The Effects of One Neurofeedback Session on Eye-Tracking Distractibility when Completing Verbal and Visuospatial Search Tasks

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THE EFFECTS OF ONE NEUROFEEDBACK SESSION ON EYE-TRACKING DISTRACTIBILITY WHEN COMPLETING VERBAL AND VISUOSPATIAL SEARCH TASKS

By

Rebecca C. Recio-Swift, Bachelor of Art

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Abstract

Attention Deficit Hyperactivity Disorder (ADHD) is a common and prevalent condition seen in all ages and throughout the world. School-aged and college-aged students seem to have the most difficulty in terms of academic performance, social functioning, and adaptive functioning. Visual attention and visual search are important aspects of attention. Visual attention drives what and how the brain processes and interprets information from the environment. Visual search is the ability to find a visual target within a set of distractors. Electroencephalography (EEG) Neurofeedback is the process of re-training brainwaves through operant conditioning. Neurofeedback (NF) has been suggested to be a non-invasive alternative treatment for ADHD symptoms in school-aged children. However, not enough research has been conducted on the effects of NF training on college-aged students’ visual search abilities. Thus, this study will investigate the effects of right and left hemisphere NF protocols on visual search distractibility.

Keywords: ADHD, Visual search, Visual attention, EEG Neurofeedback
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Chapter I

Introduction

Attention deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by persistent patterns of behaviors related to inattentiveness and hyperactivity/impulsivity (American Psychiatric Association, 2013). Specifically, this disorder has been shown to affect college-aged students’ academic performance. Attention is a cognitive process that helps individuals respond to certain stimuli while ignoring or filtering out unnecessary information (Cohen, Malloy, Jenkins, & Paul, 2006). Visual (i.e., eye fields) and neural connections that work together to highlight the relevant information are necessary for achieving adequate attention. In general, attention requires visual search to a limited number of targets in the presence of many distractors.

Neurofeedback, also known as EEG Biofeedback, is the process of retraining brain wave patterns through operant conditioning (Hammond, 2011). NF uses frequency training, which involves EEG recordings at a pre-determined number of electrode locations (Hammond et al., 2004). During training, subjects watch a display on a computer screen and listen to feedback audio tones, which signal the reaching of a goal set by the experimenter (Hammond, 2005). Through this training, it is suggested that subjects are able to adapt their brain waves into different, more adaptive, brain wave frequencies (Blanchard & Epstein, 1978; Heinrich, Gevensleben, & Strehl, 2007; Kraft, 2006; Masterpasqua & Healey, 2003). The purpose of this study was to investigate if NF
training positively influences visual search performance in healthy individuals. In specific, the purpose of this study was to determine how different brain training protocols reduce distractibility when completing different visual search tasks.
Chapter II

Literature Review

Attention Deficit Hyperactivity Disorder

Attention deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder that is seen across cultures and countries all over the world. ADHD is characterized by the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) as a persistent pattern of behaviors related to hyperactivity/impulsivity and inattention (American Psychiatric Association, 2013). In academic settings, ADHD can inhibit a student’s ability to learn appropriately and impair social functioning (DuPaul & Stoner, 2014). In schools, students with ADHD can demonstrate poor academic performance, rejection from their peers, and difficulties inhibiting undesirable problem behaviors (Pelham & Waschbusch, 2004). Therefore, ADHD is typically seen in school-aged children due to the demands of the school environment.

In 2007, Polanczyk, de Lima, Horta, Biederman, and Rohde estimated the worldwide prevalence of ADHD to be at 5.29%. Willcutt (2012) conducted a comprehensive meta-analysis of the prevalence of ADHD as defined by the DSM-IV, which included 86 studies of children and adolescents and 11 studies of adults. Willcutt (2012) concluded that the inattentive type (ADHD-I) is the most common subtype of ADHD. However, those with the combined type ADHD (ADHD-C) are more likely to be referred for clinical evaluation and services. An analysis of potential moderators of the prevalence of
ADHD was also conducted. Overall, researchers found that ADHD with Hyperactivity-Impulsivity (ADHD-H) symptoms significantly decrease with age, while ADHD-I symptoms only minimally decrease with age.

In 2010, the Center for Disease Control and Prevention (CDC) indicated that in the United States, 3-10% of children can be diagnosed with ADHD. According to the CDC’s data, with an average of 20 students in every classroom in schools across the U.S., at least one student in every class can be, or has been, diagnosed with ADHD (DuPaul & Stoner, 2014). According to DuPaul and Stoner (2014), ADHD can impair students’ abilities to pay attention to instruction, hence, affecting their schoolwork performance and completion. DuPaul and Stoner (2014) also stated that students with ADHD often have difficulties with organization, test performance, and study skills. In addition, they frequently disrupt the classroom atmosphere by talking out without permission, disturbing other students during group and independent work, and becoming angry or frustrated when consequences for their behavior are given or when faced with a difficult task (DuPaul & Stoner, 2014).

Students with ADHD often have difficulty with on-task classroom behavior. A comprehensive meta-analysis done by Kofler, Rapport, and Alderson (2008) found that, on average, students without ADHD are on-task 88% of instructional time, compared to those with ADHD who are on-task 74% of instructional time. Studies show these students typically complete work at a lower rate than their non-ADHD peers, their work is often poor when compared to other students, and they have significant difficulties with staying
on-task (DuPaul & Langberg, 1990; Davies & Witte, 2000; Frick et al., 1991). These off-task behaviors can often lead to lack of attention to teacher instruction, which then leads to poor academic performance.

Difficulties in school performance are not the only problems students with ADHD experience. Parker and Asher (1987) found that issues in social relationships with peers can affect students in the long term, making adjustment later in life more difficult and leading to dropping out of school and criminality. Social skills deficits in students with ADHD leaves students feeling rejected and alone, which in turn makes it difficult for them to form and maintain personal relationships with their peers.

**ADHD in College Students**

ADHD is also largely present in college-aged students. It is estimated that the prevalence of ADHD in college students is around 25%. However, the prevalence rates of ADHD in this population are difficult to analyze since these individuals do not need to disclose their disabilities to the university (Weyandt & DuPaul, 2008). In a review of the literature, Weyandt and DuPaul (2008) sought to summarize the large amount of research performed on ADHD in the college student population. The researchers reviewed over 50 studies on ADHD and college students. Overall, this study shows 25% of college students are receiving services for ADHD, with that number significantly increasing since 1975 (Weyandt & DuPaul, 2008). Moreover, Weyandt and DuPaul (2008) stress that research on ADHD in college students is lacking and more is needed to examine the
impact ADHD has on the social, academic, and psychological functioning of college students.

In general, college students with ADHD tend to have lower GPAs, are more likely to be placed on an academic probation plan, and report more academic problems than their non-ADHD peers (Heiligenstein, Conyers, Berns, & Smith, 1998). Murphy, Barkley, and Bush (2002) conducted a study to find the differences between comorbidity and antisocial, educational, and treatment histories of young adults with ADHD-C and ADHD-I. It was found that young adults with both subtypes of ADHD were less likely to graduate from college, had significantly less education, and had a higher chance of being placed in special education services in high school. It was also concluded that those with ADHD-C or ADHD-I were more likely to have alcohol/drug dependencies, learning disabilities, and higher psychological distress. College students with ADHD also have difficulties in social functioning. In a study by Shaw-Zirt, Popali-Lehane, Chaplin, and Bergman (2005), the researchers compared a sample of college students with ADHD to a matched sample of students without ADHD to find differences between college adjustment and self-report levels of self-esteem and social skills. It was hypothesized that a) students with ADHD would report lower levels of adjustment, self-esteem, and social skills, and b) social skills and self-esteem would be mediators between ADHD and college adjustment. In order for students to be considered for the ADHD group, they must have had high scores on at least one of the two ADHD screening questionnaires used (i.e., Wender Utah Rating Scale and ADD-H Adolescent Self Report Scale), as well
as meet DSM-IV criteria through a structured clinical interview. The results showed that students with ADHD reported lower levels of college adjustment, self-esteem, and social skills. Overall, college students with ADHD are adjusting to college at one standard deviation below the normative mean, placing then in the below average range of functioning. The researchers attributed the low severity in college adjustment to the fact that college students with ADHD may have adopted functional and appropriate mechanisms to compensate for their difficulty in academics.

Moreover, research has suggested that ADHD in college students is often associated with other psychopathologies, such as depression and anxiety. A recent study by Weyandt et al. (2013), sought to find the differences between neuropsychological and psychosocial functioning in college students with and without ADHD. In the study, 50 college students were recruited (24 subjects with ADHD and 26 without ADHD) and given a variety of rating scales and diagnostic questionnaires to test for ADHD symptomology, psychopathology, academic performance, and social functioning. When looking at psychopathology, it was hypothesized that students with ADHD would show significantly higher rates of psychopathology than their non-ADHD peers. Results confirmed the hypothesis, showing that the ADHD college students had significantly higher levels of Obsessive-Compulsive behaviors, Depression, Anxiety, Hostility, Flat Affect, and Emotional Lability. In social relationships, students with ADHD reported having difficulties with social adjustment in terms of their school work. In fact, Mortier
et al. (2015) found that ADHD was associated with suicide attempts, binge eating, and psychotic symptoms (Mortier et al., 2015).

ADHD in college students demonstrates a different pattern of academic difficulties than students in K-12 grades. While college students with ADHD may continue to struggle with academics and social functioning, college-level ADHD students may show higher cognitive abilities that allow them to compensate for attentive disorders. For instance, studies reviewed have shown that these students show more success in academic settings and better adaptive skills such as time management and study skills (Weyandt & DuPaul, 2008). Students may also have a higher ability to adapt to the socially ambiguous college atmosphere by working more individually on projects (Frazier, Youngstrom, Glutting, & Watkins, 2007; Weyandt & DuPaul, 2008).

Weyandt et al. (2013), found no significant differences between ADHD and non-ADHD students in relation to social adjustment in social and leisure activities or family relationships. This suggests that some students with ADHD adjust to the independent nature of academic college-level work and to social environments and activities that they find enjoyable. Scheithauer and Kelley (2014) provide evidence for empirically supported strategies for ADHD in college students that help them be successful. Scheithauer and Kelley (2014) found that college students with ADHD who have self-monitoring skills tend to have higher grades, use more effective study skills, and attain goals. In this study, participants were placed in two groups, study skills with self-monitoring treatment (SM+) and only study skills treatment (SM-). Results suggested
that those in the SM+ group showed improvements in inattention, test taking, reading, ADHD symptoms, GPA, and goal attainment compared to the SM- group, in which none of these effects were observed.

Overall, ADHD in college students is a prevalent and important psychological and academic concern. However, there is evidence to suggest that although college students with ADHD continue to have difficulties in academics and social functioning, some of these students are able to adapt to the environment by adopting functional and appropriate mechanisms that allow them to function in the independent college atmosphere.

Attention

Attention is a cognitive process that helps individuals respond to certain stimuli while ignoring or filtering out unnecessary information (Cohen et al., 2006). Attention is the overall function of different processes that interact to produce a behavioral response to a stimulus (D’Agati, Cerminara, Casarelli, Pitzianti, & Curatolo, 2012). Attention processes include: selective attention, sustained attention, response inhibition, and visual attention. In Selective attention, sensory processes (e.g., vision or hearing) choose what needs cognitive processing, called targets, while filtering out unnecessary stimuli or distractors. This focus allows for optimal performance by eliminating distracting variables and only attending to the relevant and most important information.

Sustained Attention is the ability to consistently hold attentional performance over time (Cohen et al., 2006). However, the ability to sustain attentional performance varies
depending on different factors such as the target-distractor ratio, the difficulty of the task, and the duration of the task. The less targets there are in a task, the more difficult it will be to sustain attention on that task because there is less of a chance that the target will be found. If the task is difficult, sustained attention will decrease and if the task lasts for too long without reinforcement, attentional performance will also decrease. Response Selection or Control (Intention) is defined by Cohen et al. (2006) as attentional processes that direct resources to selecting a response or controlling a response. Response selection and control are processes that are consciously controlled, unlike selective attention which is more automatic. Thus, adequate attention depends on three different factors: an individual’s readiness to make a response, whether the individual is expecting that a response will need to be made, and whether the individual is anticipating the need to respond.

**Visual Perception**

Visual perceptual skills combined with other elements, such as motor response, memory, attention, and visuospatial skills, underlie an individual’s non-verbal understanding of the world (Lezak et al., 2012b). These include the ability to visually match objects and figures, recognize faces, draw, design, and construct (Lezak et al., 2012b). The optimal performance of these visual perceptual skills requires an integral process of sensory information, which involves integration of visual stimuli into meaningful psychological data to process and make sense of visual information (Fuster, 2003). It also integrates the state of intensity that is assigned toward certain stimuli,
which is the ability to focus or concentrate on the task that demands action (Cohen et al., 2006). This intensity allows cognitive processes to designate resources to be used for focus on a task.

Visual perception is an integrative process that can be divided into two consecutive brain functioning stages. First, the functions in charge of the simplest sensory characteristics, such as color or shape, and the ones in charge of the higher levels of cognitive skills, such as reception and storage of visual data, visual recognition of shapes and forms, and perception of spatial orientation and perspective. Second, the functions responding to representational designs and pictures, which requires a high degree of integration and analysis of the situation. Especially those processes that involve abstract, unfamiliar, and detailed visual information or conditions under which unique visual features are partially unclear (Ganis, Thompson, Mast, & Kosslyn, 2003).

**Visual Search**

Visual search is an important element of visual attention and perception that describes the direction and movement of the eye in a pattern to locate stimuli of interest (Haber & Hershenson, 1973a). Visual search changes with context. In general, searching requires attention to a limited number of targets in the presence of many distractors. One of the most important characteristics of visual search is the ability to ignore the distractors in order to locate the target. Depending on the task, searching can take on different characteristics. For example, looking for a face in a crowd is one type
of search, looking for errors in a written passage is a type of search that is done during reading while ignoring the meaning of the passage (Haber & Hershenson, 1973a).

**The Brain and Visual Search**

Visual search starts at the eye, specifically the two synapses, one between the receptor and bipolar cells and the other between the bipolar and the ganglion cells. There are nearly one million fibers in the optic nerve that aid in carrying information to the processing areas of the brain. Different parts of the visual field will travel through different cells and receptors (Haber & Hershenson, 1973b). Regarding the eye, the difference between foveal and peripheral vision constitutes successful visual searching. Objects in the foveal view are in central vision. These are the objects to which most attention is being given in order to determine whether the object is the target being sought. The peripheral view guides searching by signaling where to look next if the object in the foveal view was determined to not be the target. Although the information in the peripheral view is not detail specific, it can help guide the brain to more important stimuli. Characteristics such as color, movement, and size help the peripheral view process (Haber & Hershenson, 1973a).

Visual information is then processed through two different streams that run along the ventral and dorsal areas of the brain. The ventral stream is responsible for the identification of objects, while the dorsal stream is charged with the identification of spatial orientation of objects and the objects proximity during movement (Kastner & Ungerleider, 2000). Research has shown that the ventral stream runs along the temporal
regions of the brain and as information of objects is processed through the ventral stream, the information becomes more specialized as object-specific cells activate. The human eye and its connection to neurological processes is one of the most complex mechanisms (see figure 1).

Figure 1. Semischematic representation of brain areas related to attention with interconnections among the regions. The connections between the regions illustrate the attention system. From “Behavioral and Psychophysiological Markers of Disordered Attention” by A. F. Mirsky, 1987, Environmental Health Perspectives, 74, pg. 197. In the public domain.

Basic visual stimuli are mostly processed in the occipital lobe, located in the posterior regions of the cortex. Downing, Jiang, Shuman, and Kanwisher (2001) found substantial evidence that certain cortical regions respond selectively to images of the human body. The occipital lobe contains the primary visual cortex, which responds when presented with different visual stimuli. However, when analyzing complex visual
information, there are multiple brain areas that work together to control visual search. The inferior parietal cortex is responsible for spatial attention while the inferior temporal lobes focus on attentional enhancement, which aids in object recognition (Cohen et al., 2006). The frontal cortex influences response selection and control as well as switching attention and searching (Cohen et al., 2006). Response inhibition and initiation, also known as the go-no go response, is controlled by the orbital frontal region. The dorsolateral frontal cortex influences switching and focus (Cohen et al., 2006). The frontal eye fields are responsible for saccadic eye-movement, which allow for visual search by attention neurons in the parietal cortex (Cohen et al., 2006). In order to sustain attention or use selective attention, regions in the limbic system, such as the amygdala, are used for motivation and affective processing, which give priority to new information (Cohen et al., 2006).

The brain hemispheres also have a specialized role in recognizing the type of visual stimuli. In general, the right hemisphere of the brain focuses more on picture stimuli such as photographs, processing the environment, or body language (Barrash, Demasio, Adolphs, & Tranel, 2000). The left hemisphere is more concrete. It focuses on verbal stimuli, such as word searches, reading words on a page, or verbal cues. The first major difference between hemispheres is related to language. The left hemisphere is specialized for language, specifically processing verbal information, whether it be oral (i.e., auditory) or written (i.e., visually) (Belligu et al., 1993; Hickok, Belligu, Klima, 1996). The left hemisphere is not only responsible for information input, but for
producing language as well (i.e., output) (Abutalebi & Cappa, 2008; Hickok, 2009). The right hemisphere’s specialization is in nonverbal language, such as visual patterns and auditory signals (e.g., body positions and music) (Barrash et al., 2000). Although the left hemisphere is specialized in verbal language comprehension, the right hemisphere has the capacity to put verbal language into personal contexts, which in turn helps build language skills and aids in the appropriate usage of language (Lezak, Howieson, Bigler, & Tranel, 2012a). Table 1 shows the functional cognitive dichotomies of left and right hemispheric dominance (Benton, 1991).

Table 1

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<td>Logical</td>
<td>Pictorial</td>
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<td>Rational</td>
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*Note.* Adapted from Lezak, Howieson, Bigler, & Tranel, 2012a and Benton, 1991.

In summary, visual information is processed through major neural areas and networks, including the ventral and dorsal streams, frontal and parietal cortices, and right and left hemispheres. These networks designate how information is processed and what
information is most important by focusing attentional and visual energy to the relevant areas in the environment. The specialization of the hemispheres plays a crucial role in visual processing. The left hemisphere has a specialized role in language related stimuli, such as verbal cues and written language, while the right hemisphere’s specialized role is in processing abstract stimuli, such as pictures or items in the environment.

**Quantitative Electroencephalogram (QEEG)**

Electroencephalogram (EEG) is an inexpensive, non-invasive neuroimaging technique that measures electrical activity from the scalp. The electrical activity (ranges from 5-100μV; frequency 1-40Hz) measured by an EEG reflects the synaptic excitation of neurons in the outer section of the cerebral cortex (Scherg, Ille, Bornfleth, & Berg, 2002). Quantitative EEG (QEEG) is the mathematical processing of recorded EEG activity, which is used to gather numerical measures (e.g., absolute power) from frequency components and amplitudes of EEG activity (Nuwer, 1997).

QEEG is usually measured by lacing electrodes on an individual’s scalp using the international 10/20 system (see Figure 2). The international 10/20 system, developed by Herbert H. Jasper (1958), is a recommended position of the electrodes based on specific measurements of cranial landmarks. The 10/20 system specifies the measurements needed to place electrodes in the appropriate locations on the skull. Percentages are used to place electrodes in 10% or 20% intervals between two fixed anatomical points. The points fall on measurements labeled with letters to indicate the cortical areas they measure: F (frontal), Fp (frontopolar), C (central), P (parietal), O (occipital), and T
(temporal), ear lobe electrodes are labeled as A. The numbering system was added to easily differentiate between left and right hemispheres. Odd numbering in the 10/20 system indicates left hemisphere: Fp1, F3, F7, C3, T3, P3, T5, and O1. Even numbers indicate the right hemisphere: Fp2, F4, F8, C4, T4, P4, T6, and O2. For electrodes that are located in the midline of the skull, a “z” (i.e., for zero) is assigned to the letter that indicates the area of the brain being measured (Klem, Lüders, Jasper, & Elger, 1999).

Figure 2. Electrode placements on the international 10/20 electrode system. (Fp = Frontal Pole; F = Frontal; T = Temporal; C = Central; P = Parietal; O = Occipital; A = Anchor). Adapted from “The Ten-Twenty Electrode System of the International Federation” by G.H. Klem, H.O. Lüders, H.H. Jasper, and C. Elger, 1999. In the public domain.

Electrical brain wave speed is measured by hertz (i.e., electrical frequency cycles per second) and they are divided into bands to delineate slow, moderate, and fast waves (Hammond, 2011). The four most researched brain wave bands are: Beta waves (12-30Hz), which are the smallest and the fastest brainwaves associated with an alert state of mind; Alpha waves (7-12Hz) are characterized by slower and larger waves than Beta and
are associated with being in a relaxed state of mind. Alpha waves are known to be prominent in the posterior and occipital regions of the brain. Theta waves (4-8Hz), which are characterized by slower and even larger waves than Alpha, are associated with a dream-like state or mental inefficiency. Finally, Delta waves (less than 4Hz) are the slowest and largest waves, and are most prominent during deep sleep.

**QEEG indicators of neurodevelopmental disorders**

QEEG indicators have been shown to be useful for the assessment of neurodevelopmental disorders because of the close association between behavior and EEG frequency (Snyder & Hall, 2006). For example, in clinical settings, QEEG has been used to identify children with ADHD (Loo & Barkley, 2005). QEEG indicators have shown that children with ADHD have greater theta activity and lower beta activity in the brain’s frontal regions than their non-ADHD peers when their eyes are open (Chabot, di Michele, Prichep, & John, 2001) or when completing a task (Monastra, Lubar, & Linden, 2001).

A study conducted by Monastra et al. (1999) showed the use of QEEG on assessing the presence of ADHD in 482 participants. The researchers gave traditional ADHD assessments to identify those with ADHD, then separated participants into three groups (i.e., ADHD inattentive, ADHD combined, and control). Monastra et al. (1999) found that QEEG correctly identified 86% of the individuals who were found to have ADHD through the traditional assessments, while correctly detecting 98% of those who were not ADHD.
Similarly, Clarke, Barry, McCarthy, and Selikowitz (2001) sought to explore the presence of EEG differences in a sample of 184 male children with ADHD. Participants were given full clinical assessments for ADHD then completed an eyes-closed resting state EEG using the international 10/20 system. It was found that the ADHD group had an increase in theta and a decrease in relative alpha activity, an increase in theta/beta ratio, a decrease in frontal delta, and increased frontal and central total power, which is consistent with past studies (Callaway, Halliday, & Naylor, 1983; Clarke et al., 1998). The cluster analysis indicated three distinct groups of children with ADHD-C. Cluster 1 showed increased amplitude of theta activity, particularly in the frontal regions, while also showing a decrease amount of delta and beta activity. Cluster 2 demonstrated high levels of slow wave activity in delta and theta bands, with reduced fast wave activity. The largest differences between Cluster 2 and the control group were found in the posterior and central regions. In Cluster 3, analysis indicated high power beta activity with decreased delta and alpha activity. In a previous study by Clarke et al. (2001b), it was found that children with high levels of beta were more likely to have temper tantrums compared to other ADHD children with a profile of increased theta. Therefore, attention can be measured and identified using QEEG indicators, and these indicators have the capacity to reliably differentiate individuals that have attention disorders from those who do not.
Neurofeedback

Neurofeedback, or EEG Biofeedback, is the process of retraining brain wave patterns through operant conditioning (Hammond, 2011). NF uses frequency training, which involves single-channel referential or sequential EEG records at a pre-determined number of electrode sites (Hammond et al., 2004). During training, patients watch a display on a computer screen and listen to feedback audio tones, which signal the reaching of a goal set by the experimenter (Hammond, 2005). Through this training, patients are able to adapt their brain waves into different electrical frequencies (Blanchard & Epstein, 1978; Heinrich, Gevensleben, & Strehl, 2007; Kraft, 2006; Masterpasqua & Healey, 2003).

It has been suggested that through NF training, some individuals with ADHD are able to gain self-control over physiological functions that are not usually consciously perceived (Heinrich et al., 2007). However, NF is still considered an experimental treatment option for this condition. In a study done by Bakhshayesh, Hänsch, Wyschkon, Rezai, and Esser (2011) it was hypothesized that the improvements in the NF group would exceed those in the control group by measuring behavioral changes, as rated by parents and teachers, and improvements in cognitive performance tests. Also, those in the NF group would show decreased activity in theta and increased activity in beta.

Thirty-eight children with ADHD, ages 6 to 14, were recruited for the study and randomly assigned to either the neurofeedback group or control group. Treatment for both groups lasted for 10-15 weeks. Children in the NF group were training on
increasing beta and decreasing theta frequencies with electrodes placed in CPz and FCz. The control group consisted of an alternative type of biofeedback training using electromyography (EMG) with electrodes placed on the frontalis musculature for EMG amplitude measurement. Analysis indicated that the overall results of the parent and teacher rating scales show significant improvements in ADHD related behaviors after treatments on all subscales of the parent ratings and in three of four subscales of the teacher ratings. However, Bakhshayesh et al., (2011) stated that they were unable to prove whether NF training was superior to EMG training when studying hyperactivity and impulsivity symptoms on rating scales.

Lévesque, Beauregard, and Mensour (2006) investigated the effects of NF training in children with ADHD on the neural substrates of the selective attentional processes involved in the Counting Stroop task. Participants were 20 children with ADHD randomly assigned to either the experimental group or control group. Those in the experimental group (N=15) received NF training, which consisted of enhancing beta amplitude and decreasing theta amplitude in phase one. In phase two, participants were trained to inhibit theta amplitude and increase the amplitude of beta 1 waves. Participants in the control group (N=5) received no treatment. Results were presented in terms of pre- and post-test results. In Time 1, data were collected on the Counting Stroop task one week before training. In Time 2, data were collected from the Counting Stroop task one week after the training was concluded. It was shown that there were no significant differences between the groups in Time 1 when assessing average scores on
Digit Span, The Connors Parent Rating Scale – Revised (CPRS-R), and the Integrated Vision and Auditory Continuous Performance Test (IVA). At Time 2 scores of those in the control group were not significantly different than their own scores in Time 1. However, for those in the experimental group, scores on the Digit Span and IVA were significantly higher and scores on the Inattention and Hyperactivity domains of the CPRS-R were significantly lower at Time 2.

Gani (2009) presented the first randomized long-term follow-up study that provided data from NF sessions two years after the termination of treatment. Gani (2009) sought to find whether 1) after 2 years participants were able to maintain the ability to self-regulate cortical activation and 2) whether improvements in attention lead to differences in the stability of cortical self-regulation and clinical effects. During treatment, participants were randomly placed in two groups; Slow Cortical Potential (SCP) group and Theta/Beta group. At the two-year follow-up, participants in both groups were administered a NF session which involved a game with various trials in place. Generalization trials were implemented into the study to foster practice of self-regulation in daily life, where no continuous feedback was provided during the session, only after the game was over. Results yielded significant findings in the Theta/Beta group; children who did not participate in the two-year follow-up exhibited significantly higher rates of ADHD symptoms than those who did participate. Results of behavior showed that the number of DSM-IV criteria for both inattention and hyperactivity declined significantly at the two-year follow-up.
Lansbergen, van Dongen-Boomsma, Buitelaar, and Slaats-Willemse (2011) conducted a pilot study to test the safety and feasibility of using a double-blind placebo feedback-controlled design in studying the effects of individualized NF training on children with ADHD. Fourteen children, ages 8-15 years old, completed the study where eight children were randomly assigned to the EEG group and six assigned to the placebo group. Since NF training was individualized, protocols were determined based on visual inspection of the participants’ QEEG recording prior to treatment. Feasibility was assessed by adherence to attendance to the study and training sessions completed. Also, parents and children were asked whether they thought the child received NF training or a placebo. Safety of this design was measured by having parents and children complete the Pittsburgh Side Effects Rating Scale (PSERS) before training and after 6, 10, 20, and 30 training sessions. The Sleep Disorders Questionnaire was used to assess for sleep problems. Efficacy of the training was measured by the total severity of inattention and hyperactivity/impulsivity symptoms, which were rated before training, during training, and 6 months after the termination of treatment. Results showed that all 14 children completed the study and 3 out of 6 children thought they received the NF training, which suggests that providing a placebo training as a control condition could be a feasible option. When analyzing safety, neither of the conditions presented significant adverse side effects on sleep, suggesting that NF and a placebo training condition can be safe approaches. Although there was clinical improvement over time in ADHD symptomatology, there were no significant differences between the EEG NF training
condition and the placebo training condition. This suggests that individualized NF training did not exceed the placebo training group in clinical improvement on ADHD DSM-IV symptomology.

Duric, Assums, Gundersen, and Elgen (2012) recognized the immense lack of controlled studies, stating that while other studies used other treatments or waitlists as control groups, randomized control studies are still needed in the field. The objective of the study was to investigate the effectiveness of NF on the core symptoms of ADHD, including attention and hyperactivity. Participants were 91 children and adolescents, ages 6-18, with a diagnosis of ADHD. Participants were randomly assigned to either the neurofeedback group, NF plus medication group, or only medication group. Those in the NF group were training to enhance beta and inhibit theta. Sessions were done three times a week, lasting 40 minutes, with 30 sessions for each participant. The pre- and post-evaluations consisted of five-minute baseline periods in the form of alpha training. In the NF plus medication group, neurofeedback protocols were identical to the neurofeedback group protocols. The medication taken in the NF plus medication group and medication only groups were 1 mg of methylphenidate taken twice per day as recommended. Parent reports showed an improvement in the core symptoms of ADHD in the NF group. Those in the NF plus medication group showed similar improvements. NF had an effect on improving attention and hyperactivity symptoms in the participants. No significant differences were found among the three treatment groups in the improvement of core symptoms of ADHD, suggesting that the effects of NF can be close to that of stimulant
drugs. This study supports the use of NF as a less invasive treatment option for those with ADHD, especially the 20% of the ADHD population that do not respond to stimulant medication.

Steiner, Sheldrick, Gotthelf, and Perrin (2011) investigated the effects of two computerized training programs on teaching children with ADHD to attend better. Participants were 41 children with ADHD from two middle schools. They were randomly assigned to a NF group which received two sessions a week: a) the attention training through a standard computer format (SCF) group, where the participants completed visual and auditory activities designed to reduce impulsivity and increase attentiveness, or b) the waitlist condition, which received no treatment until after the post intervention assessments were completed. In the NF training group, children were trained to decrease theta frequencies and increase beta frequencies. The Connors Rating Scales – Revised, the Behavior Assessment Scales for Children (BASC) and the Behavior Rating Inventory of Executive Functions (BRIEF) were used as outcome measures. Results were mixed, showing that students in the waitlist condition reported significant change on the CRS-R ADHD Index and those in the SCF condition reported significant change on the BASC Attention Problems Scale. When analyzing observed behavior, those in the NF group showed a trend toward lower levels of fidgeting and off-task behaviors. However, there were no significant findings. Parents, whose children were in the NF condition, reported significant changes on all three CRS-R and the two BASC subscales. In the SCF condition, parents reported significant change on the CRS-R
Inattention and ADHD Index, BASC Attention Problems, and BRIEF. Overall, Steiner et al., (2011) show the difficulty of maintaining reliability when conducting NF sessions outside of the clinical setting.

**Summary and Study Rationale**

Individuals that can accommodate to the demands of the environment may have the capacity to filter out unnecessary information and assign importance to stimuli of interest. Visual search is a subcomponent of visual attention and is defined as the ability to find and respond to important information through physiological eye-movements.

There are a number of brain areas associated with optimal visual search performance (i.e., frontal and parietal lobes) and brain hemispheres have shown specialization in visual search-type stimuli (i.e., left hemisphere: language; right hemisphere: visuospatial).

NF is a non-invasive learning process technique in which the brain is rewarded for positive changes in its activity through operant conditioning of QEEG waves. NF has been suggested as a possible alternative treatment for attentional disorders in children and adults. To date, several studies suggest that NF has significant effects on attention processes. In clinical settings, these studies have suggested which brain wave bands are subject to training, the location and placement of specific electrodes, and the number of sessions necessary to obtain optimal results.

To date, little is known about the effects of NF on visual search skills and how this important attentional process can be improved through NF protocols. The purpose of this study is to investigate the relationship between visual search and NF. In specific, the
The purpose of this study is to determine how different protocols decrease distraction when completing visual search. Distractibility was operationally defined as the number of fixation count and total fixation durations by the participant in a non-target stimuli.

**Hypotheses**

The following are the specific hypotheses that were tested in this study:

I. Participants who train on the left hemisphere protocol (locations C3 and F3), by increasing Beta (14-17 Hz) and inhibiting Theta (4-7 Hz), will show significantly decreased eye-tracking distractibility while scanning language-related tasks.

II. Participants who train on the right hemisphere protocol (locations F4 and P4), by increasing Beta (12-15 Hz) and inhibiting Theta (4-7 Hz), will show significant decreases on eye-tracking distractibility while scanning for non-language related tasks.
Chapter III

Methods

Participants

The current study had a total sample of 121 participants. Participants were male and female undergraduate and graduate college students from a Southwestern U.S. institution. Participants were recruited from introductory and upper level psychology courses. Recruitment was done through the university’s research participation website, Sona-Systems. The study was approved by the Institutional Review Board (IRB). Participants were excluded if they had a history of seizure or epilepsy (N=2), lack of NF training (N=11), or missing eye-tracking data (N=19) (see below). Final sample was 99 participants.

Materials

A demographics and brief medical history questionnaire was used to assess possible extraneous variables (i.e., history of Traumatic Brain Injury, chronic pain, substance abuse, medication use) and the exclusion criteria (i.e., history of seizures and epilepsy) as well as gather demographic information on the participant.

The Adult ADHD Self-Report Scale Symptom Checklist Version 1.1 (ASRS v1.1) was used to assess for ADHD symptomology (see Appendix C for copy of checklist). It is an instrument consisting of the eighteen DSM-IV-TR criteria. This scale has not been updated to DSM-5 criteria due to its recent release and insufficient norming.
data on new criteria. Six of the eighteen questions are found to be the most predictive of symptoms consistent with ADHD, which are categorized as ADHD Critical items. These Critical items are the basis for the ASRS v1.1 Screener and are also Part A of the Symptom Checklist. Part B of the Symptom Checklist contains the remaining twelve questions. Furthermore, it gives an ADHD Total Score, which is the total for all 18 items. The questions in the ASRS v1.1 are consistent with DSM-IV-TR criteria and address the manifestations of ADHD symptoms in adults. Content of the questionnaire also reflects the importance that the DSM-IV-TR places on symptoms, impairments, and history for a correct diagnosis. The ASRS v1.1 is a 5 point Likert Scale ranging from Never to Very Often. Participants were given the ASRS to assess their ADHD symptomatology. The ASRS has been shown to be valid and reliable within the adolescent and adult populations. Specifically, Adler et al. (2006) found a high internal consistency between the items with a Cronbach α of 0.93 at Visit 1 and 0.94 at Visit 2 of the study. Within the adult population, the ASRS was also found to have high internal consistency for patient and rater-administered versions of the scale (Cronbach’s α 0.88 for patient self-report and 0.89 for rater-administered). Individual items were found to have acceptable agreement (43-72% agreement) with significant Kappa coefficients for all 18 items (Adler et al., 2006).

**Neurofeedback Training**

Participants in the experimental conditions went through an EEG NF training session using the Brain Avatar software and a 19-channel signal amplifier, Discovery
Brain Avatar is a single platform that allows for patient assessment and training to be blended with EEG (Proler & Bass, 2012). EEG data was recorded from only four electrodes (F4, P4, F3, and C3) placed on the skull using the 10/20 system, with ground and reference electrodes placed on the earlobe.

Unipolar placed sensors on the scalp measured brain activity, and a computer processed the signals as brainwave frequencies. The flow of this activity is shown to the subject, who attempts to change the activity level. Such information was presented to the participants in the form of a visual and auditory stimulus. For this study, this feedback was quantified to determine individual differences in adapting to training (i.e. Beeps Total).

Participants were randomly assigned to one of three NF groups, 1) the Right Hemisphere training protocol group, 2) the Left Hemisphere training protocol, and 3) the Sham condition. The Right Hemisphere protocol consisted of NF training on locations F4 (GO 12-15Hz; STOP 20Hz and up) and P4 (GO 4-12Hz; STOP 15Hz and up). The Left Hemisphere protocol consisted of NF training on locations F3 (GO 15-20Hz; STOP 4-7Hz and 20Hz and up) and C3 (GO 4-12Hz; STOP 15Hz and up). The Sham protocol consisted of no direct training; instead participants watched a pre-recorded “sham” training session. Regardless of the condition, each participant trained for 30 minutes and received continuous auditory and visual reinforcement.
Eye-Fixation Measure

Eye tracking was performed using the Tobii X-260 eye-tracker (see http://www.tobii.se/). The Tobii X-260 eye-tacker allowed for the mapping of eye movements to various features on the screen during task performance. It is a state of the art eye-tracking device that tracks the eye-movement of participants in real time and gives data on maintenance of gaze on a single location (i.e., Fixations). Areas of interest (AOIs) were generated by a JavaScript application. This application provided the screen coordinates for each element that was of interest for a given task (i.e., distractors within visual search tasks) (see appendix B for picture of stimuli with the AOI view). Eye-tracking was used to specifically measure distractibility by determining the number of eye fixation counts and total fixation durations in non-target areas. Fixation count and total fixation duration were the eye-tracking variables of interest. Fixation count was defined as the number of times the participant fixated outside of the target. Total fixation duration was defined as the sum of the duration for all fixations outside of the target.

Visual Search Tasks

The visual search tasks consisted of different types of stimuli (see Appendix A). All tasks were presented with a screen resolution of 1920 x 1200 pixels. The first visual search task presented to the participants with dimensions of 483 x 594 pixels and consisted of a painting where multiple deer were hidden within the environment. Participants were to search for hidden deer within the painting. There was a total of seven deer hidden within the painting. Participants were given three minutes to find all
hidden deer. The deer task was found on the public domain through Steven Michael Gardner at gardnergallery.com.

The second visual search task was Letter Cancellation, presented with dimensions of 945 x 1080 pixels. This task was created on a word processor and exported into PDF format. The creation of this task was to mimic Diller et al., (1974) who created letter cancellation tasks. In the present study, participants were asked to find every instance of the letter “e” in a set of distractor letters within 30 seconds. There was a total of 10 “e” letters in a mix of 125 non- “e” letter distractors.

The third task consisted of a horse painting with nine hidden horses within the image. The image was presented at 482 x 558 pixels and participants were given 3 minutes to find as many of the hidden horses as possible. The horse task was found on the public domain through Steven Michael Gardner at gardnergallery.com.

The fourth visual search task was Word finding presented at 945 x 1080 pixels. Participants were asked to find every instance of the word “brainwave” from page 26 of Hammond (2006). Within the task, the word “brainwave” was stated 24 times. Participants had 30 seconds to find as many of those 24 words as possible.

The fifth and last visual search task was Where’s Waldo by Martin Handford. Where’s Waldo is a real-world application of a cancellation test for testing visual inattention and distractibility. This task was presented in 1024 x 768 pixels and was found on the public domain. Participants were asked to find Waldo within 60 seconds.
**Procedure**

Once the participant came into the laboratory, a researcher gave him or her an informed consent form stating the general details of the study, limits of confidentiality, and explaining voluntary participation. Participants were asked to read and sign the form if they agreed to continue. After the informed consent was signed, the researcher gave the brief medical history questionnaire as an interview, except for the last three items, which were deemed sensitive items that the participants answered privately.

The participants were given the Adult ADHD Self-Report Scale (ASRS). Once the ASRS was been completed, the researcher had the participant sit down in the assessment room and began the cap process. First, the researcher measured the participant’s head to determine what size cap was needed. Second, the researcher applied Neuro-prep gel on the 4 spots on the participants’ head that were measured. The Neuro-prep is intended to clean the scalp in order to obtain clean brain-wave pattern readings. Then, the cap was placed on the participant’s head and electro-gel was applied to their scalp. The cap was plugged into the EEG machine and the participants were instructed to relax, get as comfortable as possible, and not to move. After the 30-minute training session, the researcher removed the cap and cleaned the participant’s head. The researcher then lead the participant to the Tobii eye-tracker computer and began the visual searching tasks. Once the tasks were completed, the researcher debriefed the participant about the true purpose of the study.
CHAPTER IV

Results

Demographics and ADHD Symptomology

Table 2 summarizes the data for the final sample’s (N = 99) age, gender, classification, ethnicity, and treatment condition. The final sample consisted of mostly female, white (59%), first year college students. NF conditions were represented equally. This table also indicates the number of participants per condition.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Final Sample)</td>
<td>19.34</td>
<td>2.04</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>68</td>
<td>68.7%</td>
</tr>
<tr>
<td>Male</td>
<td>31</td>
<td>31.3%</td>
</tr>
<tr>
<td>Classification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freshman</td>
<td>58</td>
<td>58.6%</td>
</tr>
<tr>
<td>Sophomore</td>
<td>19</td>
<td>19.2%</td>
</tr>
<tr>
<td>Junior</td>
<td>12</td>
<td>12.1%</td>
</tr>
<tr>
<td>Senior</td>
<td>9</td>
<td>9.1%</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>01%</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>58</td>
<td>58.6%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>24</td>
<td>24.2%</td>
</tr>
<tr>
<td>African-American</td>
<td>14</td>
<td>14.1%</td>
</tr>
<tr>
<td>Asian</td>
<td>1</td>
<td>01%</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>02%</td>
</tr>
<tr>
<td>NF Condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Hemisphere</td>
<td>29</td>
<td>29.3%</td>
</tr>
<tr>
<td>Right Hemisphere</td>
<td>31</td>
<td>31.3%</td>
</tr>
<tr>
<td>Sham</td>
<td>39</td>
<td>39.4%</td>
</tr>
</tbody>
</table>

Note: NF = Neurofeedback training
An ANOVA was conducted to determine if NF training conditions differ in age, gender, critical ADHD, and total ADHD items reported. The data indicated no significant differences between the conditions in these variables (Table 3). Thus, these groups are similar regarding possible confounding variables.

Table 3. Group comparison for potential confounding variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Simulation</th>
<th>Left Hemisphere</th>
<th>Right Hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Age</td>
<td>19.44</td>
<td>(2.96)</td>
<td>19.31</td>
</tr>
<tr>
<td>Beeps Total</td>
<td>-</td>
<td>-</td>
<td>1349.65</td>
</tr>
<tr>
<td>Critical Item Total ADHD</td>
<td>8.61</td>
<td>(3.91)</td>
<td>8.59</td>
</tr>
<tr>
<td>Total Item ADHD</td>
<td>29.07</td>
<td>(12.63)</td>
<td>28.88</td>
</tr>
</tbody>
</table>

Note: * Signifies independent samples t-test was conducted.

Beeps Total is the number of rewards, or beeps, achieved in each training session. Critical Item Total ADHD is the total number of critical items endorsed in the ADHD Self-Report Scale (ASRS v1.1). The Total Item ADHD is the Total raw score of items endorsed on the ASRS v1.1

Table 4 displays the correlations between the dependent variables in the control group. Note that this analysis was conducted only for the control group because they received zero levels of manipulation, and as such, correlations should represent values without NF training. As expected, fixation count and total fixation duration correlated within the same task. Moreover, between task correlations were found between Letter Cancellation, Words, and Deer. Interestingly, Waldo scores did not correlate with the other visual search tasks. Table 4 also presents correlation values between ADHD
symptoms and eye-tracking variables by tasks. Results indicated that Deer fixation count and total fixation duration negatively correlated with ADHD symptomology report.

Table 4
Relationship Between Variables in the Control Group

<table>
<thead>
<tr>
<th>Eye-Tracking Variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deer TFD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deer FC</td>
<td></td>
<td>.76**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waldo TFD</td>
<td>-.22</td>
<td>-.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waldo FC</td>
<td>-.13</td>
<td>.00</td>
<td>.90**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Words TFD</td>
<td>.38*</td>
<td>.27</td>
<td>.01</td>
<td>-.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Words FC</td>
<td>.44**</td>
<td>.34*</td>
<td>-.12</td>
<td>-.10</td>
<td>.86**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Letter Cancellation TFD</td>
<td>.23</td>
<td>.10</td>
<td>.14</td>
<td>.03</td>
<td>.66**</td>
<td>.46**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Letter Cancellation FC</td>
<td>.10</td>
<td>.04</td>
<td>.07</td>
<td>-.02</td>
<td>.41*</td>
<td>.46**</td>
<td>.78**</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ADHD Variables</th>
<th>9</th>
<th>10</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical Item Total Score ADHD</td>
<td>-.43**</td>
<td>-.49**</td>
<td>-.10</td>
<td>-.12</td>
<td>-.29</td>
<td>-.32*</td>
<td>.03</td>
<td>.07</td>
<td></td>
</tr>
<tr>
<td>Total Item Score ADHD</td>
<td>-.31</td>
<td>-.04</td>
<td>-.00</td>
<td>-.06</td>
<td>-.18</td>
<td>-.25</td>
<td>.25</td>
<td>.23</td>
<td>.91**</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Note: TFD = Total Fixation Duration; FC = Fixation Count; Deer = participants searched for 7 deer hidden in a painting; Waldo = participants searched for Waldo in a Where’s Waldo task; Words = participants searched for the word “brainwave” in one article page; Letter Cancellation = participants searched for all the “e” letters in a mix of other letters.

Eight ANOVAs were conducted to determine if NF influences eye-tracking variables individually by task. As shown in table 5, no significant statistical differences were obtained for any variable at the p<.05 level. However, Tukey’s b post-hoc statistics indicated that the Left Hemisphere group scored lower than the Sham group total fixation duration and fixation count on the Waldo task (p < .05). However, it is important to note
that these ANOVA results should be interpreted with caution given a possible increase of Type I error. Given the number of analyses conducted, Bonferroni correction to alpha needed to be conducted for proper interpretation of the results. If Bonferroni corrections are applied, then the critical value score equals $p = .006$, in which case, the results are not statistically significant.

Table 5. Group Analysis for eye-tracking variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Conditions</th>
<th>Left (N=29)</th>
<th>Right (N=31)</th>
<th>Sham (N=39)</th>
<th>$F$</th>
<th>$p$</th>
<th>Cohen's $d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deer</td>
<td>total fixation duration</td>
<td>26.28 (7.69)</td>
<td>28.18 (10.37)</td>
<td>29.17 (9.01)</td>
<td>.85</td>
<td>.432</td>
<td>-0.34 -0.10</td>
</tr>
<tr>
<td></td>
<td>fixation count</td>
<td>109.10 (26.90)</td>
<td>111.62 (32.47)</td>
<td>112.33 (28.62)</td>
<td>.10</td>
<td>.900</td>
<td>-0.12 -0.02</td>
</tr>
<tr>
<td>Waldo</td>
<td>total fixation duration</td>
<td>18.83 (18.99)</td>
<td>31.86 (28.09)</td>
<td>35.89 (25.06)</td>
<td>4.22</td>
<td>.018</td>
<td>-0.75 -0.15</td>
</tr>
<tr>
<td></td>
<td>fixation count</td>
<td>92.69 (94.02)</td>
<td>137.81 (109.26)</td>
<td>158.41 (98.66)</td>
<td>3.59</td>
<td>.031</td>
<td>-0.68 -0.20</td>
</tr>
<tr>
<td>Words</td>
<td>total fixation duration</td>
<td>43.37 (20.23)</td>
<td>49.72 (22.82)</td>
<td>54.89 (21.96)</td>
<td>2.34</td>
<td>.102</td>
<td>-0.54 -0.23</td>
</tr>
<tr>
<td></td>
<td>fixation count</td>
<td>240.17 (91.67)</td>
<td>253.60 (93.96)</td>
<td>279.97 (84.06)</td>
<td>1.76</td>
<td>.177</td>
<td>-0.49 -0.45</td>
</tr>
<tr>
<td>Letter Cancellation</td>
<td>total fixation duration</td>
<td>14.61 (7.02)</td>
<td>15.57 (8.03)</td>
<td>17.45 (6.27)</td>
<td>1.43</td>
<td>.244</td>
<td>-0.43 -0.26</td>
</tr>
<tr>
<td></td>
<td>fixation count</td>
<td>72.45 (26.72)</td>
<td>74.68 (30.03)</td>
<td>81.23 (21.45)</td>
<td>1.08</td>
<td>.344</td>
<td>-0.37 -0.26</td>
</tr>
</tbody>
</table>

*Note: TFD = Total Fixation Duration outside of targets; FC = Fixation Count outside of targets; Deer = participants searched for 7 deer hidden in a painting; Waldo = participants searched for Waldo in a Where’s Waldo task; Words = participants searched for the word “brainwave” in one article page; Letter Cancellation = participants searched for all the “e” letters in a mix of other letters. Cohen’s $d$ represents the left and right hemisphere protocol trainings compare to the sham condition. ab row means with the same letter are not significantly different at alpha $< .05$; when no letters are present, there was no significant group main effect using Tukey’s b post-hoc analysis.
CHAPTER V

Discussion

The current study sought to determine the effects of one session of NF training on eye-tracking measures using visual search tasks. The study tested two hypotheses; 1) one session of NF training at right hemisphere brain areas will decrease eye-tracking distractibility while scanning non-verbal tasks; and 2) one session NF training at left hemisphere brain locations will reduce eye-tracking distractibility while scanning language-related tasks. Distractibility, in this study, was operationally defined as the number and durations of eye-fixations in non-target stimuli. Results did not support the hypotheses. Specifically, results indicated that one session of right hemisphere training did not significantly decrease distractibility in the visual tracking tasks. The left hemisphere training group had lower fixation durations while searching for words in a text compared to the Sham group. However, this result was not statistically significant given the multiple comparisons done in the study. Similarly, compared to the Sham group, the Left Hemisphere training condition demonstrated lower number and duration of fixations on a task that required finding a cartoon-like figure among several figures group. Yet, these results were also not statistically significant when correcting for possible increases in Type 1 error. Overall, the results did not provide sufficient statistical evidence to demonstrate the idea that NF training modulates verbal or visual attention.
Effect Size and Implications

Although the results of this study are not statistically significant, there are trends in the data that can lead to speculation about possible effects. If trends are a true representation of effects, rewarding Beta and stopping Theta frequencies in frontal and central locations of the left-hemisphere may help decrease the time a person spends on non-target features when searching for words in a paragraph. Moreover, this type of training may reduce distractibility by the non-target when finding a cartoon-based figure. Thus, NF could possibly help brain focus when tasks have a great deal of distraction. To support this hypothetical conclusion, this study showed that NF training has medium effect sizes on distractibility. These effect sizes are comparable to other NF studies with treatments commonly used for attention-related problems such as cognitive-behavioral therapies and chemical or electrical brain stimulants (Faraone, Biederman, Spencer, & Aleardi, 2006). Effect sizes for Cognitive Behavioral Therapy (CBT) range from small to large depending on the task required. Specifically, Virta et al. (2008) found a small effect size (d=0.38) for CBT-Oriented Rehabilitation, while Stevenson et al. (2002) found a large effect size (d=1.57) for a Cognitive Remediation Program. However, the largest effect size (d=1.97) was found when CBT was used in conjunction to medications (Safren et al., 2005). The effect sizes found in the present study are on the low end of the effect spectrum when compared to different therapy techniques (e.g., medications or CBT). Therefore, it may be important to continue to study the therapeutic effects of NF on attention related problems.
Claims about NF effects on distractibility cannot be made until one provides enough evidence to confidently reject the Null hypothesis. To provide such evidence, there are some important aspects that future studies need to take into consideration. First, the current study trained participants for one 30-minute session. Therefore, it is possible that multiple and longer sessions may increase the effects obtained in this study. Previous studies have supported this idea. Vernon (2005) conducted a review of various research articles studying the effects on NF on different performance-based fields such as sports, dance, and cognition. Vernon provided the number of sessions of each study that was analyzed. Studies with 8 or fewer sessions show to have little to no effects on performance. Whereas studies with 10 or more sessions show moderate to significant effects on performance. However, it is important to consider that the studies analyzed investigated ADHD as a whole and failed to study the components of attention that can decrease attentional performance in those with ADHD.

In a meta-analysis by Arns, de Ridder, Strehl, Breteler, and Coenen (2009), fifteen articles were included for analysis to find the efficacy of NF in the treatment of ADHD. The analysis consisted of ten prospective controlled studies, four prospective pre-/post design studies, and one retrospective pre-/post design study. Number of sessions ranged from 17 to 50. Effect sizes for hyperactivity, impulsivity, and inattention were calculated for the two different types of studies, one for the controlled between-subject design studies and another for within subject studies with active or semi-active control groups. Overall, effect sizes for neurofeedback on impulsivity and inattention
were large and a medium effect size for hyperactivity was found. Arns et al. (2009) conclude that the studies in the meta-analysis show NF to be an effective tool at treating impulsivity and inattention. More research is needed for its effects on hyperactivity since a medium effect was found. Moreover, although effects of medication on ADHD symptomology are significantly stronger, the adverse effects of medication are much more severe than those of NF. When considering long-term effects, NF may be more potent in showing lasting effects after the discontinuation of training, when the effects of medication only last as long as an individual is taking the medication.

The current study used one session of NF to reduce eye-distractibility in young healthy individuals. The objective of this research was to appraise NF as a cognitive enhancer for neuro-typical individuals, with the view to describe potential applications to ADHD treatment. However, one cannot take for granted that the protocols that have been found effective for individuals with ADHD (Drechsler et al., 2007; Gevensleben et al., 2009; Leins et al., 2007) are applicable to healthy young individuals. In specific, NF can be strongly dependent on the system state. Thus, application of the protocols that have been developed for ADHD patients might not induce the same response in healthy brains (Egner & Gruzelier, 2001; Nitsche & Paulus, 2000).

Furthermore, the current study tried to capture physiological differences in a subcomponent of attention (i.e., distraction while completing visual search tasks). Attention is a complex construct that can be divided into at least several distinct subcomponents, each of which have specific, and at the same time interconnected, neural
correlates along the frontoparietal networks (Cohen et al., 2006). The visual search tasks used in this study are not common or standardized neuropsychological measures, and as such it will be difficult to decipher if these tasks required single or multiple attention subcomponents. There has been evidence to support the Where’s Waldo task as a possible new tool in assessing visual search patterns and having practical use. Where’s Waldo tasks have been used in research for over two decades and have shown promising results as an applicable task for the measurement of visual search (Ennesser and Medioni, 1995). Specifically, Where’s Waldo tasks have familiar features (i.e., human face and body) that make it more applicable to visual search in the real world. For instance, Brown et al. (2014) used computer algorithms on a Where’s Waldo task to learn about computer user behavior. Specifically, algorithms on Where’s Waldo were used to predict each users’ speed and accuracy at which they completed the visual search task, and indicated 62% - 83% accuracy in predicting speed of task completion.

In conclusion, the present study extends the NF research by providing data on the effects of NF on subcomponents of attention (i.e., visual search). As previously described, most research has primarily focused on broad attentional deficits and has failed to break down attention and study NF’s effects on individual attentional processes. Furthermore, research in the field is only just starting to identify the necessary number of sessions needed to show effects on cognitive performance. Although no significant results were found, this study highlights the importance of understanding NF’s effects
and may aid in the development of better training protocols to increase performance in specific areas of attention.
References


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Appendix A

Visual Search Tasks

The following images are the images used for the visual search tasks. Participants had a set amount of time to find the hidden content. Mouse clicks were indicative of finding the hidden content.

Task 1: Deer Search

In this task, participants were asked to find the seven deer hidden in this image. Participants were given 3 minutes to find as many deer as possible. Mouse clicks were indicative of finding the deer in the image.
Task 2: Letter Cancelation

In this task, participants were asked to find the 10 “e” letters hidden in this image. Participants had 30 seconds to find as many “e” letters as they could. Mouse clicks were indicative of finding the “e” in the image.
Task 3: Horse Search

In this task, participants were asked to find the nine horses hidden in this image. Participants had 3 minutes to find as many horses as possible. Mouse clicks were indicative of finding the horses in the image.
Task 4: Article Word Search

In this task, participants were asked to find the 21 instances of the word “brainwave” in this image. Participants had 3 minutes to find as many “brainwave” words as they can. Mouse clicks were indicative of finding the words in the image.
Task 5: Where’s Waldo

In this task, participants were asked to find where Waldo is hidden in this image. Participants had 1 minute to find Waldo. Mouse clicks were indicative of finding Waldo in the image.
Appendix B

Visual Search Tasks with AOIs
INTRODUCTION

In the late 1960s and 1970s, researchers discovered that it was possible to recondition, retrain or learn different patterns. Some of this work began with training to increase alpha activity to increase relaxation, while other work originating at UCLA focused on uncontrolled epilepsy. This training led to the development of biofeedback or neurofeedback. Before discussing this in more detail, let me provide you with some preliminary information about the brainwaves which occur at various frequencies. Some are fast and some are quite slow. The classic names of these EEG bands are delta, theta, alpha, and beta. They are measured in cycles per second or hertz (Hz).

Beta (above 13Hz) are small, faster Brainwave 7 associated with a state of mental, intellectual activity and outwardly focused concentration. This is basically a “bright-eyed, bushy-tailed” state of alertness. Alpha Brainwave 9 are large in the back third of the brain (8-12Hz). Alpha Brainwave 9 are associated with a state of relaxation and basic represent the brain shifting into an idling gear, relaxed and a bit disengaged, waiting to respond when needed. If someone merely closes their eyes and begins picturing something peaceful, in less than half a minute there begins to be an increase in alpha Brainwave 9. These Brainwave 9 are especially large in the back third of the brain (8-12Hz). Brainwave 9 are generally described as a daydream-like, rather spaced out state of mind that is associated with mental inefficiency. At very slow levels, theta Brainwave 10 activity is a very relaxed state, representing the twilight zone between waking and sleep. Delta Brainwave 11 (5.5-3.5 Hz) are the slowest, highest amplitude Brainwave 11 and are what we experience when we are asleep. In general, different levels of awareness are associated with dominant Brainwave 11 rates.

Each of us, however, always has some degree of each of these Brainwave 11 and 12 present in different parts of our brain. Delta Brainwave 12 will also occur, for instance, when areas of the brain go “off line” to take up nourishment and delta is also associated with learning disabilities. If someone is becoming drowsy, there are more delta and slow theta Brainwave 12 creeping in and if they are somewhat indifferent to external things and their mind is wandering, there is more theta present. If someone is exceptionally anxious and tense, an excessively high frequency of beta Brainwave 13 is often present. Persons with Attention-Deficit/Hyperactivity Disorder (ADD, ADHD), head injuries, stroke, epilepsy, and often chronic fatigue syndrome and fibromyalgia tend to have excessive slow waves (usually theta and sometimes excess alpha) present. When an excessive amount of slow waves are present in the executive (frontal) parts of the brain, it becomes difficult to control attention, behavior, and/or emotions. Such persons generally have problems with concentration, memory, controlling their impulses and moods, or with hyperactivity. They can’t focus very well and exhibit diminished intellectual efficiency.

WHAT IS NEUROFEEDBACK TRAINING?

Neurofeedback training is biofeedback. During typical training, a couple of electrodes are placed on the scalp and one or two are usually put on the earlobes. Then, high-tech electronic equipment provides real-time, instantaneous audio and visual feedback about your Brainwave 22 activity. The electrodes measure the electrical patterns coming from the brain—much like a physician listens to your heart from the surface of your skin. No electrical current is put into your brain. Your brain’s electrical activity is relayed to the computer and recorded.

Ordinarily, a person cannot reliably influence their Brainwave 22 patterns because they lack awareness of them. However, when you can see your Brainwave 22 on a computer screen a few thousandths of a second after they occur, it gives you the ability to influence and change them. The mechanism of action is operant conditioning. We are literally reconditioning and retraining the brain. At first, the changes are short-lived, but the changes gradually become more enduring. With continuing feedback, coaching, and practice, healthier Brainwave patterns can usually be retrained in most people. It is a little like exercising or doing physical therapy with the brain, enhancing cognitive flexibility and control. Thus, whether the prob-
Appendix C

Adult ADHD Self-Report Scale (ASRS-v1.1) Symptom Checklist

<table>
<thead>
<tr>
<th>Patient Name</th>
<th>Today's Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please answer the questions below, rating yourself on each of the criteria shown using the scale on the right side of the page. As you answer each question, place an X in the box that best describes how you have felt and conducted yourself over the past 6 months. Please give this completed checklist to your healthcare professional to discuss during today's appointment.

1. How often do you have trouble wrapping up the final details of a project, once the challenging parts have been done?  

2. How often do you have difficulty getting things in order when you have to do a task that requires organization?  

3. How often do you have problems remembering appointments or obligations?  

4. When you have a task that requires a lot of thought, how often do you avoid or delay getting started?  

5. How often do you fidget or squirm with your hands or feet when you have to sit down for a long time?  

6. How often do you feel overly active and compelled to do things, like you were driven by a motor?  

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Part A

7. How often do you make careless mistakes when you have to work on a boring or difficult project?  

8. How often do you have difficulty keeping your attention when you are doing boring or repetitive work?  

9. How often do you have difficulty concentrating on what people say to you, even when they are speaking to you directly?  

10. How often do you misplace or have difficulty finding things at home or at work?  

11. How often are you distracted by activity or noise around you?  

12. How often do you leave your seat in meetings or other situations in which you are expected to remain seated?  

13. How often do you feel restless or fidgety?  

14. How often do you have difficulty unwinding and relaxing when you have time to yourself?  

15. How often do you find yourself talking too much when you are in social situations?  

16. When you're in a conversation, how often do you find yourself finishing the sentences of the people you are talking to, before they can finish them themselves?  

17. How often do you have difficulty waiting your turn in situations when turn taking is required?  

18. How often do you interrupt others when they are busy?  

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Part B
After graduating from High School at Diamond Ranch Academy in 2010, Rebecca completed her Bachelors of Arts in Psychology with a minor in Spanish at Stephen F. Austin State University in 2014. During her time as an undergraduate, she volunteered as a Research Assistant at the Applied Biopsychology Laboratory conducting neuropsychological research. She was accepted into the School Psychology Master’s and Doctoral program in the Fall of 2014. Rebecca worked as a Graduate Assistant for Dr. Luis Aguerrevere and a Research Assistant for the Human Neuroscience Laboratory where she continued to aid in the development and completion of neuropsychological research. Furthermore, during her years as a Graduate Assistant, Rebecca completed psychoeducational evaluations at the School Psychology Assessment Center. Currently, Rebecca is studying at Stephen F. Austin State University where she seeks a Masters of Arts and a Doctorate in School Psychology.

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