measures of visual attention. One of the main purposes of the study was to expand the current literature by investigating these relationships in a sample of undergraduate students.

## Hypotheses

The current study investigated whether ADHD symptoms relate to performance on measures of reading comprehension, working memory, and focused visual attention.

The following hypotheses were tested:

1. Ha 1: Higher current and childhood symptom count scores on the BAARS-IV (a rating scale that measures the core symptoms of ADHD) will be associated with lower scores on a reading comprehension task, indicating a relationship between ADHD symptoms and reading comprehension difficulties.
2. Ha 2 (a): Higher current and childhood symptom count scores on the BAARS-IV will be associated with lower scores on a task of working memory (Digit Span).
3. Ha 2 (b): Higher current and childhood symptom count scores on the BAARS-IV will be associated with higher total scores on a measure of executive dysfunction (BDEFs).
4. Ha 3: Higher current and childhood symptom count scores on the BAARS-IV will be associated with a greater number of backwards eye saccades in one minute segments, as determined by BIOPAC software.

Finally, two exploratory multiple linear regressions were performed in order to develop a working model that might explain the relationships among these variables:

1. A hierarchical multiple linear regression analysis was performed testing the variance accounted for by working memory (Digit Span scaled scores), executive dysfunction (BDEFS total symptom count z-scores), ADHD symptoms (BAARS-IV current and childhood symptom count z-scores), physiological measures (backwards eye saccade count z-scores), and reading ability (vocabulary quiz z-scores, and WRAT-IV word reading subtest scaled scores) on reading comprehension. This

regression was performed as a hierarchical regression, in order to build a model of reading comprehension.

2. A second multiple linear regression analysis was performed testing the variance accounted for by working memory (Digit Span scaled scores), executive dysfunction (BDEFS total symptom count z-scores), ADHD symptoms (BAARS-IV current and childhood symptom count z-scores), physiological measures (backwards eye saccade count z-scores), reading ability (vocabulary quiz z-scores, and WRAT-IV word reading subtest scaled scores), and reading comprehension (reading comprehension quiz z-scores) on reading speed. Again, this regression was performed as a hierarchical regression, in order to build a model of reading speed and its predictors.

# Method

## Participants

Fifty undergraduate students were recruited for participation in the current study. An a priori power analysis determined that for sufficient power to be achieved, the current study would require 44 participants (Faul, Erdfelder, Buchner, & Lang, 2009). The participants were undergraduate students taking a psychology course at a small southeastern university. The participants received partial course credit for their participation. Participants were recruited through a sign-up sheet on a bulletin board reserved for experiment recruitment, as well as through a computer-based experiment sign-up program.

Because of the reading requirements of the experiment, only participants for whom English is their first language were included. Uncorrected vision and failure on a vocabulary quiz and word reading task were used as rule-out measures for all participants. Of the initial 50 participants, five participants failed to obtain passing scores on the vocabulary quiz and word reading task. The data for these participants was therefore excluded on the basis of their reading level, and the data for only 45 participants was analyzed. None of the five participants who were excluded had a diagnosis of ADHD. Of the 45 participants whose data were used for the current study, biological data could not be examined for five participants due to computer failure while recording eye movements with the BIOPAC software. Therefore, for analyses using the biological measures, the study sample was 40.

**Measures**

**Vocabulary (Vocabulary Matching Words 2, (www.teach-nology.com).** A brief 15-item vocabulary test was included in the questionnaire packet, in order to assess the vocabulary level of each participant (see Appendix A). Words were selected from a list of items that are commonly taught in standard eighth grade classrooms. The vocabulary quiz served a dual purpose: (1) to exclude participants who may have difficulties following directions and completing the experimental questionnaires due to deficits in basic word knowledge, and (2) to estimate the reading level of participants. Items were selected from a list of vocabulary words and definitions developed by eighth grade English Teachers in the United States. The item list has good face and criterion validity (see www.teach-nology.com). This test was used both as a rule-out measure to exclude participants with below and eighth-grade reading level, and in the exploratory analyses as a possible predictor of both reading comprehension and reading speed. The vocabulary quiz was graded as number of correct answers out of fifteen, which was converted to z-scores for ease of comparison with other data.

**Word Reading Subtest (Wilkinson & Robertson, 2006).** The Word Reading subtest of the Wide Range Achievement Test, fourth edition (WRAT-IV) was administered. The WRAT-Iv is a brief standardized test of achievement measuring reading recognition, sentence comprehension, spelling, and math computation skills for individuals between the ages of 5 and 94. The instrument was developed as a quick measure of basic academic skills, to assist in the identification of learning disabilities. Reliability and validity of the WRAT-IV is strong, with split half reliability coefficients for reading at .98. Participants were asked to read up to 55 words aloud, from a card, and were asked to stop after reading ten words incorrectly. Subtest scores for each participant were converted to standard scores for the participant's age, and were used both as a rule-out measure to exclude participants with below and eighth-grade reading level, and in the exploratory analyses as a possible predictor of both reading comprehension and reading speed. Because these scores are norm-based, they were not converted to z-scores.

**Barkley Adult ADHD Rating Scale-IV (BAARS-IV; Barkley, 2011).** The BAARS-IV is a 27-item scale used to measure current and self-reported childhood ADHD symptoms and domains of impairment in adults between the ages of 18-89. The scale is an empirically derived measure linked to DSM-IV diagnostic criteria, and has acceptable test-retest reliability ($r = .75$) and internal consistency ($\alpha = .92$) (Barkley, 2011). Although the BAARS-IV can be scored to produce independent indexes of inattention, hyperactivity, and impulsivity, as well as sluggish cognitive tempo, a phenomenon related to the inattentive subtype of ADHD, the BAARS-IV can also be used to produce a symptom count index, by accounting for reach symptom endorsed at "often" or "very often" occurring (a 3 or 4 on the BAARS-IV self-report scales). The BAARS-IV standard self-report form was administered to determine the presence of ADHD symptoms in participants, and symptom counts were scored and converted to percentiles, developed by Barkley. The total symptom counts were converted to z-scores for use in the current study.

**Barkley Deficits in Executive Functioning Scale (BDEFS; Barkley, 2011).** The BDEFS is an empirically validated, normed scale of executive functioning deficits, which measures problems in time management, organization and problem solving, self-restraint, self-motivation, and self-regulation of emotions. Correlational and group-comparison studies have demonstrated that the BDEFS is concurrently valid with several problems such as ADHD and academic underachievement. This concurrent validity may be indicative of the relationship of executive functioning to ADHD and its sequelae. The BDEFS can be delivered to participants aged 18 to 81, and has acceptable reliability and validity (Barkley, 2011). The BDEFS consists of 89 items, answered on a Likert scale of frequency (1=never, 2= sometimes, 3=often, 4=very often). The BDEFS consists of five scales, measuring aspects of executive functioning such as management of one's time, self-organization, self-restraint in terms of behavior, self-motivation, and one's ability to regulate one's emotions, and each of these factors can be scored and analyzed independently. However, the BDEFS also provides a global measure of executive dysfunction. This global measure was used in the current study to indicate participants' current levels of executive dysfunction across these five factors, rather than between them. Scores on the BDEFS were entered as total symptom counts, reporting all symptoms which were self-reported at a level of three (often) or higher; these scores were converted into z-scores for subsequent analyses.

**Demographic Questionnaire (developed by the experimenter)**. All participants were given a short demographic questionnaire, including age, gender, and year in school. The demographic survey also asked participants for their first language. Additional information was gathered to determine a previous diagnosis of ADHD, learning disorders, other psychological diagnoses, and/or vision abnormalities (see Appendix B). Demographics data were coded (e.g., 1=female, 2= male) before being entered.

**Digit Span Task (Wechsler, 2008).** Digit Span Subtest of the Wechsler Adult Intelligence Scale (WAIS-IV) was used to assess working memory. The WAIS-IV has good reliability and validity, and the factor loading of the digit span task onto the working memory index is strong (Wechsler, 2008). The Digit Span subtest consists of three separate parts – Digits Forward, Digits Backward, and Sequencing. During the Digit Span Forward task, participants were asked to repeat a list of between two and nine numbers read out loud by the experimenter, exactly as they were read to them. During Digit Span Backwards, participants were asked to listen to a list of between two and nine numbers; they were then asked to repeat these numbers in reverse order (*e.g.*, 5-3-8 repeated as 8-3-5). Finally, in Digit Span Sequencing, participants were asked to arrange lists of between two and nine numbers read by the experimenter in numerical order (*e.g.*, 4-2-9 repeated as 2-4-9). Scores for this subtest were summed and converted to standard scores to provide an estimate of working memory span. The Digit Span was scored following its manual; because these scores are norm-based, they were not converted to z-scores.

**Physiological Measures.** The experiment utilized the BIOPAC student lab software and acquisition unit to record and gather electrooculogram (EOG) data. Disposable electrodes (six per participant) and electrode lead sets (two per participant) were used to collect eye movement data based on minute electrical impulses from muscular function (see Appendix C). These minute changes in electrical charge were received by the electrodes, transmitted through the leads, and were converted into a graphical output of micro-volts over millisecond time recordings, using BIOPAC software (Pittman, 2011).

Participants' eye movements were recorded throughout the reading task, and two randomly selected one minute segments were analyzed for backwards eye saccades. Saccades were identified manually as negative horizontal movement (*i.e.*, to the left on the screen), in the absence of negative vertical movement (*i.e.*, not moving down to another line). An example of a backwards eye saccade is included in Figure 1. Due to the difficulty in identifying these movements, each one minute sample was counted twice by the experimenter, using tallies, and the average of these two counts was used as the backwards eye saccades count. In order to further normalize these data, the resulting counts were converted to z-scores. A chinrest was used to ensure that the participant remained still while completing the reading task.

**Reading Task.** A short article, entitled *The American Fascination with Zombies* (three and a half pages in length), was selected from Scientific American magazine's website (see Appendix D). The reading level of the passage was determined to be written on an eighth grade reading level using read-able.com (http://www.read-able.com/), a free website which analyzes a passage in order to form a grade level estimation. This estimation is an amalgamation of several different grade-level estimations based on different factors such as word length, word count per sentence, sentence per paragraph, and other data (see Appendix E). The reading was presented in slide format using E-prime stimulus presentation software, which also recorded reading times for each slide. Reading times for each slide were summed and entered as total reading time. Times were converted to z-scores, and two outliers were removed (*N*=43).

A brief 15- item reading quiz, written by the experimenter, was used to assess reading comprehension (see Appendix F). The reading quiz was determined to be written on a fifth grade reading level using read-able.com (http://www.read-able.com/) (see Appendix G). This indicates that participants who meet the inclusion criterion of an eighth grade reading level should be able to understand the comprehension quiz. This quiz was the primary measure of reading comprehension in the study, and was scored as the number of correct answers out of fifteen, though partial credit was awarded. These scores were converted to z-scores for ease of comparison with other data.

**Procedure**

Participants made individual appointments to perform the experiment using a community board at the university. Upon arrival, participants were greeted by the experimenter and were given the informed consent document (see Appendix H). The experimenter fully explained the informed consent document, and answered any questions that the participant had regarding the study. Participants were informed that they were free to leave at any point during the study without penalty.

If the participant chose to continue, they completed a brief vocabulary quiz and the WRAT word reading task which served as exclusionary measures. Failing scores on both measures indicated reading ability below that required to sufficiently understand the article used in this study; five participants were excluded on the basis of these measures. Participants who were excluded were allowed to continue, to avoid the potential emotional distress that may have resulted if they were told that their reading levels were too low to fulfill the study requirements. While data were collected for these students, they were not used in the final analyses. After the WRAT and the vocabulary quiz were completed, the experimenter explained how electrodes would be attached before placing the electrodes on the participant's skin. An electrode was placed on each temple, in line with the participant's pupils (Pittman, 2011). Additional electrodes were placed on the participant's forehead above each pupil; one was placed on the center of the forehead, and the other was placed on the cheekbone below the right eye, in line with the pupil (Pittman, 2011). Electrode attachment was always completed before questionnaires were given to allow the electrode adhesive time to cure.

After the electrodes were attached, participants completed the demographic questionnaire, and the BAARS-IV and the BDEFS rating scales. The experimenter remained in the room as the questionnaires were completed. The experimenter placed the participant at the computer, and attached the electrode leads to the electrodes. The participant was instructed to keep their head as still as possible, and to maintain a twelve inch distance from the computer screen. A chinrest was provided, which was adjusted to each participant's height. After the instructions were given, the experimenter proceeded to calibrate the BIOPAC software, in order to ensure that there were no recording problems. Despite this calibration process, the data for five participants were not correctly captured; thus data for the eye tracking measure was collected for only 40 of the 45 participants.

After the calibration phase, the experimenter displayed the reading passage on the computer, delivered the relevant instructions including a reminder to remain still, and instructed the participant to raise his or her hand if he or she needed to stop or had finished the task. When the participant had finished reading passage, the experimenter disconnected the electrode leads, and turned off the computer monitor. Each participant was immediately given the 15-item reading comprehension quiz, but was not allowed to re-read the story. The participants were then asked to perform the WAIS-IV digit span task which was orally administered. After all tasks were completed, participants were debriefed regarding the purpose of the experiment, and were given an opportunity to ask any questions before leaving the lab. The entire experiment was estimated to require 1.5 hours to complete, though many participants were able to complete the study in approximately seventy to eighty minutes. Scores on the reading comprehension quiz, as well as reading speed and measures of eye-movements were analyzed using SPSS.

# Results

## Descriptive Statistics

Participants in the study ranged in ages from 18 to 24, and the sample was not gender balanced, as 40 of the participants (80%) were female. Only 10 of the participants (20%) endorsed having a previous psychological diagnosis, and 9 (18%) endorsed a diagnosis of ADHD, while 1 endorsed a reading disability. Slightly more males than females (5 of 9 participants, 55%) reported a previous diagnosis of ADHD, which is consistent with gender differences in the rates of ADHD found in community samples (Visser et al, 2011). Further demographic information is reported in Table 1.

Participants' self-reported current symptoms of ADHD ranged between 0 and 22, with an average of 5.86. The distribution was slightly skewed by higher scores, though no extreme outliers were identified. Similarly, participants' self-reported childhood symptoms of ADHD ranged between 0 and 18, with an average of 5.28. Again, no outliers were identified. On the

BDEFS, a measure of current executive dysfunction, scores ranged from 0 to 83, with an average of 18. Scaled scores obtained on the Digit Span task ranged between 5 and 17, with an average of 9.75. Although some individuals in the sample had low scores on this subtest, the group as a whole performed within the average range of the standardization sample. Participants' scores on the reading comprehension test (a measure developed for this study to assess comprehension of the Zombie article) ranged from 17 to 100%, with an average score of approximately 66%. Ceiling and floor effects are unlikely given the range of scores obtained. Participant reading times of the Zombie article ranged from 4.28 to 13.20 minutes. Two significant outliers were moved to avoid spurious study results, which resulted in an average reading time of 7.74 minutes for the remaining participants. Backwards eye saccade counts ranged from 26 to 108, with an average of 70.25. No significant outliers were identified. Further descriptive statistics for these measures are presented in Table 2.

**Hypotheses**

Hypothesis 1 predicted that high scores on the BAARS-IV would be associated with low scores on a reading comprehension task, suggesting that high levels of inattention, impulsivity and hyperactivity would be negatively correlated with reading comprehension. This hypothesis was tested through a bivariate, Pearson's correlation analysis. Although a negative correlation was expected, indicating that higher levels of ADHD symptoms would be related to lower reading comprehension scores, the data did not support this hypothesis. A correlation analysis demonstrated a weak positive correlation that was not significant in terms of current ADHD symptoms on the BAARS-IV ($r(43) = .07$, $p = .32$) or childhood symptoms ($r(43) = .20$, $p = .09$). Scatter-plot graphs of these associations are presented in Figures 2a and 2b. An independent samples t-test was performed to determine whether individuals with and without a formal diagnosis of ADHD differed in terms of reading comprehension. The relationship was not significant ($t(15.90) = -0.65$, $p = .52$).

Hypothesis 2A stated that participants with higher scores on the BAARS-IV would demonstrate lower scores on a task of working memory, specifically the Digit Span task from the WAIS IV. This hypothesis was tested through a bivariate, Pearson's correlation analysis. A negative correlation was expected, indicating that higher levels of ADHD symptoms would be related to lower working memory scores. This hypothesis was not supported, as correlation analysis yielded a weak, non-significant relationship for both current ($r(43) = .11$, $p = .25$) and childhood symptoms ($r(43) = .04$, $p = .39$). Scatter-plot graphs of the associations are presented in Figures 3a and 3b. An independent samples t-test was performed to determine whether individuals with and without a formal diagnosis of ADHD differed in terms of digit span scaled scores. The relationship was not significant ($t(11.79) = -0.63$, $p = .54$).

In hypothesis 2B, it was predicted that participants with high scores on the BAARS-IV would also demonstrate high scores on an executive function task, specifically the BDEFs. This hypothesis was tested using a bivariate, Pearson's correlation analysis. A positive correlation was expected, indicating that higher levels of ADHD symptoms were related to higher levels of executive function deficits. This hypothesis was supported by the data. Correlation analysis yielded a significant positive correlation between BAARS-IV current symptom scores and BDEFS total symptom scores ($r(43) = .80$, $p > .001$), as well as between BAARS-IV childhood symptom scores and BDEFS total symptom scores ($r(43) = .62$, $p > .001$). Scatter-plot graphs of the associations are presented in Figures 4a and 4b. An independent samples t-test was performed to determine whether individuals with and without a formal diagnosis of ADHD differed in terms of BDEFS total symptom count scores. The relationship was significant ($t(12.86) = -3.24$, $p = .01$), indicating that individuals with a formal diagnoses of ADHD do differ in terms of their scores on the BDEFS compared to participants without a diagnosis.

Finally, in hypothesis 3, it was predicted that participants with higher scores on the BAARS-IV would demonstrate a higher number of backwards eye saccades as measured by BIOPAC software. This hypothesis was tested through a bivariate, Pearson's correlation analysis. A positive correlation was expected, indicating that higher levels of ADHD symptoms are related to higher rates of backwards eye saccades during a reading task. This hypothesis was not supported for either current ADHD symptoms ($r(38) = .19$, $p = .12$), or for childhood symptoms ($r(38) = .17$, $p = .15$). Although the correlation between ADHD symptoms and backward eye saccades was in the positive direction, the relationship was not statistically significant. Scatter-plot graphs of these associations are presented in Figures 5a and 5b. An independent samples t-test was performed to determine whether individuals with and without a formal diagnosis of ADHD differed in terms of backwards eye saccade counts. The relationship was not significant ($t(7.01) = -1.61$, $p = .15$).

**Exploratory Analyses**

The variance accounted for by combining scores of working memory (digit span scaled scores), executive dysfunction (BDEFS total symptom count z-scores), ADHD symptoms (BAARS-IV current and childhood symptom count z-scores), physiological measures (backwards eye saccade count z-scores), interest (liking the article), prior exposure to information (hearing a lot about zombies), and reading ability (vocabulary quiz z-scores, and

WRAT-IV word reading subtest scaled scores) on reading comprehension was tested using a hierarchical multiple linear regression analysis. Interest in the article and prior exposure to Zombies were coded as dummy variables based on participant responses that were gathered after completing the comprehension test. These data are further presented in Table 4. The variables were entered into the regression formula based on correlations with the predicted variable (reading comprehension). These correlations are presented in Table 3.

Through a hierarchical multiple regression, it was found that that at Stage one, exposure to information about zombies (EXPOS) contributed significantly to the regression model, ($F$ (1,39) = 5.36, $p$ = .03) and accounted for 12.4% of the variation in reading comprehension. At Stage two, introducing the word reading subtest scores (WRAT) explained an additional 10.4% of variation in reading comprehension; this change in $R^2$ was significant ($F$ (1,38) = 5.00, $p$ = .03). In Stage three, adding interest in the topic (ENJOY) to the regression model explained an additional 3.2% of the variation in reading comprehension; although this change in $R^2$ was not significant, ($F$ (1,36) = 1.58, $p$ = .22) the model remained significant ($F$ (3,36) = 4.22, $p$ = .01). In stage four, the addition of vocabulary quiz scores (VOC) to the regression model explained an additional 1.0% of the variation in reading comprehension; although this change in $R^2$ was not significant, ($F$ (1,35) = 0.46, $p$ = .50) the model remained significant ($F$ (4,35) = 3.24, $p$ = .02). In stage five, the addition of childhood ADHD symptoms (BAARS-2) to the regression model explained an additional 3.0% of the variation in reading comprehension; although this change in $R^2$ was not significant, ($F$ (1,34) = 1.48, $p$ = .23) the model remained significant ($F$ (5,34) = 2.92, $p$ = .03). Similarly, in Stage six, adding backwards eye saccade counts (ESC) to the regression model explained no additional variation (0.0%) in reading comprehension; although this change in $R^2$ was not significant, ($F$ (1,33) = 1.12, $p$ = .74) the model remained significant ($F$ (6,33) = 2.39, $p$ = .05). The final significant model accounted for 30.3% of the variability in reading comprehension.

Further variables added in Stages seven through ten, including current ADHD symptoms (BAARS-1), measures of executive dysfunction (BDEFS), working memory (DSS), and reading time (RTMIN), together explained an additional 6.8% of the variability in reading comprehension. However neither the individual changes in $R^2$ nor the resulting models were significant. The most significant predictor of reading comprehension was exposure to information about zombies (EXPOS), which uniquely explained 12.4% of the variation in reading comprehension. Together the ten independent variables accounted for 36.2% of the variance in reading comprehension. While these data suggest that reading comprehension is a complex process and is dependent on additional variables, the study variables provide a start for understanding this complexity, where previous exposure to the topic (Zombies), interest in the topic and basic reading recognition abilities appear to be stronger predictors for comprehension than are ADHD symptoms, executive functions, working memory and reading rate.

The variance accounted for by combining scores of working memory (Digit Span scaled scores), executive dysfunction (BDEFS total symptom count z-scores), ADHD symptoms (BAARS-IV current and childhood symptom count z-scores), physiological measures (backwards eye saccade count z-scores), reading ability (vocabulary quiz z-scores, and WRAT-IV word reading subtest scaled scores), level of interest (liking the article), prior exposure to information (hearing a lot about zombies), and reading comprehension (reading quiz z-scores) on reading speed was also tested using multiple linear regression analysis. These data are further presented in Table 5. The variables were added in order of their correlation with the predicted variable (reading speed). These correlations are presented in Table 3.

Through a hierarchical multiple regression, it was found that that at Stage one, interest in the topic (ENJOY) failed to contribute significantly to the regression model ($F$ (1,38) = 1.60, $p$ = .21), accounting for 6.8% of the variation in reading speed. Introducing scores on the vocabulary quiz (VOC) in Stage two explained an additional 1.0% of variation in reading speed; neither the change in $R^2$ nor the resulting model were significant ($F$ (2,37) = 1.26, $p$ = .22). Adding backward eye saccade counts (ESC) to the regression model in Stage three explained an additional 0.2% of the variation in reading speed; again, neither the change in $R^2$ nor the resulting model were significant ($F$ (3,36) = 1.04, $p$ = .39). The addition of a measure of executive functioning (BDEFS) to the regression model in Stage four explained an additional 0.6% of the variation in reading speed; neither the change in $R^2$ nor the resulting model were significant ($F$ (4,35) = 0.82, $p$ = .52).

Further variables added in Stages five through ten, including childhood ADHD symptoms (BAARS-2), word reading subtest scores (WRAT), reading comprehension quiz scores (RCOMP), current ADHD symptoms (BAARS-1), prior exposure to the topic (HEAR), and working memory (DSS), together explained an additional 7.0% of the variability in reading comprehension. However neither the individual changes in $R^2$ nor the resulting models were significant. The most important predictor of reading speed was interest in the topic (ENJOY) which uniquely explained 7.0% of the variation in reading speed. Together the ten independent variables tested accounted for 15.6% of the variance in reading speed. These data suggest that reading speed is a complex variable and is dependent on additional variables, other than those included in this study. These contributing variables warrant further exploration in future studies.

## Discussion

The current study had several goals. The relationship between ADHD symptoms (with or without a formal diagnosis) and other neurocognitive and reading variables were explored individually. The variables included reading comprehension skills, executive functions (e.g., time management, organization and problem solving, self-restraint, self-motivation, and self-regulation of emotions), working memory, and changes in eye movements during a reading task. Finally, the current study attempted to explore the contributions made by a combination of these variables to reading comprehension and reading speed in a population of college students.

### Hypothesis 1:

Based on results of studies conducted on children with ADHD, it was expected that high rates of ADHD symptoms would be related to poor reading comprehension in young adults in college. However, this hypothesis was not supported in the current study. There were no significant differences between individuals with and without ADHD in terms of reading comprehension in this study, in contrast to the general deficit in reading comprehension shown in the literature. This is not consistent with findings of studies examining children with ADHD. Compared to neurotypical peers, children with ADHD demonstrate lower reading comprehension which appears related to deficits in working memory, processing speed and inattention. There may be several reasons for these inconsistencies.

First, the current study was not primarily comprised of students with a formal diagnosis or a history of ADHD. It is likely that the sample of students with ADHD symptoms who did participate were not as seriously impaired as those individuals with ADHD previous studies. Second, given the large difference between the prevalence of ADHD in the general childhood population (cited at between 8% and 9.7% of children ages 4 to 17 in community based samples), and the prevalence of ADHD in college populations (cited at between 2% and 7%), it is possible that the students with ADHD who enter colleges are in some way fundamentally different from those who do not attend (Visser et al, 2010; Wyeandt & DuPaul, 2008). Students with ADHD symptoms who manage to overcome academic and cognitive-behavioral deficits associated with the disorder may develop compensatory skills similar to non-ADHD peers. Further research, particularly longitudinal studies of children with and without ADHD, with a focus on academic progression across and within diagnostic categories, would help to resolve this unexpected result more clearly. Additionally, Semrud-Clikeman, Pliszka, and Liotti (2008) found that adolescents with ADHD who were currently taking ADHD medications showed similar performance to their neurotypical peers on a test of expressive and receptive language. Individuals with ADHD with no history of medication use performed significantly lower than the medicated individuals and their neurotypical peers on the same task. Given that the majority of individuals with self-reported ADHD in this study also reported taking medication for the disorder, it is possible that the effects of the medication masked any group differences which did exist in terms of reading comprehension. Further, the current study sample did not have a sufficient number of participants with ADHD both on and off medication to fully explore this issue.

**Hypothesis 2:**

The lack of a significant relationship between ADHD symptoms and working memory as measured by this study is in direct contrast to studies linking executive dysfunction and working memory deficits. The neurocognitive and neurodevelopmental models of ADHD predict that deficits will occur in various areas of executive functioning, of which working memory is one part. The effects of ADHD on working memory have been found in children (Huang-Pollock & Karalunas. 2010; Kasper et al., 2012) and adults (Marchetta et al., 2008; Roberts et al, 2012). There are several possible reasons why a relationship between ADHD symptoms and deficits in WM were not found in the current study. First, only a small portion of the participants in the current study had ADHD, indicating that the level and severity of ADHD symptoms appear to partially predict this relationship. Furthermore, the presence of ADHD was self reported and not obtained through a formal diagnosis which may contribute to these differences.

Secondly, Semrud-Clikeman et al. (2008) found that individuals with ADHD who were taking medication performed significantly better on a working memory task than did individuals with ADHD who were not taking medication for the disorder. In this study, individuals with ADHD who were using medications performed similarly to neurotypical individuals (Semrud-Clikeman et al., 2008). As seven of the nine participants who self-reported an ADHD diagnosis also reported current medication use, which may be enhancing their performance and masking any differences in working memory that may otherwise be present. Thirdly, although working memory differences in individuals with ADHD have been demonstrated in the literature, the impact of learning disabilities on these working memory differences cannot be ignored (Swanson et al., 1999). Although only one participant self-reported a learning disability, it is possible that undiagnosed or nondisclosed learning disabilities in some participants could have impacted the results of these analyses.

Additionally, it is possible that a different working memory task with less possibility of rehearsal (e.g., a working memory task with a distraction task) may have shown a more clear effect of ADHD symptoms on working memory. Kasper et al. (2012) found that study variables do affect this relationship. The Digit Span task, while well supported in the literature as a measure of working memory, functions only within one subsystem (the phonological subsystem of working memory), and rehearsal strategies are not easily controlled for in this test of working memory. Additionally, Baddeley (2007) and Kasper et al. (2012) found that WM tasks that place high demands on the "central executive," such as performing two processes which activate both the phonological and visual subsystems, generally show greater between group differences. Given this, because the digit span task does not place demands on the central executive component of working memory, in that it requires minimal switching between tasks, and that the task works only within the phonological subsystem of working memory, large group differences may not be found. It is possible that the use of a task with more diverse requirements would have produced different results. Finally, it is possible that these deficits are compensated for through rehearsal strategies or other methods, particularly in the cases of individuals with ADHD symptoms who manage to succeed in academic pursuits.

The significant relationship between BAARS-IV and BDEFS was predicted based on the neurocognitive model of ADHD, which states that ADHD as a disorder is related to consistent differences in neurological development. One of the main differences in neurological development which is focused on in this model is the slowed development of the frontal lobes, and their overall lower activation throughout the imaging studies cited (Geidd et al., 2006). Given that the frontal lobes are the predominant neurological area active when exhibiting the complex of behaviors termed executive functioning, slowed development and general under-activation of the frontal lobe, and particularly of the pre-frontal cortex, is quite reasonably associated with increased executive dysfunction.

Given that the current study examined ADHD symptom levels regardless of clinical diagnosis, the finding that increased symptoms are related to increased executive dysfunction is an important complement to the neurocognitive model of ADHD, as it expands the relationship between ADHD and executive functioning beyond the boundaries of the disorder itself. Although individuals with and without formal ADHD diagnoses did differ in this area, individuals without a diagnosis of ADHD still demonstrated a wide range of symptomology. If a relationship between ADHD symptomology and executive dysfunction, regardless of ADHD diagnosis, is found consistently across individuals and across developmental periods, then the effects of executive dysfunction on areas such as school success and failure and other areas traditionally viewed as being impacted by ADHD itself should be assessed. Executive functioning and executive dysfunction may have a mediating effect on the effects of ADHD on lifespan development and success; this idea should be explored in future research to determine both individual effects and any interrelationships between these two variables which may affect future life successes.

**Hypothesis 3:**

The lack of significant relationship between reading comprehension and backwards eye saccades may have occurred because of lack of specificity in the data recordings achieved.

Although BioPac can be used for electrooculogram analyses, and is certainly capable of recording large changes in the focal placement of the eye, it is possible that the small movements of the eye during typical reading may not have been captured completely. The use of a devoted electrooculogram device, which would be calibrated to obtain much more precise readings, would be helpful in identifying patterns which may currently be obscured. Additionally it is possible that, because data were lost to recording problems, any trends which did exist in the current data lacked the appropriate power levels to be noted as significant.

Additionally, a review of more recent literature regarding changes in visual fixations and saccades among individuals with ADHD indicates that stimulant medications may have ameliorated some of the anticipated differences between individuals with higher and lower ADHD symptom levels. Fried, Tsitsiashvili, Bonneh, Sterkin et al (2014) found that differences in eye saccades between ADHD and non-ADHD individuals in non-reading contexts were ameliorated when participants took ADHD medication. Given that most ADHD medications are stimulant drugs, it is possible that other stimulants, such as caffeine, may function to reduce differences in eye movements as well, particularly for individuals who may have certain features of ADHD, without the full disorder. Future studies could investigate eye tracking differences while participants are not on medication, and with restrictions on caffeine use, in order to form a better idea of the relationship between ADHD and backwards eye saccades. Only once this data is fully established can more analyses be made to determine the relationship of these backwards eye saccades with reading comprehension.

**Exploratory Analyses**

Although considerable research has been done examining the academic sequelae of ADHD, very little has been done to examine and compare the individual effects of the varied factors which may be related to the development of reading comprehension. The current study attempted to build a model to understand the abilities of working memory (digit span scaled scores), executive dysfunction (BDEFS total symptom count z-scores), ADHD symptoms (BAARS-IV current and childhood symptom count z-scores), physiological measures (backwards eye saccade count z-scores), interest (liking the article), prior exposure to information (hearing a lot about zombies), and reading ability (vocabulary quiz z-scores, and WRAT-IV word reading subtest scaled scores) to predict reading comprehension.

However, despite significant influences of previous exposure to information about zombies and word reading abilities, none of the other values were found to be sufficiently predictive in this sample. The contributions of vocabulary skills, interest in the article itself, and childhood ADHD symptoms were not significantly predictive, though they did contribute to significant models of reading comprehension, indicating that they may provide some information about an individual's reading comprehension abilities. These findings serve to underscore the complexities involved in examining certain aspects of intellectual functioning. Although each of the factors examined had face validity, and some were predictive of reading comprehension in previous research, is clear that other factors not included in this study account for this relationship. Possible other predictive variables for reading comprehension may include attention and practice effects from reading more often.

Additionally, the current study attempted to build a model to understand how working memory (digit span scaled scores), executive dysfunction (BDEFS total symptom count z-scores), ADHD symptoms (BAARS-IV current and childhood symptom count z-scores), physiological measures (backwards eye saccade count z-scores), reading ability (vocabulary quiz z-scores, and WRAT-IV word reading subtest scaled scores), interest (liking the article), prior exposure to information (hearing a lot about zombies), and reading comprehension (reading comprehension quiz z-scores) to predict reading speed

However, none of these variables were found to be significantly predictive of reading speed in this sample. This indicates that reading speed may be primarily accounted for by other factors not examined in this study. Other possible predictive variables may include having taken a speed reading course, the extent to which one reads for pleasure (i.e., practice effects, or even article length. Future studies should include controls for these variables.

**Study Limitations**

There are a number of study limitations that should be examined. As discussed earlier, only college students were tested in this sample, and thus the results of the study are difficult to generalize to non-college attending populations. Given that not all individuals with ADHD attend college, it is entirely possible that the overall reading comprehension of individuals with higher ADHD symptoms would follow a different pattern than observed in the current study. Similarly, the sample was generally quite young, with the most common age of participants being 18 years old. If the results obtained in this study represent a trend towards increasing reading comprehension abilities over time for individuals with ADHD or ADHD symptoms, it is possible that older populations would show a more advanced trend, potentially reaching significance. However, given the available population, it is difficult to address this possibility.

Also, although the reading comprehension measure used in this study showed a fairly typical grade distribution, and was written on a comparable reading level to the material it tested, it is possible that the measure did not accurately assess reading comprehension. Future studies could examine different readings and comprehension measures in order to formulate a more diverse idea of reading comprehension variability in this population. Ceiling effects, wherein the majority of participants score at the highest levels on an assessment, limiting variability in scores, were not noted in this study. Similarly, floor effects, wherein the majority of participants score at the lowest levels on an assessment, limiting variability in scores, were not noted in this study. Additionally, an article on a popular topic was selected in order to minimize distraction due to boredom during the reading task, but it is possible that a different or more complex reading could show different results. Because the article was based on a popular topic, and given that prior experience with a subject matter may improve reading comprehension, individual differences in exposure to and interest in literature and media about zombies could have contributed to the variability in reading comprehension scores. In this study, ANOVA analyses demonstrated that reading comprehension quiz scores were significantly related to both liking the article provided ($F(43,1) = 4.35$, $p = .04$), and to hearing about zombies ($F(42,2) = 4.16$, $p = .02$). These findings support indications from the literature that interest in and exposure to a topic can impact reading comprehension.

Computer recording errors which resulted in the loss of roughly 11% of the sample's biological data may have resulted in a lack of power for these analyses. Additionally, those recordings which were successful were marked by extraneous data from accidental movements on the part of participants, despite having a chin rest. These accidental movements obscured any true data during the time periods in which they occurred; it is possible that a dedicated eye-tracking device would be calibrated such that it could have reduced the interference from these movements.

A final limitation of this study was the lack of control for the consumption of caffeine and other stimulants, which may have limited the ability to identify any trends towards significance in the biological data which was obtained. A true control would require that participants not take their ADHD medications or use stimulants such as caffeine for 24 hours before participating in the study, which would have significantly reduced participation. Another possible control, which would have been less impactful on participants, would have been to include a question about caffeine consumption on the demographics survey, so that stimulant usage could have been statistically controlled, potentially yielding more accurate interpretations of the biological data obtained.

**General Conclusions and Future Directions**

Although few of the current study's hypotheses yielded significant results, the findings obtained do support the neurocognitive model of ADHD, which relates many of the typical symptoms of ADHD, including the associated deficits in executive functioning, to neurological differences across development. Given this study's findings, the neurocognitive model of ADHD can be extended to account for differences in executive functioning across ADHD symptom levels. This is particularly important in a clinical context, where there is always the question of where normal functioning differences become pathological. Although the current DSM model is categorical in nature, meaning that individuals must display a certain number of symptoms in order to be diagnosed with a disorder, below which no diagnosis may be given, it is clear that some individuals below this number of symptoms may still be demonstrating some impairment in their lives. This study demonstrated that increased symptomology was related to greater executive dysfunction, regardless of diagnostic label. These findings are more consistent with a dimensional approach, in which disorders do not begin at a certain number of symptoms, but rather as impairment increases from those symptoms which do occur. The extension of the neurocognitive model of ADHD to a more dimensional concept of this disorder is consistent with current trends in the clinical field.

Additionally, this study has supported a potential alteration of the generally accepted conclusions regarding the relationship between ADHD and reading comprehension, by presenting some evidence that the deficits observed in children with ADHD may not occur over the entire lifespan. Although the results of this study were not statistically significant, and thus cannot be said to indicate a true reversal of the trend noted in childhood studies, it is important to note that the finding that individuals with ADHD have poorer reading comprehension, which was widespread in the studies of childhood ADHD, was not supported in this study. This could represent a developmental shift, or, as discussed previously, could merely indicate that, with the development of certain coping and study skills, some individuals with ADHD may be able to overcome the deficits in reading comprehension generally associated with the disorder.

As with any research, the current study cannot be said to present a complete view of the concepts examined. More research is needed in order to more fully understand how ADHD as a spectrum of symptoms may relate to reading comprehension across the lifespan, and especially in adulthood. It would be useful for future studies examining reading comprehension in children to report symptom counts or other scores, rather than merely a diagnostic status, as this may allow for meta-analytic reviews of how these levels of symptoms affect functioning in childhood. Without a clear dimensional view of ADHD in childhood, it will be difficult to formulate a clear developmental perspective on this disorder's relationship to executive functioning, memory, and academic functioning.

Although the ideal future study would be a developmental study tracking individuals with different levels of symptomology from childhood to early or mid-adulthood, in order to track the developmental implications of the disorder on various areas of life, these studies remain difficult and expensive to perform. A possible alternative would be a cohort study, which would at least provide some developmentally useful data. If future studies are only to be performed with young adults, however, these studies should attempt to avoid the problem of selecting only the most academically successful individuals with ADHD. Individuals who are academically and financially able to attend a four year college may differ significantly from individuals who do not attend these institutions. Although studies using the general population are more difficult to perform, a possible alternative would be to draw participants from 4 and 2 year institutions, to capture a more diverse student population. It may also be possible to recruit participants from a local secondary school, who would be in a similar age range to college freshmen, without excluding those who are not able to or do not choose to attend college.

Finally, future research into biological determinants of attention, particularly eye-tracking studies, should include statistical controls which limit the statistical influence of stimulant consumption, as well as unconscious movements by the participants. By controlling for these two factors, it is possible that future studies will obtain more clear evidence of the relationship of ADHD to these biological occurrences. Similarly, the factors involved in the intellectual function of reading comprehension should be further examined in order to identify factors which consistently predict reading comprehension across the developmental course from childhood to adulthood. Such factors, once identified, can be made targets of intervention, potentially increasing the academic functioning of those individuals for whom ADHD is related to poorer reading comprehension, and its known academic and social sequelae.

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**Table and Figure Content**


*Table 1* Participant Demographics

*Table 2* Descriptive Statistics

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*Table 5* Exploratory Multiple Linear Regression of Factors Related to Reading Speed

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*Figure 2b* Scatter Plot of BAARS-IV Childhood Scores and Reading Comprehension Scores

*Figure 3a* Scatter Plot of BAARS-IV Current Scores and Digit Span Scaled Scores

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*Figure 5b* Scatter Plot of BAARS-IV Childhood Scores and Backwards Eye Saccade Counts

Table 1

*Participant demographics*

| Variable | *n* | Percent of Sample |
|---|---|---|
| Gender | | |
| Male | 10 | 20% |
| Female | 40 | 80% |
| Class Year | | |
| Freshman | 28 | 56% |
| Sophomore | 14 | 28% |
| Junior | 5 | 10% |
| Senior | 3 | 6% |
| Previous Diagnoses | | |
| None | 40 | 80% |
| ADD/ADHD | 9 | 18% |
| Learning Disability | 1 | 2% |
| Speech Language Pathology | 0 | 0% |
| Major Depression | 0 | 0% |
| Medication for ADHD | | |
| No | 43 | 86% |
| Yes | 7 | 14% |
| Enjoyed the Article | | |
| No | 18 | 36% |
| Yes | 32 | 64% |
| Hear About Zombies A Lot? | | |
| No | 14 | 28% |
| Sometimes | 13 | 26% |
| Yes | 23 | 46% |

*Note.* Total sample size N=50.

Table 2

*Descriptive statistics of variable raw scores*

| Variable | *n* | Min | Max | Median | *M* | *SD* |
|---|---|---|---|---|---|---|
| BAARS-1 | 45 | 0 | 22 | 5 | 5.86 | 5.37 |
| BAARS-2 | 45 | 0 | 18 | 3 | 5.28 | 5.20 |
| BDEFS | 45 | 0 | 83 | 15 | 18.31 | 17.22 |
| DSS [a] | 45 | 5 | 17 | 9 | 9.75 | 2.70 |
| ESC | 40 | 26 | 108 | 70 | 70.25 | 29.40 |
| RCOMP | 45 | 17 | 100 | 63 | 65.80 | 21.02 |
| RTMin | 43 | 4.28 | 13.20 | 7.34 | 7.74 | 2.01 |

*Note.* BAARS-1= Barkley adult ADHD rating scale current symptom z-score, BAARS-2= Barkley adult ADHD rating scale childhood symptom z-score, BDEFS=Barkley deficits of executive function scale total symptom count z-score, DSS= Digit span standard scores, ESC= Backward eye saccade z-scores, RCOMP= Reading comprehension z-score, RTMin= Total reading time in minutes z-score.

[a] Digit Span scores are presented as norm-referenced standard scores.

Table 3

*Intecorrelation of z-scores of major variables*

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BAARS-1 | - | .71** | .80** | .11 | .19 | .07 | .05 | -.14 | .08 | -.13 | .02 |
| BAARS-2 | | - | .62** | .04 | .17 | .20 | .08 | .11 | .12 | -.13 | .15 |
| BDEFS | | | - | -.32 | .15 | .10 | .10 | -.11 | .11 | -.30* | -.06 |
| DSS | | | | - | -.19 | -.03 | .00 | -.26 | .33* | .09 | -.22 |
| ESC | | | | | - | .14 | .12 | -.01 | .01 | .25 | .05 |
| RCOMP | | | | | | - | .07 | .24 | .31* | .30* | .36* |
| RTMin | | | | | | | - | .19 | .08 | .17 | -.05 |
| VOC | | | | | | | | - | .28 | .24 | .37* |
| WRAT | | | | | | | | | - | .03 | -.05 |
| ENJOY | | | | | | | | | | - | .32* |
| EXPOS | | | | | | | | | | | - |

*Note.* BAARS-1= Barkley adult ADHD rating scale current symptom z-score, BAARS-2= Barkley adult ADHD rating scale childhood symptom z-score, BDEFS=Barkley deficits of executive function scale total symptom count z-score, DSS= Digit span standard scores, ESC= Backward eye saccade z-scores, RCOMP= Reading comprehension z-score, RTMin= Total reading time in minutes z-score, VOC= vocabulary quiz z-score, WRAT= WRAT word reading subtest; $*p < .05$ $**p < .001$

Table 4

*Exploratory linear regression modeling of factors related to reading comprehension*

| Variables | $\beta$ | $t$ | SE | $F$ | $R$ | $R^2$ | $\Delta R^2$ |
|---|---|---|---|---|---|---|---|
| Stage 1 | | | | 5.36* | .35 | .12 | .12 |
| EXPOS | 0.35 | 2.31 | 0.19 | | | | |
| Stage 2 | | | | 5.46* | .48 | .23 | .10 |
| EXPOS | 0.37 | 2.59 | 0.18 | | | | |
| WRAT | 0.32 | 2.24 | 0.15 | | | | |
| Stage 3 | | | | 4.22* | .51 | .26 | .03 |
| EXPOS | 0.31 | 1.99 | 0.19 | | | | |
| WRAT | 0.29 | 2.00 | 0.15 | | | | |
| ENJOY | 0.19 | 1.26 | 0.33 | | | | |
| Stage 4 | | | | 3.24* | .52 | .27 | .01 |
| EXPOS | 0.26 | 1.54 | 0.21 | | | | |
| WRAT | 0.25 | 1.59 | 0.16 | | | | |
| ENJOY | 0.17 | 1.06 | 0.34 | | | | |
| VOC | 0.12 | 0.68 | 0.19 | | | | |
| Stage 5 | | | | 2.92* | .55 | .30 | .03 |
| EXPOS | 0.22 | 1.29 | 0.21 | | | | |
| WRAT | 0.22 | 1.40 | 0.16 | | | | |
| ENJOY | 0.20 | 1.23 | 0.34 | | | | |
| VOC | 0.13 | 0.76 | 0.19 | | | | |
| BAARS-2 | 0.18 | 1.22 | 0.15 | | | | |
| Stage 6 | | | | 2.39* | .55 | .30 | .00 |
| EXPOS | 0.22 | 1.28 | 0.21 | | | | |
| WRAT | 0.22 | 1.38 | 0.17 | | | | |
| ENJOY | 0.18 | 1.07 | 0.36 | | | | |
| VOC | 0.14 | 0.78 | 0.19 | | | | |
| BAARS-2 | 0.17 | 1.11 | 0.15 | | | | |
| ESC | 0.05 | 0.33 | 0.16 | | | | |

*Note.* *$p < .05$.

Table 4, Continued

*Exploratory linear regression modeling of factors related to reading comprehension*

| Variables | $\beta$ | $t$ | SE | $F$ | $R$ | $R^2$ | $\Delta R^2$ |
|---|---|---|---|---|---|---|---|
| Stage 7 | | | | 2.19 | .57 | .32 | .02 |
| EXPOS | 0.21 | 1.22 | 0.21 | | | | |
| WRAT | 0.19 | 1.15 | 0.17 | | | | |
| ENJOY | 0.22 | 1.27 | 0.37 | | | | |
| VOC | 0.18 | 0.99 | 0.20 | | | | |
| BAARS-2 | 0.04 | 0.23 | 0.20 | | | | |
| ESC | 0.03 | 0.21 | 0.16 | | | | |
| BDEFS | 0.21 | 1.00 | 0.21 | | | | |
| Stage 8 | | | | 2.10 | .59 | .35 | .03 |
| EXPOS | 0.21 | 1.24 | 0.21 | | | | |
| WRAT | 0.18 | 1.13 | 0.17 | | | | |
| ENJOY | 0.28 | 1.54 | 0.39 | | | | |
| VOC | 0.13 | 0.68 | 0.20 | | | | |
| BAARS-2 | 0.16 | 0.71 | 0.22 | | | | |
| ESC | 0.03 | 0.22 | 0.16 | | | | |
| BDEFS | 0.40 | 1.51 | 0.26 | | | | |
| BAARS-1 | -0.33 | -1.14 | 0.28 | | | | |
| Stage 9 | | | | 1.89 | .60 | .36 | .01 |
| EXPOS | 0.24 | 1.33 | 0.22 | | | | |
| WRAT | 0.18 | 1.09 | 0.17 | | | | |
| ENJOY | 0.23 | 1.22 | 0.41 | | | | |
| VOC | 0.14 | 0.72 | 0.21 | | | | |
| BAARS-2 | 0.14 | 0.63 | 0.22 | | | | |
| ESC | 0.03 | 0.20 | 0.16 | | | | |
| BDEFS | 0.38 | 1.39 | 0.27 | | | | |
| BAARS-1 | -0.30 | -1.02 | 0.28 | | | | |
| RTMIN | 0.11 | 0.68 | 0.13 | | | | |

Table 4, Continued

*Exploratory linear regression modeling of factors related to reading comprehension*

| Variables | $\beta$ | $t$ | SE | $F$ | $R$ | $R^2$ | $\Delta R^2$ |
|---|---|---|---|---|---|---|---|
| Stage 10 | | | | 1.65 | .60 | .36 | .22 |
| EXPOS | 0.12 | 0.55 | 0.23 | | | | |
| WRAT | 0.23 | 1.26 | 0.22 | | | | |
| ENJOY | 0.20 | 1.05 | 0.20 | | | | |
| VOC | 0.24 | 1.21 | 0.43 | | | | |
| BAARS-2 | 0.15 | 0.64 | 0.23 | | | | |
| ESC | 0.02 | 0.12 | 0.17 | | | | |
| BDEFS | 0.37 | 1.30 | 0.28 | | | | |
| BAARS-1 | -0.29 | -0.97 | 0.29 | | | | |
| RTMIN | 0.11 | 0.66 | 0.14 | | | | |
| DSS | -0.04 | -0.21 | 0.07 | | | | |

*Note.* Final model $R^2$= .36; BAARS-1= Barkley adult ADHD rating scale current symptom z-score, BAARS-2= Barkley adult ADHD rating scale childhood symptom z-score, BDEFS=Barkley deficits of executive function scale total symptom count z-score, DSS= Digit span standard scores, ESC= Backward eye saccade z-scores, RTMin= Total reading time in minutes z-score, VOC= vocabulary quiz z-score, WRAT= WRAT word reading subtest, ENJOY= rating of enjoyment of article, EXPOS= rating of exposure to information about zombies; *p < .05.

Table 5

*Exploratory linear regression modeling of factors related to reading speed*

| Variables | $\beta$ | $t$ | SE | $F$ | $R$ | $R^2$ | $\Delta R^2$ |
|---|---|---|---|---|---|---|---|
| Stage 1 | | | | 1.60 | .27 | .07 | .07 |
| VOC | -0.09 | -0.55 | 0.21 | | | | |
| Stage 2 | | | | 1.56 | .28 | .08 | .01 |
| VOC | -0.09 | -0.53 | 0.21 | | | | |
| ENJOY | 0.30 | 1.76 | 0.43 | | | | |
| Stage 3 | | | | 1.04 | .28 | .08 | .00 |
| VOC | -0.08 | -0.49 | 0.22 | | | | |
| ENJOY | 0.29 | 1.60 | 0.45 | | | | |
| ESC | 0.05 | 0.29 | 0.20 | | | | |
| Stage 4 | | | | 0.82 | .29 | .09 | .01 |
| VOC | -0.08 | -0.44 | 0.22 | | | | |
| ENJOY | 0.31 | 1.65 | 0.47 | | | | |
| ESC | 0.03 | 0.18 | 0.21 | | | | |
| BDEFS | 0.08 | 0.47 | 0.20 | | | | |
| Stage 5 | | | | 0.64 | .29 | .09 | .00 |
| VOC | -0.08 | -0.44 | 0.23 | | | | |
| ENJOY | 0.31 | 1.62 | 0.48 | | | | |
| ESC | 0.03 | 0.17 | 0.21 | | | | |
| BDEFS | 0.07 | 0.32 | 0.27 | | | | |
| BAARS-2 | 0.01 | 0.05 | 0.26 | | | | |
| Stage 6 | | | | 0.56 | .31 | .09 | .00 |
| VOC | -0.11 | -0.57 | 0.24 | | | | |
| ENJOY | 0.30 | 1.57 | 0.48 | | | | |
| ESC | 0.03 | 0.18 | 0.21 | | | | |
| BDEFS | 0.05 | 0.21 | 0.27 | | | | |
| BAARS-2 | 0.02 | 0.08 | 0.26 | | | | |
| WRAT | 0.09 | 0.51 | 0.22 | | | | |

Table 5, Continued

*Exploratory linear regression modeling of factors related to reading speed*

| Variables | *β* | *t* | SE | *F* | *R* | $R^2$ | $\Delta R^2$ |
|---|---|---|---|---|---|---|---|
| Stage 7 | | | | 0.53 | .32 | .10 | .01 |
| VOC | -0.14 | -0.71 | 0.26 | | | | |
| ENJOY | 0.27 | 1.33 | 0.51 | | | | |
| ESC | 0.03 | 0.16 | 0.21 | | | | |
| BDEFS | 0.02 | 0.09 | 0.28 | | | | |
| BAARS-2 | 0.01 | 0.04 | 0.26 | | | | |
| WRAT | 0.08 | 0.41 | 0.22 | | | | |
| EXPOS | -0.23 | -1.13 | 0.30 | | | | |
| Stage 8 | | | | 0.52 | .34 | .12 | .02 |
| VOC | -0.18 | -0.84 | 0.26 | | | | |
| ENJOY | 0.32 | 1.48 | 0.54 | | | | |
| ESC | 0.03 | 0.17 | 0.22 | | | | |
| BDEFS | 0.17 | 0.54 | 0.38 | | | | |
| BAARS-2 | 0.09 | 0.36 | 0.30 | | | | |
| WRAT | 0.08 | 0.41 | 0.22 | | | | |
| RCOMP | 0.09 | 0.45 | 0.24 | | | | |
| BAARS-1 | -0.24 | -0.72 | 0.39 | | | | |
| Stage 9 | | | | 0.61 | 0.39 | 0.15 | 0.03 |
| VOC | -0.09 | -0.39 | 0.28 | | | | |
| ENJOY | 0.36 | 1.66 | 0.55 | | | | |
| ESC | 0.02 | 0.12 | 0.21 | | | | |
| BDEFS | 0.17 | 0.52 | 0.37 | | | | |
| BAARS-2 | 0.11 | 0.45 | 0.30 | | | | |
| WRAT | 0.01 | 0.03 | 0.24 | | | | |
| RCOMP | 0.14 | 0.68 | 0.24 | | | | |
| BAARS-1 | -0.22 | -0.66 | 0.39 | | | | |
| EXPOS | -0.23 | 1.13 | 0.30 | | | | |

Table 5, Continued

*Exploratory linear regression modeling of factors related to reading speed*

| Variables | $\beta$ | $t$ | SE | $F$ | $R$ | $R^2$ | $\Delta R^2$ |
|---|---|---|---|---|---|---|---|
| Stage 10 | | | | 0.54 | .40 | .16 | .01 |
| VOC | -0.12 | -0.47 | 0.31 | | | | |
| ENJOY | 0.38 | 1.65 | 0.57 | | | | |
| ESC | 0.01 | 0.03 | 0.23 | | | | |
| BDEFS | 0.15 | 0.45 | 0.39 | | | | |
| BAARS-2 | 0.12 | 0.47 | 0.31 | | | | |
| WRAT | 0.03 | 0.15 | 0.27 | | | | |
| RCOMP | 0.14 | 0.66 | 0.25 | | | | |
| BAARS-1 | -0.21 | -0.61 | 0.40 | | | | |
| EXPOS | -0.24 | -1.14 | 0.30 | | | | |
| DSS | -0.06 | -0.27 | 0.09 | | | | |

*Note.* Model $R^2$= .16; BAARS-1= Barkley adult ADHD rating scale current symptom z-score, BAARS-2= Barkley adult ADHD rating scale childhood symptom z-score, BDEFS=Barkley deficits of executive function scale total symptom count z-score, DSS= digit span standard scores, ESC= backward eye saccade z-scores, RCOMP= reading comprehension z-score, VOC= vocabulary quiz z-score, WRAT= WRAT word reading subtest, ENJOY= rating of enjoyment of article, EXPOS= rating of exposure to information about zombies; $*p < .05$.

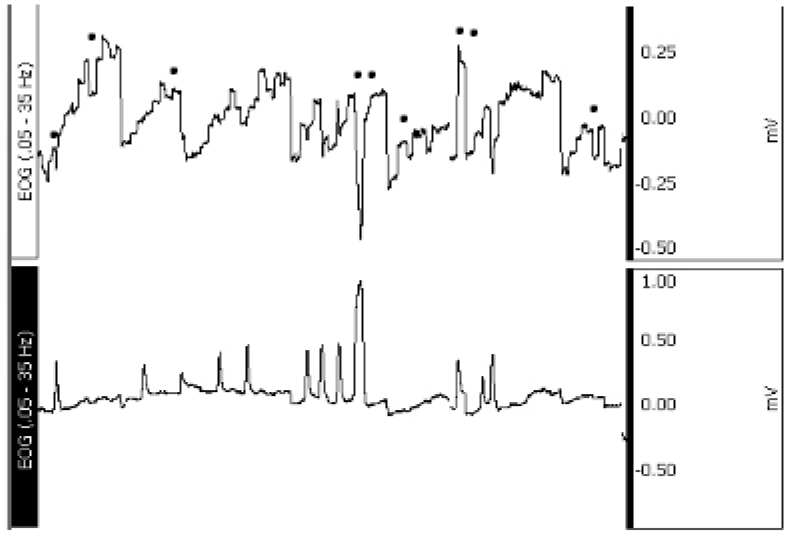


*Figure 1.*A BioPac generated graph plotting millivolt changes in electro-conductance of the skin (y-axis) against time in milliseconds (x-axis). This graph demonstrates backwards eye saccades (marked with a single asterisk *) and eye blinking (marked by two asterisks **).

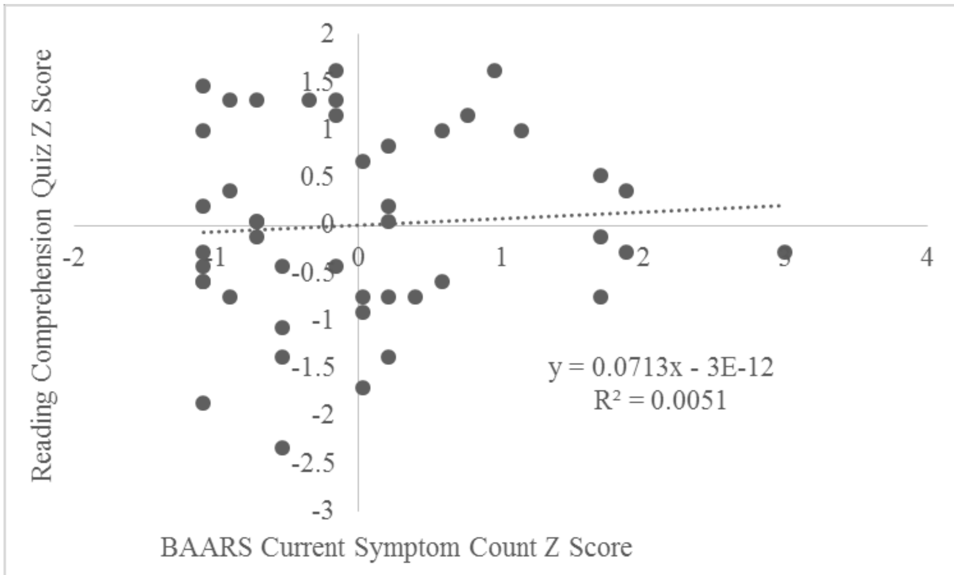


*Figure 2a.* A scatter-plot style graph showing the relationship between BAARS-IV current symptom counts z-scores (x-axis) and reading comprehension quiz z-scores (y-axis).

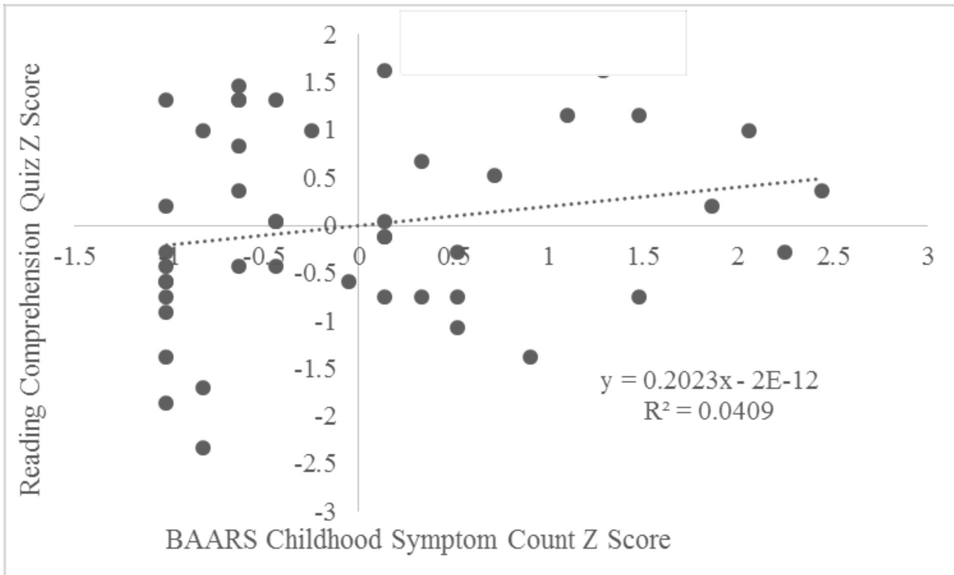


*Figure 2b.* A scatter-plot style graph showing the relationship between BAARS-IV childhood symptom count z-scores (x-axis) and reading comprehension quiz z-scores (y-axis).

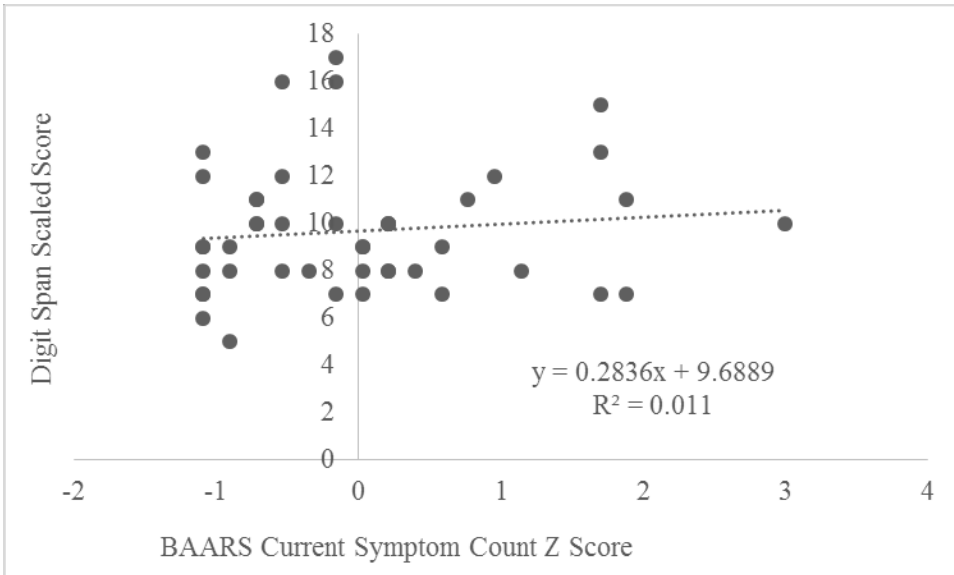


*Figure 3a.* A scatter-plot style graph showing the relationship between BAARS-IV current symptom count z-scores (x-axis) and Digit Span scaled scores (y-axis).

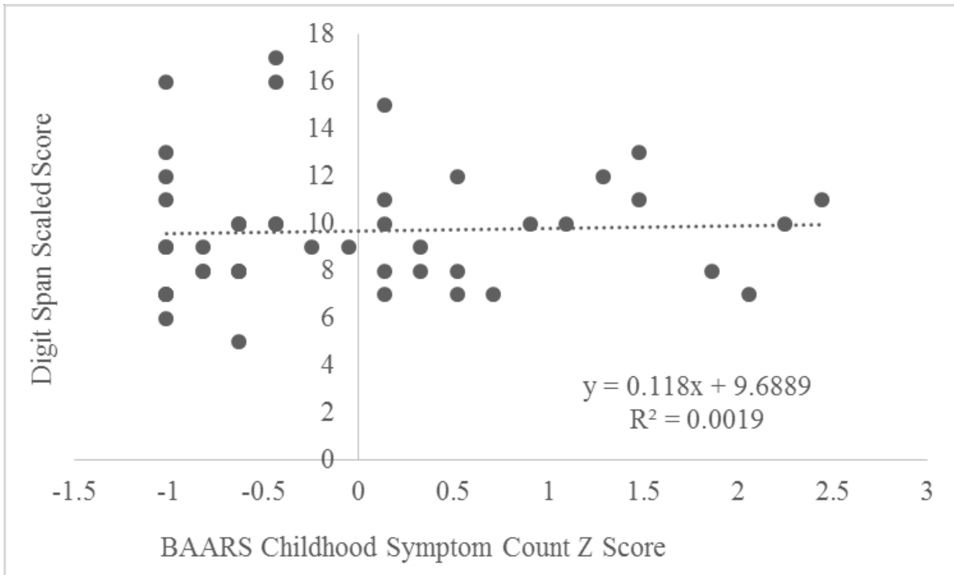


*Figure 3b.* A scatter-plot style graph showing the relationship between BAARS-IV childhoods symptom count z-scores (x-axis) and Digit Span scaled scores (y-axis).

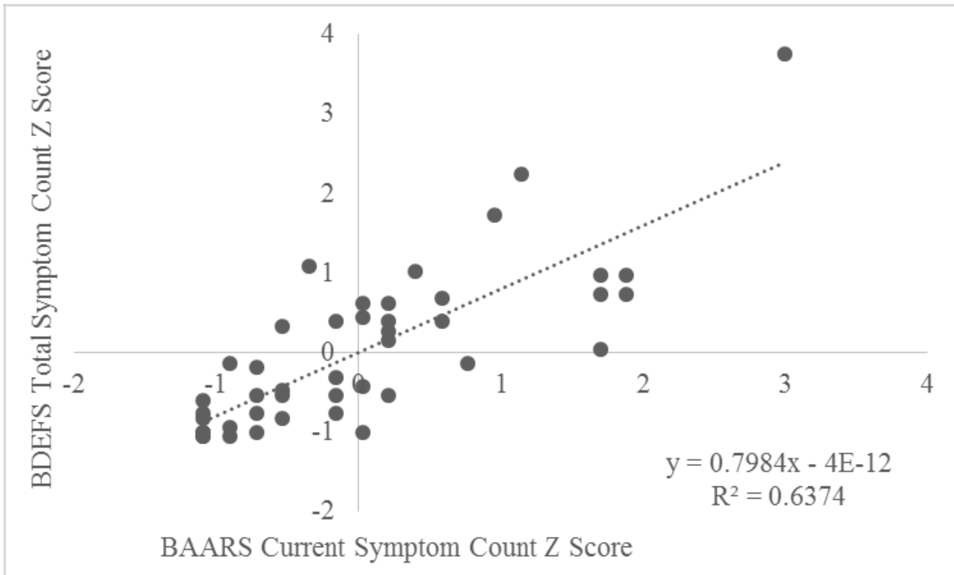


*Figure 4a.* A scatter-plot style graph showing the relationship between BAARS-IV current symptom count z-scores (x-axis) and BDEFS total symptom count z-scores (y-axis).

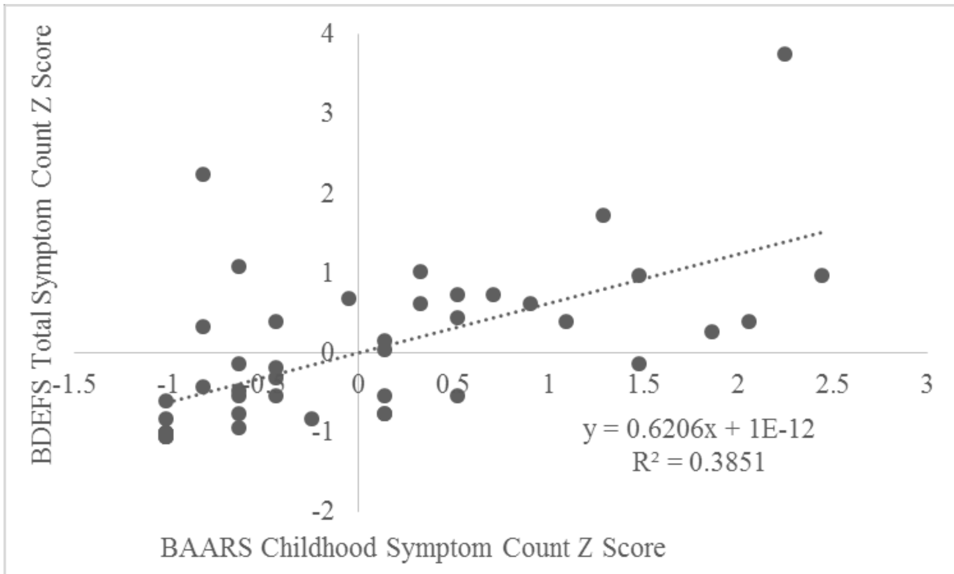


*Figure 4b*. A scatter-plot style graph showing the relationship between BAARS-IV childhood symptom count z-scores (x-axis) and BDEFS total symptom count z-scores (y-axis).

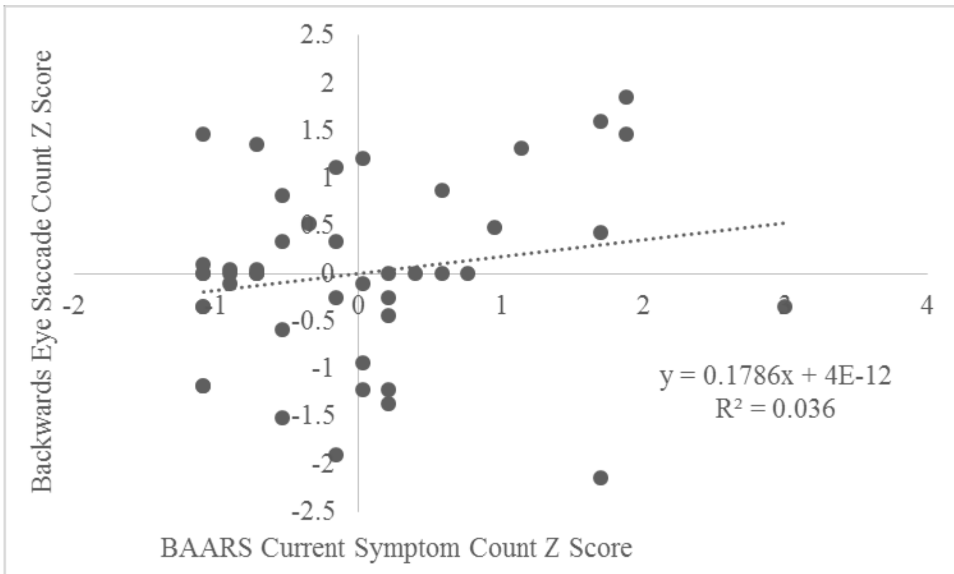


*Figure 5a.* A scatter-plot style graph showing the relationship between BAARS-IV current symptom count z-scores (x-axis) and backwards eye saccade count z-scores (y-axis).

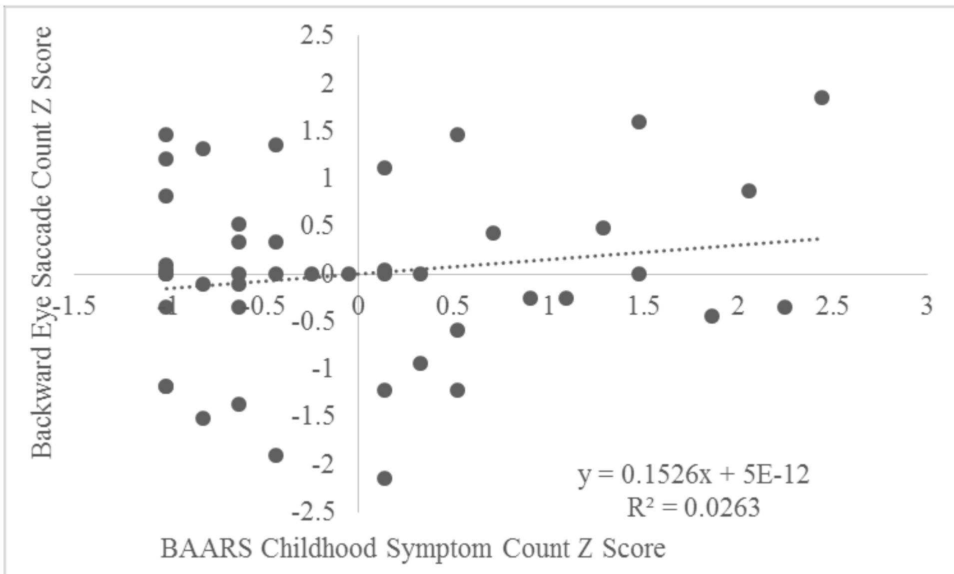


*Figure 5b.* A scatter-plot style graph showing the relationship between BAARS-IV childhood symptom count z-scores (x-axis) and backwards eye saccade count z-scores (y-axis).

Appendix A:

Word Recognition Questionnaire

**Vocabulary Matching Words 2**

Directions: Write the number of the definition that correctly defines each word in the first column.

| | | |
|---|---|---|
| ______ | ordeal | 1) a circular or spherical object often thought to posses power. |
| ______ | dialect | 2) information obtained by the sense of touch. |
| ______ | skirmish | 3) to copy or reproduce a likeness. |
| ______ | orb | 4) being discrete and not attracting attention. |
| ______ | confide | 5) a very difficult encounter or experience. |
| ______ | tactile | 6) the manner in which local people speak |
| ______ | ritual | 7) a battle that does not last long |
| ______ | mimic | 8) to tell someone in secret or confidence |
| ______ | heritage | 9) rites and customs past on through ancestry. |
| ______ | endurance | 10) having a unique quality or value. |
| ______ | virtue | 11) a custom or tradition that followed. |
| ______ | unobtrusive | 12) focused on older customs |
| ______ | shrewdest | 13) awful; often beyond imaginable. |
| ______ | traditional | 14) able to maintain in the face of great challenge. |
| ______ | horrendous | 15) the smartest of the bunch |

## Appendix B:

## Demographic Questionnaire

Please answer all of the following questions as honestly as possible. Your answers will remain anonymous. If you require any assistance, please raise your hand, and someone will be with you shortly.

**How old are you?** __________

**What is your gender?** (Circle One) Male Female Prefer not to answer

**What year are you in college?** (Circle One) Freshman Sophomore Junior Senior

**What is your current GPA?** _________

**Have you ever been diagnosed with any of the following?** (Circle All That Apply)
Attention Deficit Disorder (ADD)
Attention Deficit/Hyperactivity Disorder (ADHD)
Learning Disorder (Circle Type: Mathematical, Reading, Writing, Other _______________)
Major Depression
Speech/Language Pathology

**Are you currently on medication for ADHD?** (Circle One) Yes No

**Do you wear glasses or contacts in daily life or for reading?** (Circle One) Yes No

**If yes, did you bring these with you?** (Circle One) Yes No

# Appendix C:

## Electrode Placement

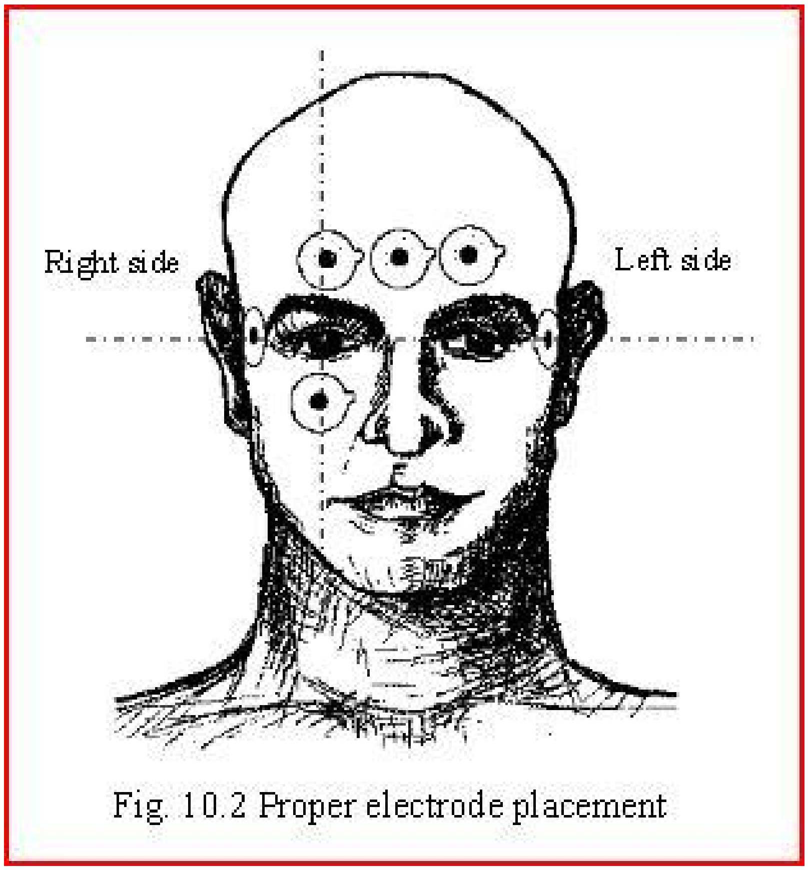


Figure 1. Electrode Placement Recommended for Biopic EOG Studies (Pittman, 2011)

The above placement was used for the electrodes and leads in the current study.

Appendix D:

The American Fascination with Zombies

Krystal Dicots

I think I must be prepared. For what? The impending zombie apocalypse, of course! Surely the plethora of zombie movies, books, survival guides, and even exercise regimens have given me a sense of how to survive in the event of this particular catastrophe. If you've seen even one zombie movie, I'd be willing to bet that you're pretty prepared too. If you haven't, go watch Zombieland. It provides a fair list of "rules" that should boost your chances of survival. For example, "When in doubt, know your way out" and "check the backseat" make a lot of sense. Then again, those might be things you should be doing anyway. And yet, they keep coming: Wikipedia lists seventeen zombie movies scheduled for release in 2011—and there are already films on the docket through 2014.

Zombies aren't pretty creatures. Popular media depicts them in assorted states of decay. They shamble. They're insatiable cannibals. And, well, they're dead. So why can't we get enough of them?

Folklore is home to a host of undead characters: mummies, skeletons, vampires, ghouls, and ghosts can be found under one name or another in almost all mythologies. Though closely linked with Vodoun magic and religion, the zombie is no exception: dybbuks, jumbies, djodjos, and duppies all bear some resemblance to the Haitian zombie, which is a composite of African beliefs transported to the Caribbean via the slave trade (1). Slaves from the Gulf of Guinea transported rites and rituals from the classical East and the Aegean, which took root following Haiti's revolution in 1804 (2). This zombie is a complex creature: though, like it's cinematic counterpart it lacks consciousness, it is a much more nuanced and manipulated figure. Anthropologist Wade Davis proposed that the Haitian zombie is a pharmacological product created by a bokor (3). A powder created from the toxins found in the puffer fish is administered to induce a lethargic sleep from which the afflicted may be roused and controlled. However, analysis of this powder has yielded frustratingly little information: ingredients appear to vary (including human remains, toads, lizards, millipedes, tarantulas, ground glass, and various plants) as does administration. For example, the powder may be strewn over the path frequented by the intended victim, or on his doorstep—this hardly seems very effective. Haitian traditions allow for the possibility of poisoning, but also posit a supernatural origin: a body is buried and resurrected without cause—it is just called by name by a sorcerer and emerges without will, memory, or consciousness, ready to do one's bidding (4). Typically, it will work for its creator, either performing labor or serving as a guard of some sort, and may be rented or loaned.

This corporeal zombie—distinguished from the spiritual zombie that Vodoun beliefs also permit—is the basis for the Hollywood zombie, which cannot be controlled and is bent on destruction. In both cases, the zombie is a shade of the human from whom it is derived, however the degradation of the latter's former humanity is precisely what makes it horror that we can't turn away from. Much has been written about the metaphors inherent in Hollywood zombies and their ties to capitalism, the Other, and science and technology gone awry (5, 6). Yet, zombies capture our imagination because they are extensions of what we know to be human—they provide a glimpse into the breakdown of the social order.

Zombies are not meant to be. We engage in systematic mourning and funeral rites to remove the deceased and his remains from our immediate awareness. While we make allowances for the length of the grieving period, we support the bereaved with the belief (even if it is unspoken) that they will eventually cease to mourn as deeply in a visible way. But we also distance ourselves from the dead because they are a reminder of our mortality. They are gone, after all. And not only that, but their bodies begin to decay. Zombies force us to confront these sorts of issues. In death, the social order does not matter:

Society's infrastructure begins to break down, especially those systems associated with the government and technology. Law enforcement is depicted as incompetent and backwater (the local sheriff is a stereotyped yokel with a "shoot first" attitude), so people must fend for themselves instead. The media do what they can, broadcasting tidbits of helpful information and advice by way of the radio and television, but the outlook is fundamentally grim: Hide if you can, fight if you have to. In the end, the rigid structure of society proves little help; human survivors are left to their own devices with no real hope of rescue or support. Motley groups are forced into hiding, holing up in safe houses of some kind where they barricade themselves and wait in vain for the trouble to pass (7).

Infectious disease researchers have already determined that in the event of a zombie outbreak, humanity would be up the creek—to put it mildly. In all the models investigated, the collapse of civilization is imminent (8). All but the most aggressive quarantine strategies would fail, and when the dead can come back to life, well, it means that there is an endless source of recruits waiting to be called forth. Albeit a bit tongue-in-cheek, researchers advise that in the face of a zombie apocalypse, quick, decisive action would be necessary: "the most effective way to control the rise of the undead is to hit hard and hit often" (9).

In these instances, the undead reflect concerns about mortality and social order. Zombies are our creation—whether in the Vodoun tradition or the result of radiation or a viral outbreak, zombies rise because we make it possible for them to do so. But perhaps because they are former human beings, it is hard for us to imagine that society would come completely undone. In recent years, we have seen the rise of a smarter class of the undead, one that can organize. And though that organization seems to make its mission the eradication of “normal” people, these new zombies are more intimidating in that they retain a bit more of their former selves. The film version of I Am Legend, gives us a class of zombie that is frightening fast, strong, and aggressive. They coordinate attacks and set traps—they can retaliate. Stephen King’s The Cell features undead who are organized around a leader, and begin a process of “turning” normals (rather than simply eating them). These zombies provide a glimpse of the world to come, a world that we may help create—which is perhaps why we just can’t turn away.

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Notes: 1. Ackerman and Gauthier (1991): 489. | 2. Bishop (2008): 143. | 3. Ackerman and Gauthier: 475. | 4. Ackerman and Gauthier: 474. | 5. Bishop (2008). | 6. Shapiro (2002): 77. | 7. Bishop (2006): 202. | 8. Munz, Hudea, Imad et. al. (2009): 146. | 9. Munz: 146.

Appendix E:

Reading Level Statistics

**Readability Test Results**

Web Address:
blogs.scientificamerican.com/anthropology-in-practice/2011/10/26/the-american-fascination-with-zombies/

This page has an average grade level of about 8.

It should be easily understood by 13 to 14 year olds.

**Readability Indices**

| | |
|---|---|
| **Flesch Kincaid Reading Ease** | 61.9 |
| **Flesch Kincaid Grade Level** | 6.8 |
| **Gunning Fog Score** | 6.9 |
| **SMOG Index** | 6.5 |
| **Coleman Liau Index** | 13.2 |
| **Automated Readability Index** | 6.2 |

**Text Statistics**

| | |
|---|---|
| **No. of sentences** | 403 |
| **No. of words** | 3096 |
| **No. of complex words** | 407 |
| **Percent of complex words** | 13.15% |
| **Average words per sentence** | 8.74 |
| **Average syllables per word** | 1.59 |

# Appendix F:

## Reading Comprehension Quiz

1. What popular media does D'Costa refer to as evidence that zombies are popular in the United States?

2. What reasons does D'Costa give that zombies should NOT be popular?

3. What cultures combined to create the Haitian Zombie?

4. What animal product is associated with the creation of Haitian Zombies?

5. In what ways can a Haitian Zombie arise?

6. What purposes do Haitian Zombies serve, and how do these differ from the traditional Hollywood Zombie?

7. What purposes do funerals serve in society, according to D'Costa?

8. In what ways do Zombies violate the social order?

9. What does D'Costa believe is shown about society by the negative presentation of law enforcement in Zombie movies?

10. What do disease researchers believe of humanity's outcome should a Zombie outbreak occur?

11. How do the Zombies of I Am Legend and The Cell differ from traditional Hollywood Zombies?

**12.** What does D'Costa imply about the responsibility of normal humans for Zombies?

______________________________________________________________________________

______________________________________________________________________________

____________________________________________________________________________

**13.** Which Zombie Movies does D'Costa reference directly? (Please select all that apply)

a. Zombie Land
b. Dawn of the Dead
c. I Am Legend
d. 28 Days Later
e. World War Z

**14.** True or False, Zombies are only found in Haitian culture? Circle One

a. True
b. False

**15.** What does D'Costa believe that Zombies symbolize?

______________________________________________________________________________

______________________________________________________________________________

___________________________________________________________________________

Did you like the article? Circle One Yes No

Do you hear about Zombies a lot? Circle One Yes Sometimes No

Appendix G:

Reading Level Statistics for Quiz

**Readability Test Results**

This page has an average grade level of about 5.

It should be easily understood by 10 to 11 year olds.

**Readability Indices**

| | |
|---|---|
| **Flesch Kincaid Reading Ease** | 73.4 |
| **Flesch Kincaid Grade Level** | 4.6 |
| **Gunning Fog Score** | 5.9 |
| **SMOG Index** | 4.7 |
| **Coleman Liau Index** | 9.1 |
| **Automated Readability Index** | 1.7 |

**Text Statistics**

| | |
|---|---|
| **No. of sentences** | 38 |
| **No. of words** | 239 |
| **No. of complex words** | 22 |
| **Percent of complex words** | 9.21% |
| **Average words per sentence** | 6.29 |
| **Average syllables per word** | 1.50 |

Appendix H:

Informed Consent Document

UNIVERSITY OF SOUTH CAROLINA

**Exploring Reading Comprehension in Undergraduate Students with ADHD Symptoms**

Helen Christine Shelton, B.S.

1) **Introduction**

You are being asked to volunteer for a research study for class credit because you are a healthy adult. Please read the following paragraphs carefully. If you have any questions or concerns regarding participation in this study, you are encouraged to raise these concerns with the investigators. The research is sponsored by The Department of Psychology. The investigator in charge of this study is Christine Shelton. Christine Shelton is presently a graduate student conducting this study to fulfill a Master's degree requirement.

***Purpose of Study***

The purpose of this study is to examine the relationship between ADHD symptoms, with or without a prior diagnosis of ADHD, and reading comprehension. Specifically, the study will attempt to understand how working memory (the ability to hold information in your mind and work with it), executive functioning (the ability to plan and to control one's behavior), ADHD symptoms, and eye movements work together to impact reading comprehension. Eye movement will be tracked in this study using Electrooculogram analysis, or EOG. We will use adhesive electrodes to measure small electrical impulses on the face. This is a non-invasive technique that allows us to look at the electrical potentials your muscles produce as your eyes move. EOG will be recorded for approximately 10 minutes during the reading task of the experiment. We are hoping to find a link between ADHD symptoms, executive functioning, and eye movement that may help explain known differences in reading comprehension among young adults. The data obtained your participation may help develop or improve programs in place to help people succeed in college by building reading comprehension and other academic skills.

***Eligibility to Participate***

Approximately 40 healthy adults will participate in the current study. You must meet the following criteria: 1) be a native speaker of English 2) have normal or corrected-to-normal vision 3) have an eighth grade reading level or above 4) be able to provide informed written consent to participate and 5) be between the ages of 18 and 65. Only participants who clearly understand the research and are able to indicate consent to participate can be enrolled in this study. You must pass a screening test for your data to be included.

**Description of Study Procedures**

If you agree to be in this study, the following will happen:

1. If you qualify and agree to participate, you will take part one session with several parts.

   **Part 1:**
   You are presently completing part 1, in which all necessary paperwork and questionnaires are completed. The first step is to read and sign this informed consent form. After signing the consent form, you will be given a short vocabulary quiz and a word reading task in which you will be asked to read familiar and unfamiliar words aloud from a card. The purpose of these two tasks is to determine your reading level eligibility. This marks the end of the first part of the experiment.

   **Part 2:**
   In part 2 of the experiment, 6 adhesive electrodes will be placed on your face. You will then be given a demographics form to fill out, which asks questions about your vision, your native language, and your diagnostic history. Your name will not be on this document. Additionally, you will be given a questionnaire regarding your behavior as an adult and as a child to complete. After these forms are complete, leads will be attached to the electrodes, which will then measure eye movements during the reading task. This is the end of the second part of the experiment.

   **Part 3:**
   In part 3 of the experiment, you will be asked to read a three page article presented on a computer screen, without moving your head. A chinrest will be provided. When you are finished reading the article, please raise your hand. The electrode leads will then be detached, and you will be given an on-paper questionnaire about the article, which is designed to test your reading comprehension. Again, your name will not be on the questionnaire. After completing the final questionnaire, you will be assisted in removing the electrodes, before being asked to complete a short memory exercise. . Upon completion of this exercise, you will be given a signed record of participation and given an opportunity to ask any questions about the experiment which arose during the process.

3) **Statement of Health Risks**

**EOG:**
EOG is a non-invasive technique that allows experimenters to measure the electrical activity your muscles produce when they move, by attaching electrodes to your facial skin. The electrodes that we use are only used one time, and only are used for you. Each electrode has a silver chloride center with a sponge underneath soaked in an electrolyte solution gel. Each electrode has a sticky adhesive area that lets us place the electrode on

your skin. In order to receive good recordings, we prepare each location where an electrode will be placed. This preparation consists of lightly scraping the area of skin in order to remove dead skin or dander, and cleaning the site with alcohol on a cotton ball. At no point should this preparation cause bleeding or injury; however, there is a small chance that once the electrode is placed on the site, you may feel a tingling or burning sensation for a minute or two after preparation of the site and electrode placement. The sensation is sometimes caused from the scraping and is a minor irritant. It should go away very quickly. There are no known risks other than minor skin irritation associated with this procedure. At no point in time does EOG cause electrocution or shock. Sometimes people may be concerned about this, especially if they have never had a measure like this taken. The EOG only takes readings of the electrical potentials your body already produces; it never transmits electricity or shock onto your body.

At any point while you are participating and you feel uncomfortable or feel the irritation is too painful, please let us know and we can remove the electrodes and gel.

4) **Participant Injury**
In the very unlikely event that you are injured because of your participation in this study, the research staff will assist you in obtaining appropriate medical treatment. However, you will be responsible for any costs associated with medical treatment.

5a) **Benefits of Participation**
There is no prediction that participants will directly benefit from participation in this experiment. Your participation in this study will provide data on how attention, executive functioning, memory and eye movements affect reading comprehension, which may lead to helpful interventions in the future for those who have difficulty in these areas.

5b) **Participant Compensation**
If you are participating to receive credits in your coursework, you will be provided with proof of participation that is signed by the researcher for your records and proof to provide your professor. Christine Shelton's contact information will be provided on this sheet in the case that your professor or you need to contact her. If you are a volunteer who is not participating for class credit, your name will be entered for a chance at winning one twenty-five dollar cash prize.

6) **Data Confidentiality and Participant Identification**
Your name will not be used in any publication that may result from this study. The USC Office of Research Compliance may request access to this form to ensure procedures designed to protect research participants are being properly followed. Your data may also be shared with other researchers around the world or with a publicly available data archive. In such cases, every reasonable effort will be made to remove identifiers from the data that would indicate any connection to you (e.g. the removal of your name, address, etc.). At no time will your name be asked for on the questionnaires used in this

experiment. Instead, a randomly assigned participant number will be used. Any information that is obtained in connection with this study and that could identify you will remain confidential and will not be released or disclosed without your further consent, except as specifically required by law.

7) **Expiration Date on the Viability of the Collected Data**
Data concerning your age, gender, handedness, task performance, etc. will be collected. The principle investigator for will maintain all data gathered from this study three-years or as required by journal, federal or state regulation.

8) **Voluntary Withdrawal**
Participation in this study is voluntary. You are free to withdraw your consent and discontinue participation in the study at any time throughout the study without negative consequences to your relationship with the University of South Carolina.

9) **Involuntary Withdrawal**
You may be removed from the study if you do not adhere to the study guidelines outlined above (e.g. not completing the reading assignment) In the case of involuntary removal from the study your record of participation will be signed for all work completed to that point in the study (rounded up to the nearest quarter hour).

10) **Investigator Contact Information**
Faculty and researchers of the University of South Carolina are conducting this research. For further information about this study, you may contact:

Dr. Anne Ellison
Department of Psychology
Phone Number (Office): (803) 641-3219
Email: anneE@usca.edu

Helen Christine Shelton
Department of Psychology
Phone Number (Cell): (803) 260-1136
Email Address: sheltonh@email.usca.edu

If you have any questions regarding your rights as a research participant, you may contact:
Thomas Coggins, Office of Research Compliance, University of South Carolina, Columbia, SC 29208, Phone: (803) 777-7095.

11) **Participant Signatures**
I have read this informed consent form and have been given a chance to ask questions about this research study. These questions have been answered to my satisfaction. I

agree to participate in this study. I have received (or will receive) a copy of this form for my own records.

Participant ___________________________________________ Date
_____/______/______

Investigator ___________________________________________ Date
_____/_____/_______