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RIVERSIDE

# Neurofeedback as an Intervention to Improve Reading Achievement in Students With Attention Deficit Hyperactivity Disorder, Inattentive Subtype

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Jeffry Peter La Marca

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Dissertation Committee:

Dr. Rollanda E. O'Connor, Chairperson
Dr. H. Lee Swanson
Dr. Kelly J. Huffman

The Dissertation of Jeffry Peter La Marca is approved:

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_____

Committee Chairperson

University of California, Riverside

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## Dedication

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ABSTRACT OF THE DISSERTATION

Neurofeedback as an Intervention to Improve Reading Achievement in Students With Attention Deficit Hyperactivity Disorder, Inattentive Subtype

by

Jeffry Peter La Marca

Doctor of Philosophy, Graduate School of Education
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Rollanda E. O'Connor, Ph.D. Chairperson

Attention deficit disorders are among the most prevalent and widely studied of all psychiatric disorders. The National Center for Health Statistics reports that 9.0% of children (12.3% of boys and 5.5% of girls) between ages 5 to 17 have been diagnosed with ADHD. Research consistently demonstrates that attention deficits have a deleterious effect on academic achievement with symptoms often appearing in early childhood and persisting throughout life. Impairments in attention, and not hyperactivity/impulsivity, are associated with learning difficulties and academic problems. To date, most studies have focused on addressing symptoms of hyperactivity/impulsivity with relatively little research being conducted on efficacious interventions to address the needs of students with ADHD, inattentive subtype. A growing body of literature now supports EEG operant conditioning (neurofeedback) as an evidence-based practice for improving attention. This study is the first to examine the use of neurofeedback as an intervention to improve reading achievement in a public school setting. A multiple-baseline-across-participants single-case model was used to assess five fourth grade students who received

40 daily sessions of neurofeedback. Following the intervention, quantitative electroenchalographic (qEEG) assessments revealed positive changes in most participants' EEGs. Improvements were observed on measures of attention; on the IVA+Plus, a continuous performance test, and/or on the CNS-VS Shifting Attention Test. While results on tests of reading fluency, the Dynamic Indicators of Basic Early Literacy Skills (DIBELS) test of Oral Reading Fluency (ORF), and the Gray Oral Reading Tests - Fifth Edition (GORT-5), revealed little change, all participants expressed gains on the GORT-5 measure of reading comprehension. These results suggest that neurofeedback may have helped participants to become more accurately engaged with the text (thus reading speed was not increased) and yet they read with more focused attention to content. Furthermore, four of the five participants continued to express gains and one participant maintained observed growth on the GORT-5 during follow-up (conducted approximately five and a half months subsequent to posttest assessments). Similarly, four of the five participants also expressed gains, and one maintained previous performance on the IVA+Plus. These findings indicate that neurofeedback may be a viable option to assist children with attention deficits as an intervention strategy for improving both attention and reading achievement.

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## Chapter 1: Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is considered to be among the most widely studied and treated of all psychiatric disorders (American Academy of Pediatrics, 2011a; Goldman, Genel, Bezman, & Slanetz, 1998; Hart, Lahey, Loeber, Applegate, & Frick, 1995; Volkow et al., 2011). It is a heterogeneous condition characterized by the presence of a variety of symptoms, the most salient of which include problems with inattention, executive function, impulsivity, memory, and hyperactivity (American Psychiatric Association, 1994). The current definition recognizes a single disorder that consists of three subtypes: the predominately hyperactive-impulsive subtype, the predominantly inattentive subtype, and the combined subtype where individuals meet criteria for both hyperactivity/impulsivity and inattention (American Psychiatric Association, 2000).

Despite widespread agreement within the scientific community that ADHD is a real medical condition (e.g., arguments have regularly appeared in the popular press that the disorder does not exist or is, at best, trivial), that it is not a benign condition, and that it has a significant adverse impact on the lives of those with the associated impairments (Barkley, 2002), consensus has yet to be reached on the nosology of the subtypes. Disagreements between researchers occur primarily around whether the subtypes are part of a unidimensional disorder or are, instead, distinct disorders (American Psychiatric Association, 2010; Frick & Nigg, 2012). An examination of the literature reveals that the combined subtype heavily predominates as the focus of study (Dige, Maahr, &

Backenroth-Ohsako, 2008; Gaub & Carlson, 1997; Nigg, 2005), with sparse research focusing solely the on hyperactive/impulsive subtype in isolation from symptoms of inattention. Likewise, the predominately inattentive subtype (i.e., attention deficit hyperactivity disorder without hyperactivity [ADD]) received little attention until the early 1990s when it was recognized by the American Psychiatric Association (1994). Since then, a small but growing body of research is leading many researchers to suggest that ADHD, inattentive subtype is a distinct disorder (Adams, Derefinko, Milich, & Fillmore, 2008; Barkley, 2001; Carlson & Mann, 2002; Carr, Henderson, & Nigg, 2010; Diamond, 2005; Milich, Balentine, & Lynam, 2001).

Although the construct of ADHD has been developed through a medical model, the impact that attention deficits have on students and the challenges they present to learning, have been inexorably tied together since the first clinical observations on the topic (American Academy of Pediatrics, 2011a; Barkley, 2009b; Crichton, 1798; Palmer & Finger, 2001; Still, 1902a, 1902b, 1902c). The saliency of the interdisciplinary relationship between medical and educational frameworks cannot be ignored. It is, therefore, not surprising that each discipline is concerned with the need to examine how attention deficits impact instruction and identify efficacious interventions, especially those that address deficiencies within an academic milieu.

**Etiology of a Brain-based Disorder and its Impact on Education**

Current scholarship credits Alexander Crichton, a Scottish physician, as the first to describe attention deficits more than 200 years ago in his book, *An Inquiry Into the Nature and Origin of Mental Derangement* (Barkley, 2009b; Crichton, 1798; Palmer &

Finger, 2001). Crichton's chapter "On Attention and its Diseases" discusses distractibility and acknowledges the difficulties that some students experience while focusing on tasks in school. It is notable that Crichton does not associate inattention with hyperactivity but provides an accurate description of a disorder that meets current criteria for the inattentive subtype (Lange, Reichl, Lange, Tucha, & Tucha, 2010; Palmer & Finger, 2001). In fact, he never acknowledges any of the disruptive behaviors now associated with hyperactivity (Palmer & Finger, 2001). His discussion focuses on distractibility and notes that many individuals with attention deficits describe their frustration by stating "they have the fidgets." Crichton's use of the term "fidgets," however, pertains to what he calls "mental restlessness" and does not refer the need to physically to move about (Crichton, 1798).

Crichton's concern for the role that attention plays in educational attainment is evident throughout; indeed, he begins his discussion with the following:

> Definition of the faculty of attention; [sic] differences between it and the power of attention; what stimuli excite it. The question whether it is under the influence of volition examined. The great readiness with which we attend to some subjects and objects, when compared with others, accounted for; the effects of education on attention (Crichton, 1798, p. 254).

His concern regarding the volitional nature of attention, as well as his recognition of the relationship between cognitive arousal and learning, particularly within an educational environment, are relevant to the modern conceptualization of ADHD.

Crichton's early observations that lack of attention and arousal are involved in underachievement are now confirmed by empirical evidence that indicates brain function is implicated. For example, he writes that students must "have their attention sufficiently

roused" in order to be successful in school. Crichton notes, however, that some children find some topics so uninteresting, even though they are "endowed with excellent natural talents," that they fail. As an example, he states that "the dryness and difficulties of the Latin and Greek grammars are so disgusting that neither the terrors of the rod, nor the indulgence of kind intreaty [sic] can cause them to give their attention to them" (Crichton, 1798, p. 278).

Researchers note differences in performance and achievement among students with attention deficits and typically developing individuals when engaged in boring tasks (Barkley, 1990; Lubar, 2003; Luman, Oosterlaan, & Sergeant, 2005). Invasive brain imagining studies using positron emission tomography (PET) are finding that dysfunctional (depressed) dopamine activity is involved in symptoms of inattention (Volkow et al., 2007). In a subsequent study, Volkow et al. (2011) examined the role of dopamine function and found preliminary evidence that individuals with ADHD may have a "motivation or interest deficit" as part of their core pathology. These researchers indicate that their findings lend support for "the use of interventions to enhance the saliency of school and work tasks to improve motivation and performance" (2011, p. 1151) and recommend the use of intrinsically motivating instructional materials as appropriate accommodations – essentially the same recommendations suggested by Crichton more than two hundred years ago.

It would be nearly fifty years after publication of Crichton's book before any mention of attention deficits appeared in the literature again. In 1845, German psychiatrist Heinrich Hoffman wrote a children's book for his 3-year-old son, Carl

Philipp, due to a lack of other suitable reading materials at the time. The book, *Der Struwwelpeter* (Shaggy-Peter), contains ten short stories including that of *Zappelphilipp* ("Fidgety Phillip"), an impulsive, hyperactive child (G. Weiss & Hechtman, 1979). The story is believed to be the first description of the hyperactive subtype of ADHD by a medical professional (Thome & Jacobs, 2004). Many in Germany still use the term *Zappelphilipp-syndrom* to describe ADHD.

It wasn't until 1902, when George Still presented a series of three lectures to the Royal College of Physicians in London, that the behavioral issues now associated with the ADHD were first discussed from a clinical perspective (Still, 1902a, 1902b, 1902c). His ideas were based on observations of 43 children from his medical practice. Although many of Still's ideas are now considered antiquated (e.g., he described these children as exhibiting deficits in "moral control of behavior"), he recognized that their aggressive, defiant, and disruptive conduct was not volitional. He noted that these appeared to be chronic difficulties that were resistant to attempts to correct them.

Following an encephalitis epidemic in 1917-1918, many children who had been infected and survived the infection manifested symptoms that are now commonly associated with ADHD. These included impaired attention, impulsivity, and socially disruptive behaviors. Cognitive impairments, particularly those related to memory, were also observed (Barkley, 2006). "Postencephalitic behavior disorder," however, was not ADHD *per se* but the result of brain damage caused by disease. The large number of children affected sparked interest in this behavioral disorder (Barkley, 2006).

Asher T. Childers, an American physician, is credited with publishing the first study of children in which participants were selected solely on the basis that they exhibited excessive levels of hyperactivity (Barkley, 2009a). He noted that the literature from the 1920s, including much that had been written on postencephalitic behavior disorder, provided examples of children who were hyperactive or restless and yet did not have medical histories to suggest that disease or brain damage were implicated. His article, *Hyper-activity in Children Having Behavior Disorders* (Childers, 1935) reported on a sample that contained more than 100 children from his clinical practice (n=30), residents of the Child Guidance Home of the Cincinnati Jewish Hospital (n=57), students who had formerly been seen by his clinic and had recently returned after an absence of several years due to "delinquency" (n=10), and a group of hyperactive children who had spent several years at another institution – the Glenview Farm School of Cincinnati (n=10). These participants were selected on the basis that their disruptive behaviors had been documented by others, observed across a variety of settings (e.g., school, home), and also examined in a clinical environment.

After a thorough review of their social histories, psychometric tests, physical examination records, and reports from psychiatric interviews, Childers reported that "overactive children usually do badly in a schoolroom setting" (Childers, 1935, p. 242) and made recommendations for accommodations for these students. Specifically, he suggested that teachers seek out engaging instructional activities that permitted students "greater freedom" in class, as well as assignments to classes taught by empathetic teachers. Half-day school schedules for younger children, particularly if these permitted

hyperactive students to take naps and rest periods while at home, were also recommended.

Strauss, Lehtinën, and Kephart (1947) described children who were hyperactive, highly distractible, and had poor organizational skills in their book, *Psychopathology and Education of the Brain-Injured Child.* They introduced the concept that "minimal brain damage" was responsible for these behaviors. Subsequently, "Strauss' Syndrome" was used to describe children who exhibited these behaviors (Baum, Olenchak, & Owen, 1998). Although brain function is now widely accepted as being responsible for symptoms of ADHD, and individuals with brain damage can exhibit behavioral characteristics associated with the disorder, cerebral insult is no longer considered as the causal factor. Other considerations, particularly genetics, are too strongly implicated.

During the 1960s and 1970s, hyperactivity had fully emerged as representing the most prominent symptom of the disorder and continued to be ascribed to brain impairment (Loney, Langhorne, & Paternite, 1978; Ross & Ross, 1976). Many continued to suggest that children had "minimal brain dysfunction" until the early 1980s, despite the lack of evidence that most had no history of disease or insult to the brain (Rie & Rie, 1980; G. Weiss & Hechtman, 1979). During this time, the role of genetics was gaining acceptance as a possible cause for the disruptive behaviors that were so evident in hyperactive children (Cantwell, 1975).

The American Psychiatric Association (APA) first recognized "Hyper-kinetic Reaction of Childhood" as a disorder in the second edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-II; APA, 1968). The DSM-II described

this condition with a single sentence: “The disorder is characterized by over activity, restlessness, distractibility, and short attention span, especially in young children; the behavior usually diminishes by adolescence.” The belief that these deficits were limited to childhood and outgrown by adolescence persisted through the 1980s (Barkley, 2006).

With the publication of the DSM-III (APA, 1980), the term Attention Deficit Disorder (ADD) was introduced, with the recognition that inattention and impulsivity, along with hyperactivity, were the primary symptoms. Inattention was, for the first time, considered as the core deficit in some children. The DSM-III again described ADD as a disorder of childhood and also required that diagnostic criteria could only be met if onset of symptoms occurred prior to the age of seven. All subsequent editions of the DSM (APA, 1987, 1994, 2000) have continued to use this criterion.

**Prevalence**

Many researchers believe that the current diagnostic criteria, as described by the DSM, Fourth Edition Text Revision (DSM-IV-TR; APA, 2000) do not adequately address symptoms of inattention without manifestations of hyperactivity, which is one of the most frequently used diagnoses in large samples (APA, 2010; Frick & Nigg, 2012). Large scale studies that have examined the prevalence of children with ADHD have consistently found that the majority of children with the disorder meet criteria for the inattentive subtype. One such study examined teacher-reported prevalence rates in a non-referred population that included every child in Kindergarten through fifth grade from a county in Tennessee (n=8,258). Using DSM-IV criteria, the study found an overall prevalence rate of 11.4% (Wolraich, Hannah, Pinnock, Baumgaertel, & Brown, 1996).

When examined by subtype, 5.4% of the sample met criteria for the inattentive subtype, 3.6% met criteria for the combined subtype, and 2.4% met criteria for the hyperactive/impulsive subtype.

The National Center for Health Statistics reported that 9.0% of children (12.3% of boys and 5.5% of girls) between ages 5 to 17 have been diagnosed with ADHD (Akinbami, Liu, Pastor, & Reuben, 2011). Another study on prevalence in the United States used a large nationally representative sample (n=3082) and estimated that an overall rate of 8.7 percent of children between the ages of 8 and 15 met DSM-IV-TR criteria for the disorder (Froehlich et al., 2007). In addition, the study examined prevalence by subtype and found that the majority of ADHD children meet criteria for the inattentive subtype (51%), followed by the combined subtype (26%), and then the hyperactive/impulsive subtype (23%).

**Age-of-Onset**

ADHD is a life-long condition with symptoms first appearing in early childhood (APA, 2000). All editions of the DSM since the publication of the DSM-III have required the presence of symptoms prior to the age of 7 in order to meet criteria for diagnosis. That criterion, however, was initially established based on clinical impressions and not research. Indeed, Barkley and Biederman (1997) report that the diagnostic criteria for ADD in the DSM-III was apparently authored by a single individual and subsequently reviewed by a small committee, and yet no rationale for these decisions were ever published. Although the age-of-onset of 7 has since been criticized for being arbitrarily

defined and lacking empirical support, it has also become the *de facto* standard (APA, 2010; Polanczyk et al., 2010).

Most children diagnosed with ADHD in preschool, kindergarten, or first grade continue to exhibit symptoms and impairments as they mature (Lahey et al., 2004). There are some problems, however, with the stability of the three subtypes (hyperactive-impulsive, inattentive, and combined) over time (Willcutt et al., in press). Children with disruptive behaviors are frequently identified in preschool, while identification of individuals with the inattentive subtype often occurs later (Kieling et al., 2010).

In one longitudinal study (Lahey, Pelham, Loney, Lee, & Willcutt, 2005), children identified with ADHD during preschool and first grade (ages 4 to 6) were assessed seven times over an eight year period to determine if DSM-IV subtypes remained stable (and, therefore, valid). The study found that the baseline diagnosis of the hyperactive-impulsive subtype was unstable over time with many children either no longer meeting criteria for that subtype as they matured, or later meeting criteria for the combined subtype. The researchers suggested that some of the children initially diagnosed with the hyperactive subtype eventually "outgrow" the disorder or that symptoms converged with the combined subtype. In addition, they reported that diagnoses of the inattentive or combined subtyped remain more stable than the hyperactive/impulsive subtype.

Another large multisite study (Applegate et al., 1997) of children ages 4 to 17 (n= 380, mean = 8.7 years) examined the validity of the age-of-onset criterion for the DSM-IV and revealed that there were statistically significant differences between children with

ADHD that were reflective of their diagnostic subtype. The study examined both the age-of-onset of the first symptom and the age at which impairment was first observed. They noted that onset of symptoms prior to the DSM-IV criterion of age 7 (i.e., symptoms were considered present based on ratings from either a parent or a teacher on the Diagnostic Interview Schedule for Children) were reported in 96% of children with the hyperactive/impulsive subtype, 100% of children with the combined subtype, and 85% of children with the inattentive subtype. The emergence of first impairment prior to the age of 7 was 82% of children with the hyperactive/impulsive subtype, 98% of children with the combined subtype, and 57% of children with inattentive subtype. The study operationally defined impairment by examining parent responses to the Children's Global Assessment Scale and two academic rating scales: the Homework Problem Checklist (completed by parents) and the Academic Performance Rating Scale (completed by teachers).

Applegate et al. (1997) also found that differences between the age-of-onset for impairment among the three subtypes were statistically significant; the hyperactive/impulsive subtype had a mean of 4.21 years, the combined subtype 4.88 years, and the inattentive subtype 6.13 years. They noted that for many children, impairments caused by ADHD are not evident until they enter school, especially for children with the inattentive subtype, who do not exhibit high levels of hyperactivity/impulsivity and may not be identified until symptoms of inattention collide with academic demands. Furthermore, the study reported that nearly all children in their sample with either hyperactive/impulsive or combined subtypes exhibited impairment

(82% and 65%, respectively) by age 7, although 43% of children with the inattentive subtype did not.

Consistent with the study by Applegate et al. (1997), other researchers have obtained similar results and expressed concerns that the current age-of-onset lacks utility for identifying individuals with the inattentive subtype. One study examined early versus late onset of ADHD and provided evidence that the DSM-IV age-of-onset criterion was appropriate for children with the hyperactive/impulsive and combined subtypes but also confirmed that it under-identified children with the inattentive subtype (Willoughby, Curran, Costello, & Angold, 2000). In studies of adults who were not diagnosed as children but later met criteria, research has revealed that many of these individuals did not meet the criterion by age 7 but did by age 12 (Faraone, Biederman, Doyle, et al., 2006; Faraone, Biederman, & Mick, 2006; McGough & Barkley, 2004; Polanczyk et al., 2010). Todd, Huang, and Henderson (2008) reported that for children who met all DSM-IV criteria at age 7 (except for the age-of-onset criterion), 10 percent reported an age-of-onset between 7 and 16 years. Polanczyk et al. (2010) conducted a study of 2,232 British children and found that increasing the age-of-onset to age 12 would only increase the prevalence of ADHD by 0.1 percent.

In response to the problem of false negatives associated with the inattentive subtype, research is now lending support to increase the age-of-onset to < 12 years in the DSM-5 (Applegate et al., 1997; Barkley & Biederman, 1997; Frick & Nigg, 2012; Todd et al., 2008). Recent studies indicate raising the age-of-onset will serve to constrain false negative diagnoses (individuals who currently do not meet the age criterion) without

increasing false positive ones (Kieling et al., 2010; Polanczyk et al., 2010). The implication for research, therefore, is that the DSM-IV criterion for age should not be used to identify participants who otherwise meet criteria for the inattentive subtype; current scholarship suggests that age 12 is a more appropriate cutoff.

In summary, children with symptoms of hyperactivity/impulsivity are usually diagnosed in preschool or during early elementary school grades. Individuals with the inattentive subtype, however, are often not diagnosed until middle school or high school when problems arise with maintaining focus, completing homework, or remembering material they have read. Indeed, many individuals with the inattentive subtype are not identified until adulthood, despite the presence of symptoms that may have previously been attributable to laziness or lack of motivation (National Resource Center on ADHD, 2004).

## Chapter 2: Literature Review

### Attention and Reading Achievement

Researchers have long noted the high rates of comorbidity between ADHD and other conditions that can interfere with learning and academic achievement. Silver (1981) conducted a study where three groups of children were followed over a period of nearly three years: (1) the first group consisted of students with learning disabilities (n=110) identified by public schools, and while none of these children were considered emotionally disturbed (ED), some exhibited symptoms of distractibility or hyperactivity but were described as "primarily learning disabled"; (2) a second group (n=95) was referred by pediatricians and had a diagnosis of hyperactivity or distractibility (based on DSM-III criteria); and (3) a third group of children (n=100) referred by a hospital, were emotionally disturbed but did not present symptoms of distractibility or hyperactivity. Results indicated that between 26 and 41 percent of the children with learning disabilities were hyperactive or distractible and that 92 percent of the hyperactive group had learning disabilities. On the other hand, of children in the ED group 12% exhibited symptoms of hyperactivity, 3% were distractible, and 8% presented with symptoms of both distractibility and hyperactivity.

High rates of comorbidity with other disorders, particularly Oppositional Defiant Disorder (ODD) and Conduct Disorder (CD), are frequently reported in children with ADHD. In a study of 79 clinic-referred preschool children from low-income households, ages 2 ½ to 5 ½ years, who exhibited problems with aggression, temper tantrums, noncompliance, or out-of-control behavior, more than 80 percent of the children with a

diagnosis of ADHD also met criteria for comorbid CD and/or ODD. The mean age-of-onset for children diagnosed with ADHD in this study was 26.1 months (K. Keenan & Wakschlag, 2000).

Studies on the prevalence of reading disabilities (RD) among children with ADHD have suggested rates of comorbidity between 16 and 39 percent (August & Garfinkel, 1990; Dykman & Ackerman, 1991; Stefanatos & Baron, 2007; Willcutt & Pennington, 2000). In one study of clinic-referred children with ADHD, August and Garfinkel (1990) found that 39 percent had comorbid RD. A previous study of non-referred school children by the same authors used a sample of 50 ADHD students who were identified in a school setting by teacher ratings on the Conners' Teacher Ratings Scale – Revised (August & Garfinkel, 1989). Participants were then matched with non-ADHD children by gender and grade level from the same school. Findings revealed that 22 percent of these children who met criteria for the ADHD also had RD. In comparison, only 8 percent of the children in the control group met criteria for RD.

Concerned with the relatively limited number of studies that specifically address ADHD and reading comprehension, Ghelani, Sidhu, Jain, and Tannock (2004) examined the reading rate and comprehension of 96 adolescents, ages 14 to 17. Study participants were selected from referrals by mental health facilities and a local learning disabilities association; placement eligibility was based on the results of a variety of measures, including Connors' Parent and Teacher Rating Scales, Woodcock Reading Mastery Test-Revised (Woodcock, 1998), the Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999), and other tests. Volunteers were recruited for a control group from an

advertisement placed in a hospital newsletter: controls were adolescents who did not have ADHD or RD. All participants were then assigned to four groups: ADHD (n=32), RD (n=20), ADHD and RD (ADHD/RD; n=19), and the control group (n=25). Study participants were then administered a variety of reading tests. Analysis revealed that all experimental groups scored lower on silent reading passages than the control group. Both the RD and ADHD/RD groups scored significantly lower on tests of reading rate and accuracy. The performance of the comorbid ADHD/RD group on tests of reading accuracy and rate was similar to that of the RD group. On reading comprehension tasks, the ADHD/RD group did poorly with silent reading but not with oral reading. These results are similar to another study (Schuck, 2008) that also found that ADHD children faced difficulties when reading silently, but not orally.

**ADHD, inattentive subtype, and RD.** Research has indicated that children with ADHD, inattentive subtype have considerably more problems with processing speed than both typically developing peers and students with other subtypes (Chhabildas, Pennington, & Willcutt, 2001; Ghelani et al., 2004). Other studies have found that individuals with the inattentive subtype process visual information slowly and exhibit impairments in allocating attention to information within their visual field (Barkley, Grodzinsky, & DuPaul, 1992; J. M. Swanson, Posner, Potkin, & Bonforte, 1991). In addition, reading and math disorders, along with other learning disabilities, appear to be more prevalent in individuals with the inattentive subtype than found in those with the

predominately hyperactive-impulsive type (Barkley et al., 1992; Bauermeister, Alegría, Bird, & Rubio-Stipec, 1992; Weiler, Bernstein, Bellinger, & Waber, 2000; Willcutt & Pennington, 2000).

Weiler et al. (2000) examined processing speed in children with ADHD, inattentive subtype. Participants included 82 children between the ages of 7 to 11 who were referred to a pediatric hospital for school-related problems. Only children who met criteria for the inattentive subtype and/or were identified as reading disabled were selected: children with either the hyperactive-impulsive or combined subtypes were excluded. Additional children were excluded during the screening process if their full-scale IQ was less than 80, if they were taking stimulant medications, or presented with behavioral or emotional problems. Study participants were then subdivided into four groups: ADHD, inattentive subtype without RD (ADHD, inattentive subtype/non-RD), ADHD, inattentive subtype with RD (ADHD, inattentive subtype/RD), no ADHD with RD (non-ADHD/RD), and a fourth group that did not have either ADHD or RD. Participants were then administered a large battery of timed tests. The main findings revealed that while all study children performed less than expected on tasks that measured processing speed, children with ADHD, inattentive subtype were significantly slower than the groups without ADHD. Due to the small group size of ADHD, inattentive subtype/RD group (n=9), results were inconclusive when compared to the non-ADHD/non-RD group. In addition, there were statistically significant differences between the ADHD, inattentive subtype/RD and non-ADHD/RD group when compared

on tasks of processing speed, written language, and a test of motor speed: the ADHD, inattentive subtype/RD group did worse on these tasks.

The Colorado Learning Disabilities Research Center twin project, which works in tandem with 27 school districts surrounding the Denver, Colorado area, examined the relationship between ADHD and RD using 867 monozygotic (identical) and dizygotic (fraternal) twins (Willcutt & Pennington, 2000). Children were first divided into two groups: with RD and without and then evaluated to determine if each child met criteria for ADHD by subtype. It was determined that students with RD had higher prevalence of ADHD than non-RD peers. For girls with RD, 24% met DSM-IV criteria for the inattentive subtype versus 4% of girls without RD. However, just 6% of girls with RD met DSM-IV criteria for the hyperactive/impulsive subtype versus 2% of girls without RD. Boys with RD were considerably more likely to meet criteria for both impulsivity and hyperactivity impulsivity than boys without RD: 60% of boys with RD met criteria for the inattentive subtype versus 2% without RD, and 30% of boys with RD met criteria for the hyperactive/impulsive subtype versus 2% of boys without RD.

Willcutt and Pennington (2000) also found that the relationship between ADHD and RD was stronger for students with symptoms of inattention than hyperactivity/impulsivity. An interesting finding concerned the relationship between gender, intelligence, RD, and ADHD: girls with RDs and lower IQs (defined by the study as a full-scale IQ [FSIQ] $\leq 100$) were more likely than girls without RD who had lower IQs to have comorbid ADHD. Girls with high RD and higher IQs (FSIQ >100) showed no statistically significant differences from non-RD girls in meeting criteria for ADHD.

In contrast, boys with RD met criteria for ADHD at statistically significant higher levels, regardless of IQ, although a significantly greater number of low IQ boys meet criteria for the hyperactive or combined subtypes than higher IQ boys. With the exception of higher IQ girls, children with RD met criteria for all subtypes of ADHD at statistically higher levels than non-RD students. Willcutt and Pennington (2000) suggested that their results indicated a genetic relationship between RD and the inattentive subtype. These findings are consistent with other studies that report reading achievement, learning disabilities, and familial history of learning problems are associated with symptoms of inattention but not hyperactivity or impulsivity (Barkley, DuPaul, & McMurray, 1990; Goodyear & Hynd, 1992; Lahey, Pelham, Schaughency, & Atkins, 1988).

Research also indicates that reading achievement is negatively influenced by attention deficits, particularly when associated with the inattentive subtype, although the inverse has not been found (Fergusson & Horwood, 1992). In another study by the Colorado Learning Disabilities Research Center twin project (Willcutt, Pennington, & DeFries, 2000), a set of 313 pairs of twins (183 monozygotic twin pairs and 130 dizygotic pairs ) were selected as participants and evaluated for comorbidity of ADHD and RD. Their results provided additional support for the hypothesis that there is a genetic component in individuals with the inattentive subtype that predisposes them to reading difficulties. Similar to Fergusson and Horwood (1992), they found considerably less support to suggest the same relationship exists between the hyperactive/impulsive subtype and reading achievement.

**Identification**

Public Law 94-142 (PL94-142), the Education for All Handicapped Children Act, was enacted by Congress in 1975. It was later reenacted in 1989 as the Individuals with Disabilities Education Act (IDEA) and was again reauthorized in 2004 as the Individuals with Disabilities Improvement Act (IDEIA). Unlike the Civil Rights Act of 1964 and Section 504 of the Rehabilitation Act of 1973 (Section 504), PL94-142 was not a civil rights law but one of entitlement that "guarantee[s] a free, appropriate public education (FAPE) to each child with a disability in every state and locality across the country" (U.S. Department of Education, 2000). In addition to FAPE, other key provisions of this Act include the right for children to receive an education in the "least restrictive environment" (LRE) and the requirement that they should be educated in settings with typically developing peers to the greatest extent possible. School districts are also obligated to proactively seek out and identify students with disabilities and refer them for services as early as possible; this responsibility is referred to as "child find." A key component of IDEA is that school districts are required to provide an Individualized Education Program (IEP) that identifies each child's special educational needs and then provide appropriate interventions to ensure they receive a FAPE.

The identification of children with ADHD presents educators with some unique considerations in that a formal diagnosis can only be made by qualified medical professionals. While a medical diagnosis of the disorder does not automatically qualify children for special education services under Federal law, it also does not preclude schools from identifying children who do not have a diagnosis of ADHD from the

requirements of child find or release them from their responsibilities to provide a FAPE. After PL94-142 was reenacted as IDEA, it included language that children with ADHD were eligible to receive services under the category of "other health impaired" (OHI). In response to the new regulations, the United States Department of Education (USDE) issued a memorandum to "clarify State and local responsibility under Federal law for addressing the needs of children with ADD in the schools" (Davila, Williams, & MacDonald, 1991) and stated that children were eligible for services when "ADD is a chronic or acute health problem that results in limited alertness, which adversely affects educational performance." In other words, schools are required to examine how the symptoms of ADHD interfere with learning and to develop intervention strategies that address issues pertaining to academic achievement (Burcham & DeMers, 1995).

Although ADHD has long been considered one of the most prevalent mental health disorders of childhood (Akinbami et al., 2011), there remain many challenges surrounding the identification process. While there is broad agreement that attention deficits exist, defining them has been more elusive and there continues to be considerable disagreement as to exactly what diagnostic criteria should be used to make specific diagnoses (American Psychiatric Association, 2010). The DSM-IV-TR requires that symptoms be observed across two or more settings (e.g., school, work, or home) in order to meet criteria for diagnosis (APA, 2000).

Given the lengthy discourse regarding the classification of attention deficits, another problem that arises is the lack of firm biological markers that may be used to diagnose ADHD: these disorders cannot be diagnosed using blood tests, genetic tests, or

other biological measures (Brown et al., 2001; L. B. Silver, 2004). In addition, all clinical criteria are behavioral (Sagvolden, Aase, Johansen, & Russell, 2005), and there are multiple pathways to the phenotypical expression of these disorders (Brown et al., 2001) which, as evidenced by the ongoing discussions regarding revisions being considered for the DSM-5 attest (APA, 2010; Frick & Nigg, 2012), continue to perplex scientists and researchers. The dearth of biological measurements to assess and identify individuals with attention deficits has historically led to reliance on subjective measures, especially rating scales, as the primary means in making diagnoses (Adler & Cohen, 2004; Goyette, Conners, & Ulrich, 1978; Zentall & Barack, 1979). Rating scales are often used in conjunction with anecdotal information provided by parents, teachers, and others.

Although no biological markers to test for attention deficits have yet been identified, behavioral and neurophysiological instruments provide objective measures to support the diagnosis of ADHD (Aman, Roberts Jr, & Pennington, 1998); these commonly include the use of electroenchalography (EEG) and quantitative electroenchalography (qEEG; Doehnert, Brandeis, Straub, Steinhausen, & Drechsler, 2008; Monastra, Lubar, & Linden, 2001). Behavioral instruments, particularly continuous performance tests (CPT) such as the Integrated Visual and Auditory Continuous Performance Test (IVA+Plus; Sandford & Turner, 2007) and the Tests of Variables of Attention (TOVA; Greenberg, 1991) are used frequently as part of the assessment process. When used in conjunction with rating scales and other measures, CPTs can provide useful information (Adler & Cohen, 2004; Madaan et al., 2008).

Neuroscientists also use more elaborate invasive brain imaging techniques such as Photon Emission Tomography (PET) and Single Photon Emission Computed Tomography scans (SPECT; Amen, Hanks, & Prunella, 2008), as well as non-invasive imaging including Magnetic Resonance Imaging (MRI) and functional Magnetic Resonance Imaging (fMRI; Aman et al., 1998). Many of these studies implicate deficits in specific regions of the brain, especially in the frontal lobes (Aman et al., 1998; Hanisch, Radach, Holtkamp, Herpertz-Dahlmann, & Konrad, 2006). Imaging is capable of distinguishing individuals with ADHD from others and these differences are often pronounced (Booth et al., 2005). Researchers are also examining saccadic eye moments (very rapid movements of the eye) and are confirming that differences exist between individuals with attention deficits and others (Hanisch et al., 2006).

**Rating scales.** At present, there are no evaluative instruments that can be used alone to identify children with ADHD. Educators and medical professionals often rely on the same methods to identify children, with rating scales and surveys (completed by parents and teachers) being among of the most common (Demaray, Elting, & Schaefer, 2003). A variety of psychometric and academic assessments, as well as an examination of each child's developmental and educational histories are relevant to those assessing children for ADHD. Although professionals generally agree that rating scales are useful to the evaluative process, they remain subjective measures that when used with objective measures, insert behavioral judgments about the child into identification procedures (Hale et al., 2011).

**Continuous performance tests.** The DSM-IV-TR states that there are no laboratory tests or attentional tests that are, in themselves, diagnostic (APA, 2000). It acknowledges, however, that some tests require sustained mental effort and produce abnormal results in individuals with ADHD when compared to typically developing children, although they cannot be used alone for diagnostic purposes. While not mentioned specifically, potential measures would include continuous performance tests (CPT). These are designed to be intentionally boring and fatiguing, thereby requiring participants to sustain attention. CPTs are primarily used to: (a) assess attention, (b) screen for attention deficits, (c) assist in the diagnosis of attention disorders, (d) predict medication responses for ADHD, (e) titrate medications, and (f) monitor treatment over time (Halperin, Matier, Bedi, Sharma, & Newcorn, 1992; Loew, 2001; Tinius, 2003).

CPTs first appeared during the 1950s when researchers from Yale University discovered that EEG data indicated brain-damaged patients did poorly on tasks requiring sustained attention in comparison to non-brain damaged individuals (Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956). In order to test their hypothesis, Rosvold et al. devised a mechanical device that presented letters in random order; whenever the letter *A* appeared, followed by an *X*, participants were required to press a switch that recorded reaction time as well as documented correct and incorrect responses. Results indicated that brain-damaged individuals differed from control groups on tasks that required attention.

During the 1960s, a double-blind study was conducted to test "hyperkinetic children" with a device using more sophisticated electronics (Leark, Greenberg,

Kindschi, Dupuy, & Huges, 2007). This CPT consisted of a tachistoscopic shutter and a slide projector. Like the earlier Yale study, the intent was to study attention and examine the effects of various medications (e.g., a stimulant, a tranquilizer, and a minor tranquilizer) on hyperactive children. While this device was primitive by today's standards, the study provided useful data on the ability of CPTs to assess the efficacy of stimulant medications and was valuable in helping to distinguish hyperactivity from inattention.

Researchers noted that CPTs differentiated children with ADHD from typically developing peers (Halperin et al., 1992). Studies also indicated that CPTs have a high rate of sensitivity; tests such as the IVA+Plus and the TOVA correctly identify attention deficit disorders 92% and 80% of the time, respectively (Greenberg, 2009; Sandford & Turner, 2009b). An area of concern is that CPTs can also provide false positive or false negative results for 20% of test takers (Greenberg, Kindschi, Dupuy, & Hughes, 2007). While there is general agreement that CPTs should be used in conjunction with other measures, they remain highly cost effective, require minimal training to administer, and are efficient as an assessment tool for attention deficits.

**Brain imaging**. Brain imaging technologies are now providing evidence of neurophysiological differences between individuals with ADHD and others. Although rating scales are useful and CPTs provide objective data that inform the identification process, high resolution imaging techniques have many advantages: they provide detailed representations of the physical structures of the brain and permit direct observation of cerebral functioning in near real time. On the other hand, low resolution imaging from

qEEGs provide “maps” based on the electrical activity of the brain and is a non-invasive diagnostic tool for a variety of pathologies. While MRI and fMRI lack the temporal resolution of qEEG, they provide high resolution images of the brain thereby allowing examination of brain structures in great detail and also deliver information on cerebral blood flow. These technologies are finding considerable use in research and, among other things, are now providing evidence for the genetic basis of ADHD, as well as confirming a potential neurophysiological basis for the differential performance observed on CPTs (Suskauer et al., 2008).

***Single photon emission computed tomography***. Amen (2001) has used SPECT, an invasive imaging procedure that requires injection of a radioisotope, to examine blood flow within the brain. In one study that compared the cerebral blood flow of medication-free children from an outpatient psychiatric clinic, 54 of whom meet DSM-III-R (APA, 1987) criteria for ADHD and 18 children who did not, Amen and Carmichael (1997) found that 65 percent of children with ADHD presented with hypoperfusion (decreased blood flow) in the prefrontal cortex during tasks that required intellectual challenges, whereas just 5 percent of non-ADHD children did and this difference was significant. Based on his SPECT studies, Amen (2001) has since proposed that six types of ADHD exist.

***Magnetic resonance imaging and functional magnetic resonance imaging***. MRI studies were the first to reveal morphological differences among individuals with ADHD and others (Filipek et al., 1997). Like SPECT, fMRI studies also produce high resolution brain images, but examine metabolic function (blood flow). These studies are beginning to reveal statistically significant differences in the brain that indicate the activation of the prefrontal cortex is reduced in individuals with ADHD (Passarotti, Sweeney, & Pavuluri, 2010).

A meta-analysis of the literature (Yang et al., 2007) on the neurotransmitter dopamine, DAT1, which has previously been associated with the expression of ADHD symptoms (including inefficient executive function, inattention, and impulsivity), revealed a weak, but statistically significant association between the gene and the disorder. Specifically, individuals inherit one of the two alleles (forms) of this gene, DAT1 10 or DAT1 9. The study identified a positive association between DAT1 10 and susceptibility for ADHD. In an effort to clarify this association, researchers at Georgetown University conducted an fMRI study that compared individuals with DAT1 10 to those with DAT1 9 (Gordon, Stollstorff, Devaney, Bean, & Vaidya, 2011). The results of the study provided evidence that further supports the contention that DAT1 10 is one of many genes associated with ADHD, and that it is correlated with symptoms of inattention and not hyperactivity, thus providing additional evidence that ADHD, inattentive subtype and ADHD may be distinct disorders. In addition, the researchers noted that the gene appears to cause interference in brain structures, particularly the prefrontal cortex, that are associated with inattention.

**Quantitative electroencephalography.** Electroencephalography (EEG) is a technology that is used to examine the electrical activity of the brain (EEG will be described in greater detail later). Quantitative electroencephalography (qEEG) uses exactly the same technology but, unlike EEG that often measures brainwave activity at just a few sites on the scalp (most often one or two, and seldom more than three or four), a qEEG montage measures brain activity at 19 sites simultaneously. EEG electrodes (sensors) are usually positioned on the scalp at standardized locations established by the International 10/20 System (Figure 1; Jasper, 1958). The name of this system is derived from the distance between each of the 19 standardized locations with each positioned within 10 or 20 percent of the distance from each other between the front and back of the brain, as well as side to side. This system assigns letters to positions on the scalp that correspond to underlying brain structures (i.e., F = frontal lobe, Fp = frontal poles, T = temporal lobe, O = occipital lobe, C = central cortex and sensorimotor cortex, and z = centerline that divides the left and right hemispheres). Numbers are assigned to specific positions (odd numbers are assigned to locations on the left side of the brain and even numbers are assigned to the right); the lower the number, the closer the location is to the midline (z). Two additional sites are identified as A1 and A2, and are assigned to the left and right ear respectively; these are used for additional electrode placements but do not represent brain structures and EEG measurements are not gathered at these locations. They are used as a ground and a reference for the other electrodes, which do collect data. Expanded versions of the 10/20 system extend the 19 sites available to up to 345

locations (Chatrian, Lettich, & Nelson, 1985; Jurcak, Tsuzuki, & Dan, 2007; Oostenveld & Praamstra, 2001).

Unlike SPECT, MRI, and fMRI imagining that provide high resolution images of brain structures, qEEG provides low resolution images that represent cortical electrical activity. However, qEEG and EEG have a distinct advantage in that their temporal resolution measures brain activity in milliseconds. In contrast, SPECT, MRI, and fMRI are significantly slower and have time resolutions that range from a few seconds to minutes. Also, qEEG is more practical than high resolution imaging technologies because the equipment is portable, significantly less expensive, non-invasive, and relatively simple to use (Hughes & John, 1999; Monastra et al., 1999).

In addition to the images produced by qEEG, data are gathered at each of the 19 scalp locations on specific bands of brainwave frequencies (to be discussed later). Frequencies are measured in Hertz (Hz or cycles per second) and information on their low-level amplitudes, measured in microvolts (μV or one millionth of a volt), is provided. These data are then subjected to statistical analyses that compare measurements between each of the 19 sites and provide localized cortical electrophysiological information that can be matched to large normative databases (Hughes & John, 1999). qEEG studies have consistently revealed that individuals with ADHD exhibit abnormal EEG patterns that include statistically significant elevations in amplitude of slow brainwave activity and a decrease in amplitude of brainwave bands associated with focused attention. Furthermore, significant differences in coherence between and within hemispheric regions have long been recognized as differentiating children with ADHD from typically

developing peers (Chabot, Orgill, Crawford, Harris, & Serfontein, 1999; Chabot & Serfontein, 1996; Hughes & John, 1999; Sterman, 2000).

In a large study that compared the qEEGs of ADHD children (n=407) with typically developing peers (n=310), Chabot and Serfontein (1996) reported that qEEG has a sensitivity (correctly identifies individuals with a diagnosis of ADHD) of 93.7% and a specificity (recognizes when ADHD is not implicated) of 88%. Their results indicated homogeneity in the EEG of children with ADHD despite the heterogeneity of symptoms found across subtypes. Although EEG differences were found between subtypes, with the frontal regions being most often implicated regardless of these differences, most were related to the degree and not the type of abnormality when compared to typically developing populations. It was noted that data from qEEG are useful in distinguishing neurophysiological profiles between individuals with ADHD and individuals with attention problems who do not meet criteria for ADHD.

Similarly, researchers from another large multi-site study hypothesized that cortical slowing (i.e., the presence of higher amplitude low-frequency brainwaves) in the prefrontal region, as measured by qEEG, can differentiate between individuals with ADHD from a non-clinical control group (Monastra et al., 1999). For their study, Monastra et al. examined the qEEGs of participants who met criteria for either the inattentive or combined subtypes. Participants consisted of 482 individuals, ages 6 to 30, who were assigned to one of two clinical groups (i.e., inattentive or combined subtypes), or a control group. Placement in the clinical groups was contingent on meeting DSM-IV criteria for either subtype, as well as positive scores for ADHD on rating scales and

CPTs. As rating scales do not identify individuals with the predominately hyperactive/impulsive subtype, potential participants with this subtype were excluded from the study. Participants were assigned to the control group if they: (1) did not met criteria for ADHD or other psychiatric disorders, (2) received scores on rating scales that were not congruent with profiles indicative of ADHD, and (3) performance on CPTs were not at levels typically associated with attention deficits.

Monastra et al. (1999) operationally defined cortical slowing with an attentional index derived from the theta-beta ratios. This index was calculated from the means of each participant's EEG theta and beta bandwidths while they were engaged in four tasks: baseline, silent reading, listening, and drawing. Previous research had provided evidence that individuals with ADHD have higher ratios (i.e., elevated cortical slowing) when compared to typically developing peers, particularly when examining theta/beta ratios measured at Cz (top of the head) and Fz (center of the forehead), using the 10/20 system (Figure 1; Lubar, Swartwood, Swartwood, & Timmermann, 1995). The use of theta/beta ratios as a diagnostic tool continues to receive support; the United States Food and Drug Administration has now approved the marketing of a medical device to help confirm a diagnosis of ADHD (U.S. Food and Drug Administration, 2013) based on EEG.

While imaging techniques, particularly qEEG, currently provide the most state-of-the-art methods for identifying children with ADHD, their use is relegated to medical professionals. Nevertheless, the diagnostic utility of qEEG, especially when compared to other evaluative tools, is very high, with wide consensus that the EEG profiles of children with ADHD differ from others (Chabot et al., 1999; Chabot & Serfontein, 1996; Hughes

& John, 1999; Sterman, 2000). Results from medical evaluations, however, may be considered as part of the IEP process (Burcham & DeMers, 1995). In addition, the United States Department of Education (2008) recognizes the value of obtaining data from behavioral, medical, and educational domains as part of the identification process, although a medical diagnosis does not automatically ensure that a child receives special education and other services.

**Intervention Models: Medical, Psychological, and Educational**

The literature has long recognized that identifying efficacious interventions for attention deficits (and associated cognitive and behavioral impairments) is an arduous and complex task due, in part, to the heterogeneity of the phenotypical expression of the disorder as well as the variance of individual responses to treatments. Little has changed since the National Institutes of Health (NIH) was required by Congress (PL 99-158; "Health Research Extension Act of 1985, 42 U.S.C. § 281 (2006),") to "establish an Interagency Committee on Learning Disabilities [ICLD] to review and assess Federal research priorities, activities, and findings regarding learning disabilities (including central nervous system dysfunction in children)." The report noted that management of ADHD is generally relegated to two domains: "(a) nonpharmacologic (educational and cognitive-behavioral, and other psychological and psychiatric approaches); and (b) pharmacologic therapies." Although the ICLD predominantly comprised representatives from medical agencies within the Federal government (and also included representatives from the USDE and a few other governmental entities), their report emphasized the primacy of education with regard to interventions. Specifically, it stated that,

"*Educational management represents an important priority and often forms the cornerstone of all other therapies, nonpharmaco1ogic or pharmacologic*" (emphasis added; Interagency Committee on Learning Disabilities, 1987, p. 201).

The need for cross-disciplinary intervention strategies that include educational, behavioral, and pharmacological approaches that address the educational requirements of individuals with ADHD continues to be recognized as essential by both the educational and medical communities (American Academy of Pediatrics, 2011b; USDE, OSERS, OSEP, 2008). Nevertheless, there is not a single intervention that has been found to sufficiently address the heterogeneous symptoms of ADHD, with research lending support for multimodal models (American Academy of Pediatrics, 2011c; Jensen et al., 2007; Jensen et al., 2001; Reid, Trout, & Schartz, 2005).

In their biannual report, *Evidence-Based Child and Adolescent Psychosocial Interventions*, intended as a guide to assist pediatricians, educators, and families in making informed decisions regarding appropriate interventions for several common mental health disorders, the American Academy of Pediatrics (AAP) concludes that "best support" for children with ADHD is provided by the combination of behavioral therapy and medication together. On October 1, 2012, PracticeWise, the proprietary research organization that prepares the biannual report for the AAP announced that neurofeedback had also obtained their highest rating of efficacy (Level 1 – Best Support), based on their review of the scientific literature (American Academy of Pediatrics, 2012).

The AAP, however, does not publish a reference list to accompany their report and defer all requests for clarification to PracticeWise, a proprietary company. Queries to

PracticeWise revealed that several studies were considered in determining the support of biofeedback as an evidence-based intervention (PracticeWise, personal communication, October 1, 2012). Of these, three examined the use of electromyography (EMG), a type of biofeedback that measures electrical activity within muscles (Kaduson & Finnerty, 1995; Omizo & Michael, 1982; Rivera & Omizo, 1980) and other studies examined the use of neurofeedback (Beauregard & Lévesque, 2006; Carmody, Radvanski, Wadhwani, Sabo, & Vergara, 2001; Gevensleben et al., 2009; Lévesque, Beauregard, & Mensour, 2006).

One recent meta-analysis (Toplak, Connors, Shuster, Knezevic, & Parks, 2008) examined research related to the efficacy of non-pharmacological treatment interventions that used cognitive training or strategies to improve working memory or attention. Of the limited number of studies identified (26 in all), the researchers subdivided these into three categories: (1) cognitive-behavioral treatments (CBT) that attempt to modify behavior to enhance academic or cognitive performance; (2) cognitive-based interventions (CBI) that involved repeated exposure to stimuli designed to train working memory and attention; and (3) neural-based interventions that examined the efficacy of electroencephalogram (EEG) biofeedback. For their analysis of CBT, Toplak et al. examined six studies that were published after a previous review of the literature (Abikoff, 1991) failed to provide empirical evidence to support its use. Of the studies that were reviewed, mixed results were reported and it was concluded that the efficacy of CBT was difficult to evaluate.

Limited evidence was found to support the use of CBI strategies to assist individuals with ADHD. These studies addressed training attention (Karatekin, 2006;

O'Connell, Bellgrove, Dockree, & Robertson, 2006; White & Shah, 2006) or working memory (Klingberg et al., 2005; Klingberg, Forssberg, & Westerberg, 2002). Although these studies provided some evidence that CBI may be an efficacious intervention strategy, more research is required to confirm the utility of their use (Toplak et al., 2008).

In the final category, Toplak et al. (2008) looked at 14 studies on the efficacy of neural-based interventions; of these, 13 used neurofeedback and one used transcutaneous electrical nerve stimulation (TENS; a procedure that provides a very low level of electrical stimulation to the brain). The researchers noted that neurofeedback produced significant results in some studies, while other studies produced mixed results. They attributed these disparities to the heterogeneity in the methodological designs of the research examined.

**School-based interventions.** Addressing the needs of students with ADHD is especially critical in schools, as this is where most children are first identified and their impairments become evident (USDE, OSERS, & OSEP, 2008). Research consistently demonstrates that attention deficits have a deleterious effect on academic attainment (Barkley, 2002). Although medical and psychological interventions cannot be ignored, especially since as these are often implemented with the specific goal of maximizing school success, the responsibility for accommodating students with special needs in school ultimately falls to educators.

Similar to the AAP, the USDE recognizes that parents, teachers, and medical professionals are essential to the identification process and that a comprehensive evaluation must include three components: educational, behavioral, medical (USDE,

OSERS, & OSEP, 2008). In addition, they acknowledge the role of behavioral and pharmacological interventions and indicate the best way to address symptoms of ADHD is through the use of multimodal strategies. The USDE report does not provide specific guidelines for interventions outside of behavioral and medical domains, but instead provides general suggestions for accommodations and instructional strategies that may also be beneficial for students who do not have ADHD (USDE, OSERS, & OSEP, 2008).

Studies on school-based interventions often focus only on alleviating disruptive behaviors and the social relationship difficulties that are associated with ADHD. Rarely do they examine the problems experienced by ADHD, inattentive subtype students who lack symptoms of hyperactivity or impulsivity. As an example, DuPaul and Weyandt (2006) conducted a literature review of classroom interventions for children with ADHD, although they did not acknowledge the three subtypes. They identified three types of evidence-based interventions: behavioral (e.g., token reinforcement, response cost), academic (e.g., peer tutoring), and social (e.g., social skills training). While "relatively strong support" for behavioral interventions designed to reduce disruptive behaviors was found, they indicated that evidence for social interventions was weaker. Furthermore, they noted that the literature on academic interventions generally examines those that reduce disruptive behaviors and enhance engagement on school-related tasks rather than focus on improving academic achievement. They stated that additional research on academic and social interventions was "sorely needed" (DuPaul & Weyandt, 2006).

**Pharmacological interventions**. Medications, particularly stimulants, have long been used as one of the primary interventions to address both the behavioral and

academic symptoms of ADHD. A significant body of literature supports the short-term efficacy of pharmaceuticals: they are relatively inexpensive, and are often administered (by authorized personnel) to children during the school day (DuPaul & Weyandt, 2006; Pelham, Wheeler, & Chronis, 1998; USDE, OSERS, & OSEP, 2008). Despite their widespread use, studies indicate that pharmaceutical interventions are more efficacious at ameliorating symptoms of hyperactivity/impulsivity than symptoms of inattention (Filipek et al., 1997; Hale et al., 2011); indeed, some individuals with the inattentive subtype do not respond to stimulants (Hale et al., 2011).

**Early use of stimulants and academic achievement.** A. T. Childers (1935) is given credit for the first discussion of pharmaceuticals to treat hyperactivity. Although not included in his study, Childers noted other physicians had employed the use of sedatives (not stimulants) with hyperactive children, particularly those with behavioral difficulties attributed to complications from encephalitis. He stated that the use of sedatives had not been particularly encouraging and recommended that they should not be used at all (Childers, 1935).

Three years after the publication of Childers' research, Charles Bradley conducted the first study on the effect of an amphetamine (Benzedrine) on children with unspecified neurological and behavioral disorders (Bradley, 1937). Bradley was trained in pediatrics at Harvard and became the first medical director of the Emma Pendleton Bradley Home, Rhode Island in 1933. The facility was the first psychiatric hospital established specifically for children with behavioral disorders in the United States (Bradley, 1937; Jones, 2006; Strohl, 2011). Benzedrine was initially studied at the Bradley Home to

determine if it could alleviate headaches caused by pneumonencephlalograms, an invasive X-ray procedure that introduces gases into the spinal column in order to increase contrast. Although the drug had no effect on eliminating headaches, unexpected dramatic improvements in behavior were noted and lead to the first research on the use of stimulants to modify disruptive behavior (Strohl, 2011).

Bradley conducted a study in which 30 children diagnosed with behavioral disorders, but of otherwise normal intelligence, were administered Benzedrine. The results were immediately observable (within 30 or 40 minutes after the drug was administered), which was contrary to what was expected from a stimulant that had been, until that time, used almost exclusively to treat depressed, self-absorbed, or underactive patients. Paradoxically, Bradley found that the amphetamine reduced emotionally labile behaviors in 15 of his participants and that they increased their interest in their surroundings (Bradley, 1937). Only one child had an unfavorable response and became more hyperactive, aggressive, and irritable – behaviors that would typically be expected following the administration of an overdose of a stimulant. The most significant finding, however, was a substantial improvement in academic performance; Bradley wrote, ". . . the most spectacular change in behavior brought about by the use of Benzedrine was the remarkably improved school performance of approximately half the children. This is the more striking when we note that these patients were of good intelligence and that they were receiving adequate attention for any personality disorders which might affect their school progress" (1937, p. 582). All of the positive changes in behavior and school performance disappeared as soon as use of the drug stopped. A few years later, Bradley

conducted a second and larger study (n=100) and found that amphetamines provided additional benefits for hyperactive children, including improved academic achievement, a reduction in nocturnal enuresis (bedwetting), and increased scores on psychometric tests (Bradley & Bowen, 1941).

**Methylphenidate (Ritalin): Brief history and MTA studies**. Although Bradley's findings were to remain relatively unnoticed for several decades (Strohl, 2011), the use of pharmaceuticals and, in particular stimulant medications, are now considered to be among some of the most effective psychotropic medications (Nair, Ehimare, Beitman, Nair, & Lavin, 2006) with a vast body of literature documenting their efficaciousness. By 1957, Methylphenidate (Ritalin) replaced Benzedrine because it produced significantly fewer side effects (Strohl, 2011). Stimulants have been found to reduce symptoms consistently in approximately 75% to 80% of individuals with ADHD (Goldstein & Goldstein, 1998; J. M. Swanson et al., 1998). Despite the extensive research on the use of medication, few longitudinal studies have explored their long-term effects. Goldstein and Goldstein (1998) note that while pharmaceuticals often produce "dramatic positive effects, there is little evidence to support expectation of long-term benefits" (p. 491).

Prior to 2001, no published studies had examined the long-term use of stimulant medications. In order to address this concern, the National Institute of Mental Health (NIMH) conducted a multisite clinical trial, the Multimodal Treatment of Attention-Deficit Hyperactivity Disorder (MTA) study. Two forms of evidenced-based treatments for which substantial research had substantiated short-term benefits were examined:

pharmaceutical interventions (using stimulants) and behavioral therapy (Jensen et al., 2001). For the MTA study, 579 participants were randomly selected and assigned to one of three treatment conditions: monthly medication management, behavior therapy, or a combined group (medication and therapy). A control group participated in a routine community care program. Behavioral therapy consisted of 35 individual and group sessions for the parents of children in the study on behavioral management techniques and on coordinating the children's needs with their school. Children received behavioral treatment and attended an intensive eight-week summer program on sports and social skills, as well as instruction on improving academic skills. In addition, a behavioral aide, supervised by the same therapists who provided parent training, worked directly with the children in the classroom for 12 weeks (Jensen et al., 2001).

The MTA study found that after 14 months of treatment, the outcomes for the medication management group and combined group (medication management with behavioral treatments) were "substantially superior" to the behavioral treatment or control groups (Jensen et al., 2001). A follow-up study at 36 months, however, found that the advantages obtained by the medication and combined groups over the behavioral treatment group had dissipated: there were no statistically significant differences between the treatment groups on any outcome measures. Nevertheless, each treatment group showed significant improvements over baseline measures (Jensen et al., 2007). The authors suggested that perhaps all of the treatments were effective but that the benefits of each were realized at different rates and periods of time.

Hale et al. (2011) reported that the optimal dosage to address behavioral concerns differs from that used to enhance academic achievement. They suggest that higher dosages of methylphenidate (Ritalin) are required, when dosage is titrated for behavior even in individuals who are good responders to the medication. They also found that the optimal dosage for addressing problems with academic achievement in the same individuals was lower. If a higher dosage is used for behavior, children will continue to experience problems with executive function, learning, and working memory.

In general, the use of pharmaceuticals has found broad support as a medical intervention. Research, beginning with Bradley's first study in 1937, has consistently confirmed the efficaciousness of stimulants to enhance school performance for many children (Bradley, 1937; Bradley & Bowen, 1940, 1941; Strohl, 2011). Nevertheless, the use of medications also presents difficulties; the most obvious is that they can only be prescribed by medical doctors. Also, a significant number of individuals are "non-responders" – studies suggest that between 20 and 50 percent of individuals with attention deficits receive no benefits from medications (Chronis, Jones, & Raggi, 2006; Nair et al., 2006; J. M. Swanson et al., 1998). In addition, a significant number of individuals with the inattentive subtype do not respond to stimulant medications (Barkley, 2001; Barkley, DuPaul, & McMurray, 1991; Diamond, 2005; Milich et al., 2001; M. Weiss, Worling, & Wasdell, 2003).

Even when a reduction of symptoms occurs, there are persistent problems with side-effects including anxiety, headaches, insomnia, loss of appetite, nausea, stomach aches, and weight loss; these are reported in 20-50% of children (Goldstein & Goldstein,

1998). Sleep disturbances have been observed beginning with Bradley's first study (Bradley, 1937; Strohl, 2011; J. M. Swanson et al., 2008). Although growth suppression had long been discounted (Goldstein & Goldstein, 1998), the MTA studies, as well as the Preschool ADHD Treatment Study (PATS), found significant and clear evidence that stimulant-related growth suppression does occur (J. M. Swanson et al., 2008; J. M. Swanson et al., 2006). Goldstein and Goldstein (1998) indicate that one percent of children receiving medication develop tics that usually subside when pharmacological interventions are stopped; however, "reports of persistent tics and Tourette's syndrome raise the possibility of permanent injury from stimulant medication as a rare occurrence in some children" (p. 531).

**Electroencephalography (EEG) Biofeedback**

Biofeedback is a process that trains individuals to alter their behaviors by conditioning them to react to the physiological responses of their own body. The process involves placing sensors on various locations on the body that are dependent on the type of biofeedback being used. The most common types of biofeedback use brainwaves, breathing rate, heart rate, electrical activity of muscles, sweat gland responses, and body temperature (Gartha, 1976; Sterman, 2000). The data obtained from sensors are filtered through instruments (often computers) in order to provide visual, auditory, or other information that is based on moment-to-moment changes in the processes being measured. The individual receiving biofeedback then attempts to change the feedback, usually by altering their thoughts, emotions, or behaviors (International Society for Neurofeedback & Research, 2012). Biofeedback is used with a broad spectrum of

disorders including but not limited to: ADHD, depression, anxiety, and sleep disorders (Hammond, 2011). It is often used to alleviate stress, teach relaxation skills, and boost academic performance (Slawecki, 2009).

EEG biofeedback, also referred to as neurofeedback, provides real-time data on brainwave activity and delivers objective data that is then used to provide feedback, most often through a computer, to the individual via a variety of activities, typically computer games. Neurofeedback can be used as a non-invasive intervention to treat attention deficits and improve academic performance (Monastra et al., 1999). Research on neurofeedback supports its use as an efficacious intervention for reducing symptoms of ADHD (Hammond et al., 2011; Lubar & Shouse, 1976; Lubar, Swartwood, Swartwood, & O'Donnell, 1995). Studies indicate that neurofeedback training enhances cognitive performance (Vernon et al., 2003), increases scores on measures of IQ (Linden, Habib, & Radojevic, 1996), and improves attention (Leins et al., 2007). Furthermore, positive changes in these domains remain robust in follow-up studies (Braud, 1978; Braud, Lupin, & Braud, 1975; Gevensleben et al., 2010; Strehl et al., 2006).

The literature on neurofeedback provides evidence that neurofeedback training is an efficacious intervention for reducing the symptoms of ADHD (Arns, de Ridder, Strehl, Breteler, & Coenen, 2009; Kaiser & Othmer, 2000; La Marca, 2011; Linden et al., 1996; Lubar, 1991; Lubar, Swartwood, Swartwood, & O'Donnell, 1995). Studies also provide evidence that neurofeedback is as efficacious as pharmaceutical interventions (Fuchs, Birbaumer, Lutzenberger, Gruzelier, & Kaiser, 2003; Rossiter, 2004; Rossiter & La Vaque, 1995), although others suggest additional research is needed to fully substantiate

this (Loo, 2003). Perhaps the most common criticism of neurofeedback is that it is a promising intervention but requires ongoing and well-designed research to confirm its efficacy (Lofthouse, Arnold, Hersch, Hurt, & DeBeus, 2011).

**A brief history of electroencephalography**. German psychiatrist Hans Berger's discovery of brainwaves in 1924 has made enormous contributions to modern medicine. The instrument he invented, the electroencephalogram (EEG), continues to serve as one of the fundamental tools of clinical neurology (Millett, 2001). After experimenting for many years without success, Berger was able to adapt and refine the electrocardiogram (EKG), which had already been in use for many years, to measure the electrical activity of the heart in developing the EEG. The technical challenges faced by Berger were considerable and his earliest EEG's were primitive. By early 1929, he was able to record brainwaves from hundreds of individuals with considerable quality and published his seminal book, *Über das elektrenkephalogramm des menschen* (On the Electroencephalogram of Man; Berger, 1929). Berger was also the first to identify specific brainwave frequency bands, which he labeled as alpha and beta, and discovered that thought processes, alertness, and emotional states (i.e., anxiety, depression, etc.), as well as seizures could be correlated with specific EEG patterns (Demos, 2005; Millett, 2001). In some of his earliest high-quality recordings, made between 1928 and 1929, Berger identified "alpha waves" (7.5-12 Hz). He observed spikes (increases in amplitude) in this frequency band whenever his participants closed their eyes and/or were in a state of physical and mental rest (Millett, 2001). Similarly, he also noted a second band of faster frequencies that he identified as "beta waves." He theorized that alpha was

correlated with attention and beta was associated with the metabolic activity of the brain, although these theories are now considered antiquated. His work, however, confirmed that EEG reflects cognitive functioning. In one instance, Berger connected his 14-year-old daughter to his EEG machine and asked her to perform simple math calculations: the EEG was able to record when his daughter began and ended the process (Robbins, 2001).

Berger's discoveries were initially ignored and remained relatively unknown; his book was published in German and was not available to scholars from other countries. In 1934, two physiologists from Cambridge University, Lord Edgar Adrian and B. H. C. Matthews, were able to replicate Berger's findings (Robbins, 2001). It is particularly notable that Charles Bradley and others at the Emma Pendleton Bradley Home were exploring the use of EEG at exactly the same time they were beginning their research with Benzedrine (Jasper & Shagass, 1941a; Jasper, Solomon, & Bradley, 1938). Participants in these studies included children who were hyperactive, impulsive, were emotionally immature, and exhibited problems in school. Their research was also the first to use EEG to examine the efficacy of both Benzedrine and phenobarbital (Cutts & Jasper, 1939). In a review of these early studies at the Bradley Home, Shalloo (1940) reported that "abnormal brain function as revealed by the electroencephalogram is an important component in the aetiological [sic] picture of the majority of a group of problem children whose disorder has been considered primarily psychogenic previous to using this method of diagnosis. The nature of the fundamental pathology of the brain indicated is not as yet known."

**Conditioning**. Neurofeedback is based on the principles of classical and operant conditioning. Pavlov's seminal work with dogs led to the traditional behaviorist paradigm of classical conditioning. Specifically, when an organism is presented with a naturally occurring or "unconditioned stimulus" (US; e.g., food), a behavioral response or "unconditioned response" (UR; e.g., salivation) is triggered. Pavlov noted that inborn or "instinctive reflexes," such as salivation, can be triggered by other stimuli that the organism associates with food; the sight of a feeding bowl, the presence of the individual who usually provides food, or even the sound of that person's approaching footsteps (Pavlov, 1927). In his archetypal experiment, Pavlov paired a "conditioned stimulus" (CS), a bell with a US, meat. Initially, this evoked no response from the dogs. As the dogs learned to associate the CS with the US, they would salivate, even after the US had been removed. In other words, the dogs had been "classically conditioned" (e.g., trained) to salivate when only the bell was used as a trigger.

Thorndike's early work with animals, beginning with his doctoral dissertation (1898) at Columbia University, led to the development of his "Law of Effect" that he introduced in *Animal Intelligence: Experimental Studies*:

> The Law of Effect is that: Of several responses made to the same situation, those which are accompanied or closely followed by satisfaction to the animal will, other things being equal, be more firmly connected with the situation, so that, when it recurs, they will be more likely to recur; those which are accompanied or closely followed by discomfort to the animal will, other things being equal, have their connections with that situation weakened, so that, when it recurs, they will be less likely to occur. The greater the satisfaction or discomfort, the greater the strengthening or weakening of the bond (Thorndike, 1911, p. 244).

Although Thorndike's research was conducted during the same period as Pavlov's, both scientists were initially naïve of each other's work (Pavlov, 1927). Thorndike, however, was examining something slightly different; specifically, he noted that animals could be taught new behaviors through the use of rewards and punishments. Pavlov, on the other hand, was able to elicit naturally occurring behaviors after paring them with neutral stimuli. Among Thorndike's studies were those in which he placed hungry cats into enclosed boxes with doors that they could escape from by "pulling at a loop of cord, pressing a lever, or stepping on a platform" (Thorndike, 1911, p. 26). Food would be placed outside of the box and would be visible to the cats. The cats were not trained to escape and were left to discover that they could open the door on their own and thereby gain access to the food. Most of the animals he observed learned to escape in order to obtain food.

Thorndike also observed that the interval of time between the cats' behavior and the opening of the door was strongly correlated with learning. He noted that when given four different boxes, with each designed so that "turning a button caused a door to open (and permit a cat to get freedom and food) in one, five, fifty, and five hundred seconds, respectively, cats would form the habit of prompt escape from the first box most rapidly and would almost certainly never form that habit in the case of the fourth" (Thorndike, 1911, p. 248). Skinner (1938) would later draw upon, refine, and extend Thorndike's law of effect in formulating the construct of operant conditioning. In essence, organisms acquire or learn new behaviors by volitionally "operating" on their environment in response to the consequences of specific reinforcements or punishments.

***Classical conditioning and EEG***. The earliest attempts to pair classical conditioning with EEG occurred during the 1930s and appeared in studies published in France (Durup & Fessard, 1935) and the United States (Loomis, Harvey, & Hobart, 1936). Loomis et al. examined many of the characteristic features of alpha waves. They noted that the production of alpha is strongly associated with vision and, when present, is particularly prevalent in the occipital lobes. Specifically, they reported, ". . . that opening the eyes in a lighted room is the surest method of stopping them [alpha waves] and closing the eyes the surest way to start them" (Loomis et al., 1936, p. 269). In addition, they also observed that when their study participants were placed in complete darkness and asked to open their eyes, alpha did not recede as expected but continued to be produced. However, if the participants were told they would see an object (e.g., a face) when they opened their eyes, alpha would recede even though they remained in darkness. When they would close their eyes, alpha would return. Given these findings, Loomis et al. had participants lie in a darkened room with their eyes open and presented them with a "low tone." The presentation of the tone would not reduce or eliminate (block) alpha. However, when the tone was also paired with a light stimulus (US), alpha-blocking by the study's participants was observed. After several trials, the light stimulus was removed and yet when presented with the tone (CS), alpha-blocking continued although the effect would disappear after two or three additional trials. In other words, Loomis et al. classically conditioned participants to exhibit alpha-blocking with the CS and observed extinction within a few trials after the US was removed.

In their study of the EEGs of children with behavior problems, Jasper, Solomon, and Bradley (1938), from the Emma Pendleton Bradley Home where Benzedrine was also being studied, discovered that many of these children exhibited higher amplitude slow brainwave patterns, including a "sub-alpha rhythm" that appeared in the frontal and central regions of the head. They indicated that these frequencies ranged from 3 to 6 Hz, which are now described by the frequency bands referred to as delta (1-4 Hz) and theta (4-8 Hz). Researchers from the Bradley Home continued to report that their population exhibited slower frequencies of greater amplitude when compared to typically developing peers (Lindsley & Cutts, 1940). These findings were also the first to reveal that cortical under-arousal was associated with behavior, which contributed to their subsequent research on the use of stimulant medications (Lindsley & Henry, 1942).

Acknowledging that Loomis et al. (1936) had demonstrated that classical conditioning of alpha-blocking was possible, Jasper and Shagass (1941b) hypothesized that voluntary control over an involuntary response (e.g., alpha) could be conditioned. Specifically, two adult males were studied to see if they could volitionally exhibit control over alpha-blocking. Each participant was first instructed to subvocally repeat the word 'block' and press a button while doing so; they were asked to hold the button for approximately ten seconds (the actual time was determined by the participant) and upon release, subvocally repeated the word 'stop.' Participants were then placed in a darkened soundproof room and asked to repeat the procedure. Pressing the button inside the room would turn on a light and elicit the UR, alpha-blocking. When the button was released, the light shut off and the alpha-response was again observed.

The button inside the room, however, could also be controlled by the researchers. They could open or close the switch in order to enable the light to respond to the button press. Initially, each participant was presented with several control trials in which the light would not turn on and the presence of alpha was continued to be observed. The researcher then closed the switch so that the light stimulus would turn on when the button was pressed and turn off when released. Alpha-blocking was then observed. Jasper and Shagass reported that after five trials, one participant had become classically conditioned and continued to exhibit alpha-blocking despite the absence of light. The second participant was not as responsive and required eighty-four trials before conditioning was observed.

***Operant conditioning and EEG***. In 1958, Joseph Kamiya, a behaviorist from the University of Chicago, hypothesized that humans could be operantly conditioned to consciously detect the presence of, as well as volitionally produce, alpha waves. His interest in this frequency band stemmed from the long-observed alpha-blocking response associated with the opening and closing of the eyes and that these waves also wax and wane approximately every 2 to 6 seconds during the waking state. In addition, alpha diminishes with increased drowsiness and completely disappears with the onset of sleep (Kamiya, 2011). Kamiya was also intrigued by informal studies conducted during the 1930s and 1940s that observed that engagement in certain cognitive exercises, such the imagination of visual images, could alter the amplitude of alpha, particularly in the occipital lobes.

To test his hypothesis, Kamiya utilized the principles of operant conditioning, and employed the use of a discriminative stimulus (DS), which is similar to the CS of classical conditioning, except that it is used to indicate the presence of a specific response. This response is then reinforced (or punished) in order to increase the probability of its occurrence (Gould, 2003). Kamiya was particularly interested in determining if a DS could be used to condition physiological responses within the body (e.g., the presence of alpha waves), rather than overt externally observable behaviors.

Kamiya's initial study used a single participant, Richard Bach, one of his graduate students from the University of Chicago. Bach was placed in a darkened room and asked to close his eyes while his EEG was monitored. Approximately five times per minute over a period of approximately 30 minutes, a bell was sounded, with each ring occurring during alternating times in which alpha was either present or absent. Bach was asked to guess if he believed alpha was present at the moment the bell rang by stating either "yes" or "no." Correct responses where reinforced by Kamiya with the utterance of the word "correct." Kamiya would later write that,

> The first day, he [Bach] was right only about 50 per cent of the time, no better than chance. The second day, he was right 65 per cent of the time; the third day, 85 percent. By the fourth day, he guessed right on every trial – 400 times in a row. But, the discrimination between the two states is subtle, so subtle that on the 401st trial, the subject deliberately guessed wrong to see if we had been tricking him (Kamiya, 1968, p. 57).

Kamiya then altered the experiment by placing his student in the darkened room again but with the instruction that when the bell rang once, Bach was to produce alpha; when it rang twice, he was to inhibit alpha. Kamiya noted that Bach exhibited "perfect

control," although he would also report that his graduate student was exceptionally astute at both perceiving and influencing his alpha.

Shortly after his initial experiment, Kamiya accepted a position at the University of California, San Francisco where he continued to examine EEG, conditioning, and the alpha-response. Although his work was conducted more out of curiosity than to "help the ailments of mankind" (Robbins, 2001, p. 55), Kamiya consistently observed that EEG could be conditioned and his work is considered to be the foundation upon which the use of neurofeedback is built. Although he presented papers on his findings that EGG could be conditioned at professional conferences (Kamiya, 1962, 1966), it was the publication of an article for *Psychology Today* (Kamiya, 1968) that first drew attention to his work and also piqued the interest of the public (Kamiya, 2011; Robbins, 2001).

M. Barry Sterman, from the University of California, Los Angeles (UCLA) examined the use of classical conditioning and EEG to induce sleeping behaviors in cats for his dissertation (Sterman, 1963). In 1967, Sterman and one of his graduate students, Wanda Wyrwicka, published an article (Sterman & Wyrwicka, 1967) that reported on an unexpected observation in cats where certain EEG frequencies associated with drowsiness and sleep (4 to 12 Hz) were also associated with discrete behaviors, such as drinking milk, while the animals were awake. Specifically, they noted a brief increase in the amplitude of these slower frequencies while they were drinking. They also observed another discrete EEG bandwidth (12 to 20 Hz) that they referred to as the Sensorimotor Rhythm (SMR) in reference to the sensorimotor cortex, located on the top of the brain (Sterman, 2010, Summer). They noted that SMR is often present during sleep and is also

observed in certain states during wakefulness; it is particularly evident in states of high alertness but physical quietude. Sterman and Wyrwicka reported that "the EEG response [SMR] was clearly correlated with volitional somatomotor inhibition" (p. 149). (It should be noted that SMR is now more narrowly defined as the bandwidth encompassing 12 to 15 Hz.)

In 1968, they published their seminal study on brainwave activities in cats (Wyrwicka & Sterman, 1968). Sterman had heard one of Kamiya's presentations at a conference and hypothesized that EEG could be operantly conditioned in cats (Kamiya, 2011). Specifically, Sterman and Wyrwicka designed an experiment to determine whether the animals could be operantly conditioned to produce SMR. As part of their research, food-deprived cats were rewarded with small amounts of milk each time they produced SMR. Sterman would later report that this conditioning was "found to profoundly influence EEG and motor patterns over long periods of time" (Sterman, LoPresti, & Fairchild, 1969, p. 296). This study was the first to use neurofeedback and demonstrated that cats were not only able to volitionally enhance SMR in order to receive rewards of food but that brainwaves found in a certain location (on the top of brain) seemed to play a critical role.

Later, the National Aeronautics and Space Administration (NASA) awarded a grant to UCLA to conduct studies on monomethylhydrazine (MMH), a rocket fuel that had been associated with seizure activity and hallucinations in astronauts (Demos, 2005; Sterman et al., 1969). When the principal investigator of the study, Dr. Gordon Allies, died before the study was over, one of his graduate students, David Fairchild asked

Sterman to help complete their research (Kaiser, 2004). The results of this study led to a startling and highly important accidental discovery. Specifically, Sterman randomly selected 50 cats and injected them with MMH. Within an hour, forty out of the fifty cats experienced severe grand mal seizures and died. Of the remaining ten cats, seven took significantly longer to seize and three did not experience any convulsions at all (Kaiser, 2010, Summer; Robbins, 2001; Sterman et al., 1969). It wasn't until after Sterman examined the histories of these animals, that he discovered that all of the surviving cats had previously been trained to produce SMR in his earlier and completely unrelated study (Egner & Sterman, 2006; Robbins, 2001).

With the discovery that operant conditioning of SMR could dramatically increase the resiliency of cats to seizures caused by rocket fuel, Sterman and others began to study the impact of SMR training with epileptics (Sterman, MacDonald, & Stone, 1974). From the onset, these studies showed great promise in reducing seizure activity in humans. The role of SMR, which is associated with a physiological state of a calm body but alert mind, is considered optimal for learning; however, this state is less prominent in individuals with ADHD. The findings of Kamiya and Sterman have since led to further inquiry into how EEG can be used to diagnose and treat a variety of conditions including epilepsy, depression, and ADHD (Egner & Sterman, 2006).

Studies have not only consistently indicated that EEG provides important diagnostic information and that the predictive value of EEG is useful for identifying children with learning disabilities (Egner & Sterman, 2006; Lubar, 1991; Lubar et al., 1985), but that its use as an intervention strategy for variety of disorders is also indicated.

In comparison to pharmaceuticals, the use of EEG and qEEG provide relatively low cost measures to assess individuals with attention deficits, although administration and interpretation of these measures requires considerable training.

**Neurofeedback**

As with pharmacological interventions, neurofeedback has an established history and holds considerable potential for improving the lives of those with special needs (Egner & Sterman, 2006). Neurofeedback uses EEG amplifiers that measure cortical electrical activity. Filters then isolate frequencies (ranging from 1 to 42 Hz) into different bandwidths (Demos, 2005). Scientists classify these frequencies by bandwidths that are associated with specific behavioral characteristics (Table 1). Although the brain continually produces all of these frequencies, some are more predominant than others at various times throughout the day and their respective bandwidths are associated with different neurophysiological states. For example, higher amplitudes of delta are evident during deep sleep while beta, particularly SMR and low beta, are evident in states of alertness, although SMR is also present during rapid eye movement (REM) sleep and is associated with dreaming. The goal of neurofeedback is to train individuals to alter their EEG patterns to maximize performance (e.g., enhance academic functioning in school). Neurofeedback is also used to provide alternative treatment approaches for brain-based conditions including anxiety, brain injuries, depression, epilepsy, sleep disorders, and stroke. Unlike other commonly used interventions – especially pharmaceuticals – neurofeedback has no known side effects (Sterman, 2000).

During the early 1970s, a team of scientists at UCLA and the University of California, Irvine (UCI) were noting that the most salient characteristic of EEGs in children with "minimal brain dysfunction" was that of high amplitude, low frequency activity (Satterfield & Dawson, 1971; Satterfield, Lesser, Saul, & Cantwell, 1973). These results lead Satterfield et al. to suggest that hypo-arousal of cortical activity was implicated; this was later referred to as the "low-arousal hypothesis" of hyperkinesis (Lubar, 1991). In noting these results, they confirmed the very early research of Berger (1929), as well as that of Jasper, Solomon, and Bradley (1938).

Joel Lubar from the University of Tennessee (UT) was the first to hypothesize that neurofeedback could be used as an intervention for children with hyperactivity, especially when symptoms of inattention were also present (Lubar, 1991). Specifically, Lubar theorized that these children would present with reduced beta activity (low beta and SMR) and excessive theta activity. During this time, Lubar was also working with Sterman at UCLA, as well as replicating Sterman's research with operant conditioning of SMR to reduce seizure activities in high school students and college students at UT with epilepsy (Lubar & Bahler, 1976). Following SMR training, it was observed that several of these students also appeared to have increased attention and better concentration (Lubar, 1991).

The first study by Lubar and Shouse (1976) in which SMR neurofeedback training was examined as an intervention strategy for ADHD used a single-case ABA design with one participant, an 8 year 11 month old boy. For the initial phase of the study, enhancement of SMR (defined in the study as 12-14 Hz) and inhibition of theta (4-

7 Hz) was enhanced. During the initial phase, the amount of time in which the participant was able to produce SMR during training tripled. Simultaneously, independent observers of the child in his classroom (the child was not aware of their presence) reported decreases in self-stimulation, object play, out-of-seat behavior, and oppositional behavior. Increases were observed in sustained attention, sustained school work, and cooperative behaviors. For the next phase, the treatment was reversed, the child was trained to inhibit SMR and enhance theta. Behavioral gains made during initial training reverted to baseline levels. For the final phase, SMR production and theta inhibition was again enhanced. Behavioral gains and significant improvements in school performance were again noted. Lubar would later report that follow-up over several years indicated that their participant was able to maintain positive changes (Lubar, 1991). Several additional studies with similar designs and larger samples would soon follow, with SMR training reducing excessive motor activity and, to a lesser extent, improvement in attentional components (Lubar, 1991; Lubar & Shouse, 1979).

Following his findings that enhancement of SMR with concurrent inhibition of theta had positive effects on behavioral and academic outcomes, Lubar began using neurofeedback in clinical settings. From 1976 to early the 1980s, he observed that children with attention deficits who lacked symptoms of hyperactivity exhibited excessive theta activity as well as depressed levels of low beta (which he then defined as 16 to 20 Hz), in addition to deficiencies in SMR. These characteristics were observed while establishing baselines, as well as during neurofeedback tasks while children were reading grade level materials (Lubar, 1991). Lubar hypothesized that neurofeedback

training to inhibit theta while enhancing SMR and low beta would produce favorable outcomes on academic tasks including reading, spelling disorders, and associated learning problems. To test his theory, he added low beta enhancement to his study protocols and in 1984, compared 37 children with attention deficits from Knox County, Tennessee schools who received training to decrease theta and increase beta with 37 controls, all of whom had profiles indicative of ADHD but did not receive neurofeedback. Participants in the groups were matched by age and IQ. Children in both groups also received services in resource classrooms for (unspecified) reading disabilities. Results found that the experimental group made statistically significant gains on Metropolitan Achievement Test scores ($t = 2.21$, $p < .05$) and also improved grade point averages (GPA). At one year follow-up, the children receiving neurofeedback continued to obtain higher GPAs whereas the children in the control group did not (Lubar, 1991).

Subsequent studies, including those that used qEEG, have confirmed that attention deficits are associated with higher amplitudes of theta and lower levels of beta (Barry, Clarke, & Johnstone, 2003). One qEEG study of 25 boys, ages 9 to 12, with ADHD reported elevated levels of theta (defined as 4 to 7.75 Hz) and decreased levels of low beta (defined as 12.75 Hz to 21 Hz) when compared to typically developing age and grade level matched controls. The differences between groups were attenuated, with increased theta most evident in the region of the frontal lobes and decreased beta noted in the area near the temporal lobes, when participants were engaged in reading and drawing tasks (Mann, Lubar, Zimmerman, Miller, & Muenchen, 1992).

**Training sessions and protocols**. Neurofeedback training sessions typically involve playing games that appear on a computer monitor. No joysticks or other controls are needed, as the individual's brainwaves drive the games. The standard for attaching sensors to the scalp has long used an electrically-conductive paste to hold electrodes in place. A variation of this approach attaches sensors to the scalp via disposable electrodes with adhesive backings. Recent technology, however, has seen the advent of "dry electrodes," which do not require skin preparation or the use of pastes, gels, or other adhesives (Sullivan, Deiss, Jung, & Cauwenberghs, 2008; Taheri, Knight, & Smith, 1994; Yasui, 2009). These are now commercially available to the public at low cost (< $100) and resemble hairbands and audio headphones. EEG amplifiers and filters are built-in and connect to neurofeedback software wirelessly, thereby minimizing setup procedures.

The most common training protocol for addressing symptoms of ADHD described by Lubar (1991) attempt to decrease the theta/beta ratio at the location of the frontal lobes (Fz [located between Fp1 and Fp2] or AFz [located between Fpz and Fz]), and over the sensorimotor cortex (Cz). This protocol was developed from research that found that children with ADHD but without hyperactivity (n = 69) exhibited statistically significant elevations of theta (4 to 7 Hz) compared to typically developing controls (n = 34; Lubar et al., 1985). Another study revealed that when ADHD, inattentive subtype children engaged in academic activities that included simple and challenging reading tasks, easy and complex arithmetic problems, and solving puzzles, they experienced increased production of theta, particularly in the frontal regions, and decreased

production of low beta (Mann et al., 1992), thereby increasing their theta/beta ratio – precisely opposite of what is desirable.

Using this protocol, individuals learn to inhibit theta waves and simultaneously enhance low beta/SMR. Parameters are set within the EEG software application prior to each session. Feedback is usually provided by games, sounds, and/or visual cues provided by a computer and driven by EEG. For example, an animated monkey may climb up a tree on a computer monitor when target brainwave levels are met by increasing and/or decreasing the amplitude of one or more frequency bands (Figure 2; Sandford, 2012). When target criteria are not met, nothing happens and the monkey does not move.

While the production of specific frequency bands, or changes in amplitude of those bands, allows individuals to learn how to control their EEG, most people cannot describe exactly what they do in order to produce the target levels because no physical sensations indicate that goals have been met (Millett, 2001). Other than external feedback provided by a computer or a person monitoring brainwave activity, most individuals are trained without direct awareness what they are doing and yet they are able to volitionally alter their EEG patterns (Kamiya, 1979; Lubar, 2003).

**Neurofeedback and reading achievement**. The literature has long noted that neurofeedback produces positive outcomes on a variety of cognitive and academic measures (Leins et al., 2007; Linden et al., 1996; Vernon et al., 2003). However, no research specifically addresses the use of neurofeedback to enhance reading achievement

(Thornton & Carmody, 2005). Nevertheless, studies have provided preliminary evidence that operant conditioning of EEG may produce improvement on measures for reading.

In a review of medical records of 111 patients (i.e., n = 98 children and 13 adults) who attended a neurofeedback clinic and received forty 50-minute sessions of training to inhibit theta (4-7 Hz) and enhance beta (15-18 Hz), Thompson and Thompson (1998) reported statistically significant gains ($p < 0.0001$) between pre- and posttest scores on the Wide Range Achievement Test (WRAT-3) when children with hyperactivity were also trained to enhance SMR. Although the WRAT-3 does not measure reading comprehension, the authors noted that reports of improvement in reading comprehension were obtained from parents and teachers. An examination of a subset of children (n = 30) who had pre- and posttest scores on the Wechsler Intelligence Scale for Children (WISC-III) also found a statistically significant increase in FSIQ ($p < 0.0001$) after adjusting scores by 7 points to account for practice effects.

Orlando and Rivera (2004) conducted the only published study examine the use of neurofeedback with "identified learning problems" to improve reading performance. Participants included 34 public school students with ADHD in grades six, seven, and eight, with three additional students from grades one, four, and five. Students were randomly assigned to either an experimental group that received neurofeedback training or a control group that did not. Participants in both groups had existing IEPs or Section 504 plans. Treatment protocols were individualized for nine of the students in the experimental group based on qEEG data collected at the study's onset, while the remaining students had treatment protocols based on "clinical judgments" by the primary

author, a school psychologist. Basic reading, reading comprehension, and reading composite scores from the Wechsler Individual Achievement Test (WIAT) from both pre- and post-test administrations of the test were analyzed. Improvements on all three measures were reported.

Despite these findings, there were serious limitations in the design and methodology of the Orlando and Rivera (2004) study. For example, the participant selection process did not adequately control for heterogeneity in the sample. Although every child had either an IEP for a Specific Learning Disability (SLD) or qualified as Other Health Impaired (OHI), three of the participants had a Section 504 Plan due to "complications surrounding a medical diagnosis of ADHD." The number of students who met criteria for a diagnosis of ADHD was not provided. In addition, subtypes were not discussed. The authors reported that participants were selected from grades six, seven, and eight at one school based on the criterion that they had unspecified "learning disability problems." These students had a mean age of 12.5 years (SD was not provided). However, three additional students from other schools were also included; they were from grades one, four, and five (m = 8.2 years). No justification was provided for the inclusion of these younger children and it cannot be determined to which groups these students were assigned. In addition, the experimental and control groups lost several students due to attrition. Both groups initially contained seventeen students each; only twelve students (m = 11.27 years, SD = 2) in the experimental group completed the study, while fourteen students in the control group (m = 13.14 years, SD = 0.77) finished. No explanation was provided as to why five students in the experimental group did not

complete the study. Of the twelve remaining participants in the experimental group, two additional students had to be excluded from the final analysis as they did not receive the psycho-educational assessments that were given to the other participants at the onset of the study. Attrition in the control group also appears to be related to inadequate screening procedures to control for comorbid conditions. Of the three students in the control group who did not complete the study, one was jailed as the study commenced, another one was placed in a classroom for the "mildly mentally retarded," and the final student moved to another school.

The establishment of treatment protocols was not consistent between participants. Orlando and Rivera (2004) did not state if EEG specific bandwidths were being enhanced or inhibited. Observed changes in EEG during or at the conclusion of the study were not reported. Neurofeedback sessions were conducted once per week over a period of seven months although “absences, field trips, testing, and other natural rhythms of home and school life” (p. 6) interfered with the number of sessions each participant received. Standardized procedures were not established for pre- and post-assessments. Given the problems and inadequate attention to the experimental design, it is difficult to infer the efficacy of neurofeedback in this study. The authors concluded, however, that neurofeedback appeared to be more effective than no training for improving reading achievement and that additional research is justified.

Rossiter (2002) conducted a case study of a 13-year-old male who had been diagnosed with ADHD at age 7. At that time, it was reported that the participant’s performance on tasks of reading, spelling, and mathematics was significantly less than

expected for his intelligence (FSIQ = 101) and grade level. By age 13, he was receiving special education services for mathematics and language arts, although not specifically for reading. Forty-five 35-minute sessions of neurofeedback were conducted over a period of four months; protocols where adjusted over the treatment phase to suppress delta and theta (2 to 7 Hz) or theta and alpha (7 to 10 Hz) and enhance beta (12 to 15 Hz or 15 to 18 Hz). The Kaufmann Test of Educational Achievement (KTEA-Brief) had been administered six months prior to the study and re-administered at the end of treatment. While no significant gains were found on measures of mathematics or spelling, the participant showed an increase of 31 standard score points and a grade level increase from 5.2 to 12.5 (7.3 grade levels) for reading comprehension. Also reported were significant improvements on the TOVA-A, a version of the TOVA that examines auditory responses. These included a gain of 81 standard score points pertaining to processing speed, an increase from 55 at baseline to 133 after forty sessions of neurofeedback. A gain of 40 standard score points on variability in attention was also observed and represented an increase from 75 at baseline to 155 following training. At 17-month follow-up, parents reported that the participant was making good progress in school.

Thornton and Carmody (2005) also described a case study of a 17-year-old student with a reading disability. Following 20 sessions of neurofeedback (protocols were not described), the participant exhibited improvements in reading comprehension on the Burns/Roe Reading Inventory with gains on alternate versions of 45% to 90% (eighth

grade level) and 20% to 70% (tenth grade level), respectively. The student also obtained a standard score of 99 for age and grade level on the WIAT reading comprehension subtest.

**Summary**

The growing body of literature on neurofeedback continues to indicate that it is an efficacious intervention for ADHD. While the debate within the scientific community explores to what extent it can be considered as an evidence-based treatment for ADHD, most discussions center on issues pertaining to the quantity and quality of research, while also suggesting that neurofeedback shows promise as an intervention strategy for which further research is justified (Loo & Barkley, 2005; Rabiner, 2012; Willis, Weyandt, Lubiner, & Schubart, 2011).

In an effort to overcome criticisms of methodological weaknesses (e.g., concerns regarding diagnostic criteria for subject identification, small sample sizes, lack of controlled studies, or studies that form treatment groups from clinical samples) for studies pertaining to neurofeedback, the Association for Applied Psychophysiology and Biofeedback (AAPB) and the International Society for Neurofeedback and Research (ISNR) collaboratively developed and adopted *Guidelines for the Evaluation of the Clinical Efficacy of Psychophysiological Interventions* (La Vaque et al., 2002). These guidelines describe five levels of efficacy: 1) Not empirically supported, 2) Possibly efficacious, 3) Probably efficacious, 4) Efficacious, and 5) Efficacious and specific.

A review of the literature by Monastra, Lynn, Linden, Lubar, Gruzelier, and La Vaque (2005) identified neurofeedback using the AAPB/ISNR Guidelines as "Level 3: Probably Efficacious. Multiple observational studies, clinical studies, wait-list controlled

studies, and within-subject and intra-subject replication studies that demonstrate efficacy." At the same time, Loo and Barkley (2005) conducted another review of the literature and called for additional research to exam behavioral and cognitive gains attributable to neurofeedback. They noted that studies have consistently demonstrated the utility of EEG/qEEG evaluations to differentiate between individuals with ADHD and typically developing peers. They concluded that neurofeedback requires more research that is "scientifically rigorous" to establish its efficacy as an intervention strategy for ADHD.

Arns et al. (2009) conducted a meta-analysis of research on the efficacy of neurofeedback as a treatment for ADHD and specifically addressed concerns raised by Loo and Barkley (2005). Fifteen studies were selected based on exclusionary criteria that required "sufficient scientific rigidity," sound methodology, and utilized control groups or single-case designs. These included six studies from Germany and five from the United States, with a total of 1194 participants. After excluding studies that contributed greater variance than expected from sampling error, effect size (ES) for inattention was 1.0238 (95% confidence interval [CI] 0.84 to 1.21; total N=324); ES for impulsivity was 0.9394 (95% CI 0.76 to 1.12; total N=338); and ES for hyperactivity was 0.7082 (95% CI 0.54-0.87; total N=375). Arns et al. conclude that the large ES for inattention and impulsivity, along with the moderate ES for hyperactivity meets criteria under the AAPB/ISNR Guidelines as "efficacious and specific" (Level 5) indicating research has demonstrated that neurofeedback is "statistically superior to a credible sham therapy, pill, or bona fide treatment in at least two independent studies" (La Vaque et al., 2002).

The literature on neurofeedback now spans several decades. Beginning with the first study to report on its successful use as an intervention for ADHD (Lubar & Shouse, 1976), improvements in school performance have since been reported (Lubar, 1991; Thompson & Thompson, 1998; Thornton & Carmody, 2005). Given that symptoms of inattention, and not hyperactivity/impulsivity, are most associated with learning difficulties and academic problems (Bauermeister et al., 1992; Chhabildas et al., 2001; Willcutt & Pennington, 2000) and the literature suggesting that neurofeedback is most efficacious for ameliorating symptoms of inattention (Arns et al., 2009; Monastra, Monastra, & George, 2002), more well-designed research is warranted. However, a veritable dearth of studies on the efficacy of neurofeedback for academic achievement and ADHD remains. Indications are that neurofeedback has the potential to find considerable utility as an intervention strategy in academic settings for individuals with ADHD; however, much work must be done before its potential can be realized.

**Research Questions**

**Question 1:** ***Will neurofeedback enhance attention as measured by CPTs?***

CPTs have long been used in the assessment of individuals with ADHD and research has demonstrated they are capable of differentiating children with ADHD from others (Barkley, 1991; Greenberg, 2009; Halperin et al., 1992; Sandford & Turner, 2009b). In addition, research indicates that performance on CPTs "suggest significant parallels with current models of attention" (Riccio, Reynolds, Lowe, & Moore, 2002) and that there is a direct relationship between outcomes on these tests and levels of impairment. It is therefore hypothesized that following 40 sessions of neurofeedback

(details on the specific protocols to be used will be described later) improvements will be observed on CPT performance.

**Question 2:** ***Will neurofeedback improve performance on measures of reading fluency?***

No research has been identified that specifically examines the efficacy of neurofeedback to improve reading fluency. There are, however, studies that have demonstrated improvement in processing speed and variability (particularly as measured by CPTs), as well as consolidation of attention (Rossiter, 2002; Thornton & Carmody, 2005). Given these findings, changes in attention, particularly those pertaining to any improvements in efficiency (e.g., speed and variability) may translate into changes in reading rate (speed) and/or a reduction of errors made while reading. It is currently unknown if improvements in attention will generalize to reading fluency. It is believed that this is the first study to exam neurofeedback and reading fluency.

**Question 3:** ***Will neurofeedback improve performance on measures of reading comprehension?***

To date, only one study (Orlando & Rivera, 2004) has specifically examined the use of neurofeedback to enhance reading comprehension. That study, however, is beset with serious design and methodological problems and therefore can only be considered for its heuristic value. As previously discussed, a limited number of other studies have also provided preliminary evidence that reading comprehension improves with neurofeedback training. Rossiter (2002) documented a case study of a 13-year-old boy with ADHD who received forty-five 36-minute sessions of neurofeedback training that

used protocols to decrease theta/beta ratios, over a four month period. He reported a very large increase in reading scores (7.3 grade levels and 31 standard score points) on the Kaufman Test of Educational Achievement-Brief Form. A review of records by Thompson and Thompson (1998) for 98 children from their ADHD clinic also noted statistically significant increases on achievement tests and consistent reports of improvement in reading comprehension from parents and teachers after 40 sessions of neurofeedback training using protocols to reduce theta/beta ratios.

## Chapter 3: Methods

### Participants

Five participants were selected from a single elementary school located in southern California. The sample included an ethnically diverse group of students consisting of four boys and one girl, all between the ages of nine and ten. The participants were selected from a larger pool of potential candidates ($n \approx 15$) that included school referred students in grades 3 to 5, all of whom had profiles that suggested an attention deficit. Screening procedures, listed below, were used to eliminate students who did not meet this study's criteria.

**Description of setting.** Participants were students in general education classrooms at the Sunny Shoals Elementary School[1], one of many schools within the large Maritime Unified School District (MUSD). The school is located in a relatively affluent suburban coastal community of southern California. During the 2012/2013 school year, 611 students in grades K to 5 were served by 18 general education classroom teachers and four special education teachers.

Children at Sunny Shoals have access to many resources. Special needs students receive services from credentialed teachers in one Resource Specialist Program (RSP) and three Autism Special Day Classes. All students participate in music programs taught by credentialed music teachers with children in grades K to 3 receiving one half-hour of instruction each week and all students in 4th and 5$^{th}$ grade participating in band, orchestra, or choir. Additional services are provided by support staff that includes a

[1] The name of the school and school district are pseudonymous.

school psychologist, a speech-language specialist, and others. The school also has a library, two computer labs, and a science lab.

The Sunny Shoal School's Accountability Record Card and demographic data provided by MUSD (Table 2) indicates that the school has a culturally diverse student body. During the 2011/2012 school year (the most recent data available), 18.5 percent of students came from socioeconomically disadvantaged backgrounds, 15.4 percent were English language learners, and 11.3 percent were identified with disabilities. The school is also the site of a new Mandarin Language Immersion Program that currently serves Kindergarten and 1st grade students.

**Institutional Review Board (IRB)**. All procedures for this research met the stringent requirements of the University of California, Riverside Human Research Review Board (HRRB; Appendix 1). One of the conditions required for approval of this study prohibited the researcher from actively soliciting participants; all students had to be referred by school officials. Specifically, the school psychologist and administrators identified candidates (blind to the researcher) for screening based on reviews of educational records. Students with profiles suggestive of ADHD, the inattentive subtype were referred for screening; participants were not required to have a medical diagnosis of ADHD.

As noted previously, more research exists on the hyperactive/impulsive and combined subtypes than on the purely inattentive subtype (Dige et al., 2008; Nigg, 2005). Therefore, it was the intent of this study to examine the impact of neurofeedback as an intervention strategy for children with the inattentive subtype. Potential participants who

did not meet criteria for ADHD or those with profiles indicative of either the ADHD hyperactive or combined subtypes were excluded.

**Participant selection process**. School officials consulted with classroom teachers and special education personnel to identify other potential candidates. The target group included students in the third, fourth, and fifth grades, between the ages of 8 and 10, as children of this age have already received several years of reading instruction and surpassed the age-of-onset criterion for ADHD as established by the DSM-IV-TR (APA, 2000). As designed, this study originally required six participants assigned to three cohorts (although nine participants were requested from the IRB [Appendix 1]). Due to concerns with labeling issues, the researcher was not permitted to provide staff development opportunities for instructional staff on ADHD, inattentive subtype or neurofeedback in order to describe the study or to describe the differences between the inattentive and hyperactive/impulsive subtypes. Each child's school attendance record was also considered in order to help minimize absences and attrition during the study.

Once the initial pool of potential candidates had been identified ($n \approx 15$), the school provided each student's parents with a packet containing an information letter (Appendix 2) and a consent form (Appendix 3). Due to the requirements of the IRB, two sets of consent and assent forms were required; one for the initial screening process (described below) to identify students who exhibited symptoms of an attention deficit that were consistent with the requirements of this study and another for the second phase of screening that included an evaluation of EEG.

The parents of ten students returned signed initial consent forms and each of their students were provided with, and signed, an assent form (Appendix 4). The students who participated in the initial screening process consisted of one student in third grade, eight students in fourth, and one student in fifth. All of these students were between nine and ten years of age.

Following the initial screening process, three participants (two in fourth grade and one in fifth) did not meet the study's criteria and were excluded. This left seven students, all of whom appeared to be good candidates, to continue. The second set of letters (Appendix 5) and consent forms (Appendix 6) were sent to the parents of these students. In addition, the remaining participants were asked to sign a second assent form (Appendix 7).

One fourth grade student's parents declined to give consent for the second phase of screening and their child was excluded from the rest of the study. Although all consent and assent forms were signed for the third grade student, that child became anxious immediately prior to the beginning of the final assessment (a qEEG evaluation) of the second screening phase and withdrew from the study. Of the five students remaining, all completed screening procedures and participated in the study. The decision was made to proceed with five students assigned to three cohorts; the final cohort contained one student.

**Selection criteria**. In addition to the age/grade, consents, expressed interest, and school attendance requirements previously discussed, students selected for the study met the following inclusionary criteria:

- Ratings by a parent and/or a teacher on an ADHD rating scale that exceeded the cutoff for an attention deficit,
- Demonstrated impaired performance on a CPT that was consistent with ADHD,
- A FSIQ $\geq$ 80,
- Elevated theta/beta ratios $\geq$ 4.0 (theta = 4 to 8 Hz, beta = 15 to 18 Hz), and
- EEG/qEEG profiles consistent with ADHD.

Further clarification of these selection criteria are described in the measures section that follows. Students who otherwise met the above criteria were excluded from participation if screening procedures indicated a diagnosis of either the ADHD hyperactive/impulsive or combined subtypes. The presence of comorbid conditions (e.g., seizure activity, brain injury, psychiatric conditions such as anxiety, depression, or other brain-based impairments) would have also resulted in exclusion from participation; however, no potential candidates were excluded for these reasons.

**Measures**

**Screening measures**. Participant selection was based on pre-established criteria that identified students with profiles consistent with the current definition of ADHD, as defined by the DSM-IV-TR. Children with an existing diagnosis (made by a qualified medical professional) of ADHD, Inattentive Subtype were considered for inclusion. As discussed earlier, there are no "gold standards" for the identification of children with attention deficits and, therefore, several measures were used for participant selection.

***Student Health History Questionnaire.*** Parents were asked to complete a Student Health History Questionnaire (Appendix 8). In addition to demographic information that included each participant's name, age, gender, grade, and ethnicity (Table 3), information was obtained about each participant's medical history, and examined to see if it indicated an existing diagnosis of ADHD. This information was used to determine eligibility; students diagnosed with the inattentive subtype were considered and those diagnosed with either the hyperactive/impulsive or combined subtypes were excluded. Two participants had been previously diagnosed with ADHD and two additional students had parents indicate a family history of the disorder. Data obtained from the final group of participants are listed in Table 4. Students with comorbid psychiatric conditions, disruptive behavior disorders, head injuries, or a family history of seizure disorders were excluded from participation as the presence of these disorders had the potential to interfere with study outcomes and require different neurofeedback protocols than those used.

Parents of participants were asked at the onset of the study to disclose if their child was receiving pharmaceutical interventions. Many medications can influence EEG and therefore interfere with or confound study outcomes. Therefore, potential participants were excluded from the screening process if they received pharmaceutical or other independent medical interventions for ADHD, especially if they received psychotropic medications (i.e., stimulant or other prescription medications). In the event that participants began medical interventions during the study, parents were requested to disclose this information as it was relevant to the final analysis; especially since

modifications, changes, and titrations of these treatments could affect progress monitoring and the results of outcome measures.

***School records***. Additional data were gathered on whether each student had been referred by a teacher for possible participation in special education programs, had been recommended for IEP/Section 504 programs, and had been found eligible for services. Although all students had received teacher referrals for special education services, only two had been recommended for IEP/Section 504 plans, and just one had been found eligible. All teachers reported that referred students appeared to have problems with attention in the classroom environment.

***Conners 3 ADHD Index*** (Conners 3AI; Conners, 2008a). The Conners 3AI is a screening instrument designed to differentiate ADHD children, ages 6 to 18, from typically developing peers (Arffa, 2010) and requires approximately five minutes to administer. There are separate forms for parents (Conners 3AI-P) and teachers (Conners 3AI-T), as well as a self-report form for students ages 8 to 18 (Conners 3AI-SR). The Conners 3AI-SR was not used in this study. Each form contains questions about behaviors observed during the previous month and uses a scale ranging from 0 to 3: not at all true/seldom/never to very much true/very often/very frequently. The Conners 3AI-P and the Conners 3AI-T both contain ten questions (Arffa, 2010; Dunn, 2010).

Raw scores from each form are summed and then converted to T-scores (M = 50, SD = 10) to provide for interpretation that is age and gender specific. T-scores also serve as an indicator of whether the child is more similar to those with a clinical diagnosis of ADHD or to those without a diagnosis. Higher scores indicate greater similarities to

children with a clinical diagnosis of ADHD and lower scores represent fewer similarities. T-scores ≥ 61 suggest that "responses are very similar to those describing youth with ADHD" and may be clinically significant (Conners & Research and Development Department, 2009). Participants will be considered for inclusion in the study if scores from both a parent and a teacher exceed a T-score of 61. A probability score is also provided. This score matches the raw score with those in the normative sample. The score represents the percentage of age-matched individuals with the same score who have been diagnosed with ADHD compared to individuals in the general population. For example, a score of 85 percent would indicate that the score would occur 85 times out of 100 in individuals with ADHD when compared to the general population.

The ranges of internal reliability on the subtests of the parent and teacher scales for ages 6 to 9 are: 3AI-P (0.91), 3AI-T (0.94). Test-retest reliability (adjusted) over a period of two to four weeks are: 3AI-P (0.93), 3AI-T (0.84). The inter-rater reliability coefficient (adjusted) between parent and teacher forms is 0.85. The sensitivity of the 3AI-P is 88% and the 3AI-T is 79% (Conners, 2008b). Data on the specificity of the 3AI-P and 3AI-T are not yet available (Kollins & Sparrow, 2010).

Rating scales such as the Conners 3AI are just one piece of the assessment process. For this study, if there was a discrepancy between raters, and just one rater (parent or teacher) indicated that a potential participant's score exceeded the cutoff, screening continued with other measures to determine if the student's profile was congruent with a diagnosis of ADHD. The test developers indicate that the Conners

should not be relied on as the exclusive measure to determine if an individual meets criteria for ADHD (Conners, 2008b).

***Integrated Visual and Auditory Continuous Performance Test*** (IVA+Plus; Sandford & Turner, 2007). Researchers have noted that CPTs are able to discriminate between children with ADHD and typically developing peers (Halperin et al., 1992). In addition, children with attention deficits exhibit impaired performance on CPTs that use auditory or visual tasks (H. L. Swanson, 1983). Children with impairments that extend across both of these domains are believed to be at greater risk for problems with academic performance (Aylward, Brager, & Harper, 2002). Tinius (2003) reported that individuals diagnosed with ADHD exhibit impaired performance on the IVA (the predecessor of the IVA+Plus) on measures of reaction time, inattention, impulsivity, and variability of RT.

The IVA+Plus is a 13-minute CPT that uses both visual and auditory prompts to provide an objective measure of behaviors that are associated with the core symptoms of ADHD. During the test, participants are presented with one of two visual targets (the numeral "1" or the numeral "2") displayed on a computer screen. Similarly, the words "one" or "two" are presented aurally (via the computer). Audio and visual targets are displayed in pseudo-random order for 500 trials, 1.54 seconds apart, with each presentation lasting for 500 milliseconds. Whenever the numeral "1" appears on the screen or the number one is spoken, the subject is required to respond by clicking once on a computer mouse. The failure to respond to "1s" is considered an error of omission and provides a measure of inattention. Presentations of the "2s" serve as foils and responses

to these are considered as errors of commission, a measure of hyperactivity and impulsivity. The number of mouse clicks for all responses (correct and incorrect) and response times (in milliseconds) are recorded and evaluated.

The set of 500 trials is further subdivided into two types of smaller "blocks" consisting of 50 trials each and are alternated throughout the test. A "frequent block" contains a predominance of targets ("1s") with fewer foils ("2s"). These blocks serve as a measure of impulsivity by requiring continuous responses to targets (84% of the time) that suddenly require the participant to inhibit responses. A "rare block" is a mirror of the preceding frequent block in that targets ("1s") have been replaced with foils ("2s") and vice versa; these provide a respite from the high demands made of participants during frequent blocks as targets are present for just 16% of the trials while foils are present for 84%. Rare blocks provide a measure of sustained attention and vigilance. The use of alternating frequent and rare blocks is intended to control for fatigue and practice effects (Sandford & Turner, 2009b).

The IVA+Plus then calculates and provides scores, based on test data, clustered around several categories referred to as: response control, attention, attribute, and symptomatic, with the first two serving as the primary diagnostic tools of the CPT (Sandford & Turner, 2009a). The response control score is used to "describe problems of response inhibition, sustaining effort, and making consistent responses" (Sandford & Turner, 2009b, p. 27). It is designed to serve as a measure of ADHD, Hyperactive-Impulsive Subtype that is based around Barkley's (1993) theory that the most salient feature of the subtype is represented by a primary deficit in response inhibition. The

attention score provides measures of vigilance (problems with inattention), loss of focus, and slow processing speed; it is used to identify symptoms associated with ADHD, inattentive subtype as described by the DSM-IV (Sandford & Turner, 2009b). Each score consists of a quotient (standard) score that is derived from separate auditory and visual scores. These are, in turn, derived from three additional subscales (Figure 2).

The attribute scores consist of two scales: balance and readiness. The balance scale examines the reaction times of correct responses to visual and auditory targets and provides an indication of whether the test-taker performs better on visual or auditory tasks. The readiness scale compares reaction times during high intensity conditions (frequent blocks) and low intensity conditions (rare blocks). The readiness scale is used to suggest whether the test taker is able to better maintain alertness under high or low demand situations.

Symptomatic scores provide three additional sets of scales that examine comprehension (effort by the test-taker to respond appropriately and not randomly) and persistence. The latter exams the responses made during the IVA+Plus' "Warm-up" and "Cool-down" phases. These scores are used to suggest if the test taker exhibits compliance with test instructions. A Sensory/Motor scale also exams reaction times during the test's "Warm-up" and "Cool-down" phases when very low-level demand targets are presented intervals at between 1.5 to 2.5 seconds without foils. The scale is an attempt to determine if there are any underlying sensory or motor impairments (other than attention) that may have influenced overall test performance (Sandford & Turner, 2009b).

Each of the quotients, scores, and subscales are described in the IVA+Plus Interpretation Manual (Sandford & Turner, 2009b) as follows:

[Full-Scale] Response Control Quotient (FS-RCQ; hyperactivity/impulsivity):

1. **Prudence** is a measure of impulsivity and response inhibition as evidenced by three different types of errors of commission. [Errors of commission are false responses to foils ("2s") rather than targets ("1s"). The errors of commission examined by the IVA+Plus are: impulsivity, propensity, and mode shift. Impulsivity errors occur when a response is provided to a foil ("2s") during frequent blocks. Propensity errors occur during the transition between frequent blocks (when a large number of responses to "1s" are required) and rare blocks (when targets are only present for 16% of the trials). Propensity errors occur at the beginning of rare blocks when two foils ("2s") are presented and the test taker provides a response to the second foil. Mode shift errors occur during rare blocks when two or more visual foils ("2") are presented, followed by an auditory foil ("2") and are an indication that the test taker exhibits impulsivity, exhibits difficulties "shifting" between visual and auditory stimuli, and/or overreacts to unexpected change].
2. **Consistency** measures the general reliability and variability of response times and is used to help measure the ability to stay on task.
3. **Stamina** compares the mean reaction times of correct responses during the first 200 trials to the last 200 trials. This score is used to identify problems related to sustaining attention and effort over time (p. 9).

[Full Scale] Attention Quotient (FS-AQ; inattention):

1. **Vigilance** is a measure of inattention as evidenced by two different types of errors of omission.
2. **Focus** reflects the total variability of mental processing speed for all correct responses.
3. **Speed** reflects the average reaction time for all correct responses throughout the test and helps to identify attention processing problems related to slow discriminatory mental processing (p. 9).

Both the FS-RCQ and FS-ACQ scores are comprised from auditory and visual subscales; the Auditory Response Control Quotient (A-RCQ), the Visual Response Control Quotient

(V-RCQ), the Auditory Attention Quotient (A-AQ), and the Visual Attention Quotient (V-AQ), respectively.

A study of the IVA+Plus' validity reveals a sensitivity of 92%, specificity of 90%, and a concurrent validity with other diagnostic instruments (Test of Variables of Attention CPT [TOVA], the Gordon CPT, the Conners Abbreviated Symptom Questionnaire, and the Conners Rating Scales) ranging from 90% to 100% (Sandford & Turner, 2009b). Test-retest reliability, covering a span of one to four weeks, has a range of 0.66 to 0.75 for AQ scores (inattention) and 0.37 to 0.41 for RCQ scores (hyperactivity/impulsivity). Concurrent validity with other CPTs including the TOVA and the Gordon Diagnostic System is 0.9 and 1.0, respectively. Maddux (2010) has noted that the reliability and validity data may not be sufficient as they are based on a small group of 70 individuals, ages 5 to 70.

Test results from the IVA+Plus are analyzed using algorithms described in the IVA+Plus Interpretive Flowchart For ADHD (Sandford, 2005). A Combined Sustained Attention (C-SA) score (found only on the IVA+Plus Core ADHD Interpretive Report), derived from an Auditory Sustained Attention (A-SA) quotient scaled score and a Visual Sustained Attention (V-SA), is used for this analysis. In the event that results suggest an individual has ADHD, the flowchart is used to match observed characteristics with one of the three subtypes, ADHD not otherwise specified (ADHD-NOS), or suggests that another cognitive disorder may be indicated. Should results identify test takers as ADHD-NOS or with a cognitive disorder, further evaluation is recommended. Potential

participants with scores that were indicative of an attention deficit were considered for the study.

***Wechsler Abbreviated Scale of Intelligence – Second Edition*** (WASI-II; Wechsler, 2011). The WASI-II is a 15-minute intelligence test for individuals ages 6 to 90 and provides estimates of Verbal IQ (VIQ), Performance IQ (PIQ), and FSIQ[2] that are derived from four subtests: Vocabulary, Similarities, Block Design, and Matrix Reasoning. All scores have a mean of 100 and a SD of 15, with a range from 40 to 160. For children ages 8 to 9, split-half reliabilities range from 0.85 to 0.91 for the subtests and 0.90 to 0.96 for the IQ scores. Concurrent validity with the WISC-IV, have correlations ranging from 0.73 to 0.83 on the subtests and 0.79 to 0.91 for the IQ scores. A FSIQ $\geq$ 80 was used as a criterion for participants to be included in this study.

***Woodcock Reading Mastery Test, Third Edition*** (WRMT-III; Woodcock, 2011). The WRMT-III is a standardized measure of reading readiness, basic skills, and comprehension. It consists of a battery of tests that measure several important aspects of reading ability: word identification, word attack (ability to read "nonsense" words), listening comprehension, word comprehension (antonyms, synonyms, and analogies), passage comprehension, and oral reading fluency (Woodcock, 2011). Split-half reliability coefficients are provided by age level; for ages 9 and 10 subtests range from 0.85 to 0.96. Concurrent validity with other tests of reading achievement including the WRMT-R/NU

[2] The WASI-II provides two FSIQ scores, the FSIQ-4, which is derived from all four subtests and the FSIQ-2, which is derived from Vocabulary and Matrix Reasoning subtests. The FSIQ-4 was used for the IQ estimate in this study and shall be referred to as the FSIQ.

and the WIAT-III is 0.85 and 0.89 respectively. The WRMT-III was used as a screening device to assess reading achievement.

**Neurofeedback software and equipment.**

***SmartMind Pro Neurofeedback System*** (SmartMind Pro; Sandford, 2012). SmartMind Pro, an EEG software application developed by BrainTrain of Richmond, VA, was used for this study. The software ran on a laptop computer using Microsoft's Windows 7 operating system that was connected to the SmartMind Two-Channel EEG Station. Precious metal (gold) disk recording electrodes and ear clips, by Grass Products, were used to measure EEG. Electrodes were attached using Ten20® conductive paste following preparation of the skin using Nuprep®. Ear clips were attached using Signacreme® Electrode Cream.

SmartMind Pro displays each participant's EEG in real time with output customizable to show only the bandwidths selected for training. Although neurofeedback can be accomplished using some of the clinical screens (Figure 5), games including the one presented in Figure 2 were used. Although some SmartMind games require the use of a mouse, only those the only used EEG were implemented in this study in order to avoid variability that might be attributed to operating the computer through physical activity. The software records and maintains information about each activity within a session; these data include the mean amplitude of EEG bandwidths being trained in Hz, standard deviation of each frequency band, and session time. Graphs (Figure 6) can be generated to display changes in the ratio between two frequency bands over time and the software maintains statistics for each session.

SmartMind was used during the final stage of the screening process to identify potential participants with elevated theta/beta ratios. Studies have shown that higher ratios are particularly observable over the frontal and central, midline regions. Elevated ratios are considered to be the primary electrophysiological indicator found in the qEEGs in individuals with ADHD (Monastra et al., 2005; Snyder & Hall, 2006). Research has reported that the individuals with ADHD who benefit most from neurofeedback are those with elevated theta/beta ratios (Monastra et al., 2002).

***qEEG software and equipment***. The qEEG assessments were conducted using WinEEG software developed by Nova Tech EEG, Inc. Data were collected with a 21 channel Mitsar EEG-201 amplifier. Similar to the equipment used with SmartMind Pro, precious metal (gold) disk recording electrodes and ear clips, by Grass Products, were used to measure EEG at all 19 standardized locations established by the International 10/20 System (Figure 1; Jasper, 1958). Electrodes were attached using Ten20® conductive paste following preparation of the skin using Nuprep®. Ear clips were attached using Signacreme® Electrode Cream. Following each assessment, statistical analysis was completed using NeuroGuide software (Thatcher, 2013) and compared with a normative database. qEEG results were then examined by an expert in qEEG evaluations, a medical doctor, and a clinical psychologist, all of whom had extensive experience in qEEG assessments.

**Baseline and outcome measures.**

***Gray Oral Reading Tests - Fifth Edition*** (GORT-5; Wiederholt & Bryant, 2012a). The GORT-5 is a standardized norm-referenced test of oral reading skills and

provides measures of rate, accuracy, fluency, and comprehension. Students are presented with a series of scaled passages that increase in difficulty. Students begin reading passages based on grade-level recommendations provided by the test developer. In the event that examinees fail to meet a basal level on the first two passages read, reading continues on to more difficult passages until a ceiling is reached and then preceding passages are read until a basal can be determined (Wiederholt & Bryant, 2012b). Rate and accuracy are scaled scores (scaled from 1 to 20 with a mean of 10 and a SD = 3) derived from the speed with which each passage is read in seconds and the number of words read correctly, respectively. The fluency score is derived from the rate and accuracy scores. Comprehension is a scaled score derived from correct responses to open-ended passage-dependent questions. An Oral Reading Index (ORI) provides a composite score derived from the fluency and comprehension scores.

Previous editions (e.g., the GORT-3 and GORT-4) required students to answer multiple-choice questions about each passage. In these earlier editions, the comprehension questions were read aloud while students were also permitted to read them; students were not permitted to reexamine each passage. Keenan and Betjemann (2006) reported a significant problem in that more than half of the comprehension questions in the earlier editions could be answered correctly, even though the passages had not been read, based upon contextual features within each question and the general knowledge background of examinees. This led them to conclude that the comprehension score lacked both content validity and concurrent validity. Their criticisms, however, were only limited to the comprehension score and they reported that they found

considerable support for other scores pertaining to oral reading fluency. O'Connor et al. (2013) suggest that the problems with passage-independence on the earlier editions may be attributable to background knowledge and may negatively influence comprehension scores of children from disadvantaged homes or who are English learners (EL).

The passage-independence problem was addressed by test developers in the GORT-5; the multiple choice questions were eliminated and replaced with open-ended passage-dependent ones (Hall & Tannebaum, 2013). Examinees are no longer permitted to view printed copies of the questions; thus, the GORT-5 may provide a more accurate assessment of reading comprehension. Furthermore, the GORT-5 uses essentially the same passages as the previous versions. Unlike passages found on the WRMT, which may result in scores more reflective of decoding skills rather than comprehension, the passages on the GORT-5 are longer and may be more closely aligned with requirements for reading comprehension found in a classroom (O'Connor et al., 2013).

The GORT-5 contains two alternate forms that may be used for pre- and posttest assessments and research; both tests require approximately 15 to 45 minutes to administer (Wiederholt & Bryant, 2012b). The reliability coefficients for the subtest scores on each form exceeds > 0.85; the ORI coefficient on each from is 0.96 and 0.97, respectively. Test–retest reliability on each form, administered one to two weeks apart, is 0.82 to 0.90. When one form was administered, followed by the alternate form, the test–retest reliability is 0.77 to 0.88 (Hall & Tannebaum, 2013; Wiederholt & Bryant, 2012b).

***qEEG Assessment***. As noted previously, qEEG assessments provide very high temporal resolution of EEG activity and deliver low resolution "maps" of brain function.

With a sensitivity of 93.7% and a specificity of 88% as reported by Chabot and Serfontein (1996), qEEG maps, as well as the accompanying data, provide the most state-of-the-art method for identifying children with ADHD. As these assessments must be conducted by highly trained specialists and medical professionals, and also require considerable expertise to interpret; only the final set of candidates being considered as participants were evaluated. qEEGs were used as a baseline measure and confirmed that participants were good candidates for neurofeedback with profiles that were indicative of the ADHD, inattentive subtype. In addition, the initial qEEG assessment served as a final screening device to exclude potential candidates with comorbid conditions that may not have been readily apparent (i.e., seizures, brain injuries, anxiety, depression, etc.), especially since these conditions require different neurofeedback training protocols that may have conflicted with those to be used in this study. Data obtained from the qEEG assessments were considered when developing the neurofeedback protocols that addressed the unique EEG profiles of each participant.

**Progress monitoring measures**. Participants had their progress monitored throughout the study on measures of attention, reading comprehension, and reading fluency. In addition, data were collected during each session by the neurofeedback software and contained information pertaining to each participant's EEG, as well their progress towards goals.

***CNS Vital Signs*** (CNS-VS; Gualtieri & Johnson, 2006). CNS-VS is a battery of computerized neurocognitive tests (CNT) that consists of several commonly used neuropsychological assessments including measures of: verbal and visual memory, finger

tapping, symbol digit coding, a Stroop color test, shifting attention, and a CPT. The CNS-VS Shifting Attention Test (SAT) provided a measure of attention during progress monitoring and also provided a measure of executive function that may indicate the presence of an attention deficit (Gualtieri & Johnson, 2006). Throughout the administration of the SAT, participants are presented with two geometric shapes (e.g., a circle and a rectangle) that are randomly assigned to one of three positions on a computer monitor; one that appears along the top portion of the computer monitor that is centered horizontally, and two on the bottom that appear on each side (Figure 7). In addition, these shapes are randomly assigned one of two colors, blue or red. Participants are then given one of two tasks; select the correct figure on the bottom of the monitor that matches either the color or the shape of the figure on the top, as directed by a written prompt that appears that above the top shape. This procedure begins with a practice set that requires approximately 30 seconds to complete. The practice session is then followed by a 90-second assessment. Scores are provided for correct responses, number of errors, and correct reaction time in milliseconds. The test-retest reliability of the SAT for ages 7 to 90 (based on a normative sample, n=99) with a median interval of 27 days, ranges from 0.69 to 0.80 (Gualtieri & Johnson, 2006).

***Dynamic Indicators of Basic Early Literacy Skills (DIBELS).*** The DIBELS test of Oral Reading Fluency (ORF) is a standardized measure of reading rate and accuracy. This task requires students to read aloud for one minute from graded passages. Outcomes are measured in terms of the number of words read correctly. Scores are calculated based on the total number of words read per minute minus the number of errors. Although one

review of the test indicates that alternate form reliability is 0.92, test-retest reliability is 0.92 to 0.97, and concurrent validity with other tests is 0.80 (Shanahan, 2005), the author notes that access to this information was difficult to obtain from the developer. Others have also reported that the information on the psychometric properties of the test is sparse and that some statistics are based on older studies (Bellinger & DiPerna, 2011; Collaborative Center for Literacy Development, 2011; Pearson, 2006).

***AIMSweb Reading Curriculum-Based Measurement*** (R-CBM; Shinn & Shinn, 2002a). The R-CBM was used for baseline and progress monitoring. The instrument is a skills-based reading assessment designed to monitor reading comprehension and reading fluency. Reading comprehension is measured using the R-CBM Standard Maze Passages (Maze), a multiple choice cloze task. The Maze requires participants to read silently for three minutes. The first sentence is complete. Every 7$^{th}$ word after that is replaced with a set of three words of which only one is correct (Figure 4). Participants are asked to select the correct word and correct and incorrect responses are counted to obtain raw scores (Shinn & Shinn, 2002b). Validity coefficients on the R-CBM range from 0.60 to 0.80 (Shinn & Shinn, 2002a). The test-retest reliability of the R-CBM Maze for grades 1 to 7 (the time between administrations was not noted), has a range of 0.66 to 0.91 (National Center on Response to Intervention, 2012).

**Procedures**

**Research design**. Studies using single-case design (SCD) have been of considerable utility in the development of evidence-based practices in special education (Horner et al., 2005; Kennedy, 2005; Kratochwill et al., 2010), applied and clinical

psychology (Chambless & Hollon, 1998; Gustafson, Nassar, & Waddell, 2011), and within the field of neurofeedback (Kratochwill et al., 2010). SCDs are used to establish causal relations between independent and dependent variables. In other words, by examining whether experimental control of an independent variable produces a consistent effect on a dependent variable, SCDs can determine if there is a functional relation between the two (Kennedy, 2005). Unlike correlational studies that use randomized control-group designs requiring a large number of participants, SCD research needs just a few participants (i.e., one to twelve), with each serving as his or her own control. Individual performance of each participant is examined prior to, during, and after the intervention (Horner et al., 2005). Although disagreements exist regarding the minimum number of participants required within a SCD to lend support that an intervention is efficacious, Chambless and Hollon (1998) suggest that three or more are required, along with replication of the study from another independent research site, to suggest that the treatment is "possibly efficacious."

Horner et al. (2005) noted that SCD has a long-established history that has been particularly useful in research that has studied the principles of behaviorism and conditioning. Indeed, one of the earliest studies that demonstrated EEG could be conditioned used a SCD. Knott and Henry (1941) found that classical (not operant) conditioning of the alpha-blocking response was possible. The first neurofeedback study that examined operant conditioning of EEG to alleviate symptoms of ADHD also used a SCD. Specifically, Lubar and Shouse (1976) reported that operant conditioning of EEG

to enhance SMR, in a single participant, reduced symptoms of hyperactivity and improved scores on behavioral assessments in an elementary school classroom.

This study used a multiple-baseline-across-participants SCD model. This model requires that participants begin the initial baseline phase at the same time and they are then staggered into the intervention phase. The reason for this is that each participant not only serves as his or her own control but is also the unit of analysis (Horner et al., 2005). By staggering the introduction of additional participants, researchers are able test if the effect of the intervention on a single case replicates multiple times and therefore permit within- and between-participant comparisons (Kratochwill et al., 2010). Doing so helps control for threats to internal validity (Horner et al., 2005). Kratochwill et al. (2010) state that staggering participants also permits causal inferences to be made on the effect of the intervention on the outcomes.

Neurofeedback training, based on qEEG-guided protocols is the independent variable. Reading achievement (as measured by scores on the GORT-5, AIMSweb Maze, and DIBELS ORF) and attention (as measured by the IVA+Plus and SAT) serve as the dependent variables. Pre- and post-intervention qEEG maps were compared to examine changes in brain function.

Unlike other SCD models, multiple baseline designs do not require the withdrawal, reversal, or repeated alterations of the independent variable. Prior to the commencement of this study, participants selected during the screening process were randomly assigned to one of three sets (Cohort 1, Cohort 2, and Cohort 3), with two participants in each one (Table 5). When one student declined to participate at the end of

the second phase of screening, the decision was made to continue with just one student in Cohort 3 as screening for an additional participant would have delayed the entire study until the following school year.

***Screening***. Prior to the commencement of the study, all consent and assent forms were signed, the Student Health History was completed and evaluated, and the Conners 3AI (parent and teacher versions) were completed. All eligible candidates were administered the IVA+Plus, WASI-II, and the WRMT-III. The results of all measures were tabulated and assessed to ensure that participants met criteria.

IVA+Plus results (Table 6) confirmed that all participants expressed symptoms of inattention; their FS-AQ standard scores ranged from 54 to 99 and C-SA ranged from 28 to 91. All participants met criteria for FSIQ, with IQ estimates ranging from 90 to 107 (Table 11). Results from the WRMT-III (Table 12) indicated that participants' Total Reading (standard) scores, derived from the Basic Skills and Reading Comprehension cluster scores ranged from 84 to 112. Oral Reading Fluency standard scores ranged from 85 to 100. One student, Webster[3], obtained high scores on several of the WRMT-III subtests and obtained a Reading Comprehension cluster score of 124. His Oral Reading Fluency Score, however, was 96. Although Webster appeared to be a good reader, this study's exclusionary criteria did not address ceilings on screening instruments and as this participant met criteria on all other measures, he was retained as a participant.

The qEEG evaluations were the last assessments to be done and arrangements were made with Brain Science International (BSI), which had provided a technician, to

[3] The names of all participants are pseudonymous.

conduct the process at Sunny Shoals Elementary School. All students were assessed during the school day (although one student had to be rescheduled a few days later as he was absent). For this procedure, electrodes were placed each of the 19 locations on the scalp, using the International 10/20 System, as well as at A1 and A2 for the ground and reference (Figure 1; Jasper, 1958), after being prepared with Nuprep®. Precious metal (gold) electrodes were applied using Ten20® conductive paste and precious metal (gold) ear clips were attached with Signacreme®. Impedance was checked to ensure levels were ≤ 10 K ohms. Participants' EEG was assessed under three conditions: 10 minutes with eyes closed, 5 minutes with eyes open, and 5 minutes during a reading task (using grade level materials). During each assessment, participants were monitored by the technician to reduce EMG artifact. They were provided with instructions such as, "Relax your jaw," "Don't clench teeth," "Watch the blinking," "Keep your eyes still," "Relax," "Try to keep still," etc. as EEG was being recorded.

Interpretations of the results were made by an expert in qEEG evaluations from BSI and then approved by a medical doctor (neurology), with all data and reporting compliant with the Health Insurance Portability and Accountability Act (HIPAA) to ensure participant confidentiality and privacy. The final qEEG-guided protocols were then evaluated and approved by a third-party clinical psychologist with expertise in qEEG assessment who had been approved as a consultant for this research by the ISNR. These individualized protocols were developed for each participant with the intent to maximize the efficacy of the neurofeedback training.

***Baseline phase***. All participants began the baseline phase at the same time. During this phase, EEG assessment commenced and students were introduced to the neurofeedback equipment and software. The procedure for each participant included placing an active electrode at Cz, as well as reference and ground electrodes at A1 and A2, respectively. After ensuring good connections, EEG was monitored for three minutes using an eyes open condition. Although monitoring continued throughout baseline, participants did not receive neurofeedback training.

Progress monitoring also commenced during this phase and each participant was assessed on a daily basis with the Maze, ORF, and SAT. Once Cohort 1 had established a stable baseline (based on the assessment of the EEG theta/beta ratio), they proceeded to the intervention phase where they received 30 minutes of neurofeedback training, five days per week, for 40 sessions. In the event of absences or other unforeseen circumstances, training continued until 40 sessions have been completed. An examination of the literature indicates that 40 sessions is considered sufficient to operantly condition EEG in individuals with ADHD (Lofthouse et al., 2011). Some studies, however, have reported that as few as 20 sessions produce a significant reduction of symptoms (Rossiter & La Vaque, 1995).

***Intervention phase***. During the first week of the intervention phase, participants received an additional four minutes of training each day to reduce EMG artifact. Artifact is defined as the intrusion of electrical activity of the facial muscles into the EEG. It is caused by movement of the eyes, eye blinks, and facial/head muscles. Although SmartMind provides algorithms to automatically remove heart rate and facial artifact

from EEG, training was conducted to help participants to "relax their face" and reduce muscle electrical activity (measured from 33 to 48 Hz); this served to help minimize unnecessary facial/head movement that could reduce the efficacy of neurofeedback training (BrainTrain, 2011). Following the EMG training during first week, participants' EMG was assessed to calibrate SmartMind's automatic artifact removal algorithms that were used throughout the study. EMG was also reevaluated any time that the qEEG-guided neurofeedback protocols were changed.

As mean amplitudes of EEG bandwidths fluctuate throughout the day, as well as from day-to-day, SmartMind provides an automated assessment of EEG to calibrate neurofeedback training goals to adjust for these differences. During this study, a three-minute assessment was conducted at the beginning of each session; the software evaluated the current mean amplitudes of bandwidths being trained and adjusted daily goals accordingly. Specifically, this assessment set filters for each bandwidth so that an improvement in mean EEG amplitude of 0.3 SD from the mean rewarded the participant during training and an improvement of 1.0 SD from the mean was set as the daily target goal. Although training goals were individualized for each participant, typically goals were set to inhibit mean theta amplitude and enhance beta thereby reducing the theta/beta ratio. The precise protocols used with each participant will be discussed later. When participants reduced mean theta amplitude by 0.3 SD they were rewarded by the game; they were rewarded by a greater amount for meeting the threshold of 1.0 SD. Likewise, an increase in beta amplitudes was similarly rewarded. When goals for both a reduction of theta and an increase of beta occurred simultaneously, rewards were the greatest.

Rewards were both visual and aural: visual rewards were often provided in the form of an animated figure moving across on the computer monitor driven by the amplitude of the participant's EEG, and aural rewards were provided by the presence of music or other sounds to indicate success. Failure to meet goals resulted in no (or reduced) movement or sound. Meeting goals for both bandwidths (e.g., theta and beta) simultaneously resulted in faster movement of the animation and increased the volume of sound/music. Each neurofeedback game used the default setting to allow participants to successfully meet goals for each bandwidth 84 percent of the time, and both bandwidths simultaneously 71 percent of the time. These goals were set each day, prior to the training, based on the three-minute assessment of each participant's EEG. Although the probability of success rates could be changed, as well as adjusted on the fly to make training easier or more challenging, the default setting was used for this study.

When visual assessment of the EEG of one or more participants in Cohort 1 indicated change in the desired direction, Cohort 2 began receiving the intervention. This process was repeated until all cohorts had been staggered in. Figure 8 provides an example of the model.

*Intervention protocols*. This study was originally designed to use theta/beta ratio training protocols, with all participants being trained to inhibit theta and enhance SMR/beta. As noted earlier, this protocol was first described by Lubar (1991). Monastra et al. (1999) reported that theta/beta ratios obtained at Cz and Fz produce the most significant differences with other studies (Lubar, 1995; Lubar, Swartwood, Swartwood, & Timmermann, 1995) finding that the differences between individuals with ADHD and

typically developing peers are most pronounced at Cz. This study intended to use the theta/beta protocol in which theta (4 to 8 Hz) is suppressed and beta (16 to 20 Hz) is enhanced (Monastra et al., 2005). A grant, however, was received from Brain Science International that permitted the use of pre- and posttest qEEGs. As a result, qEEG-guided protocols were used to individualize the intervention in an effort to maximize the efficacy of the neurofeedback training.

Given that this study did not commence until relatively late in the school year (February 2013) and the fact that the other screening processes had to be completed prior to the administration of the pre-intervention qEEGs to ensure that only the most viable candidates were evaluated, the participants were not assessed until the day before they were to begin the baseline phase. Furthermore, Cohort 1 had to begin the intervention phase prior to the completion of the qEEG reports in order for the study to be completed prior to the end of the school year. Thus, the decision was made to commence with neurofeedback training for the first ten sessions using standardized theta/beta protocols for all participants, after which qEEG-guided protocols would be used for the final thirty sessions of the intervention.

During the establishment of baseline, EEG recordings were be made with a monopolar montage[4] using an active electrode placed at Cz (Figure 1) as this location is considered optimal for training (Lubar, 1991). Reference and ground electrodes were placed at A1 and A2, respectively. Mean amplitudes of each participant's theta (4 to 8

[4] Monopolar montages require the use of three electrodes; an "active" electrode where the EEG is recorded, a "reference" electrode that is used to record the difference between it and the active electrode, and a "ground" electrode that is used for safety and to protect the equipment.

Hz) were recorded using an eyes open condition for three minutes per session. Two subsets of the beta bandwidth (15 to 18 Hz and 16 to 20 Hz) were also monitored as both of these have been reported in the literature (Gruzelier & Egner, 2005; Monastra et al., 2005). Following the completion of three baseline sessions with all participants, theta/beta ratios were calculated using each of the two beta bandwidths recorded and compared. It was found that for all participants, theta/beta ratios where higher when calculated with the beta bandwidth at 15 to 18 Hz (Figure 9). Given that reductions in the theta/beta ratio are associated with increased attentiveness, the decision was made to provide all participants with 10 sessions of neurofeedback in which theta (4 to 8 Hz) was inhibited and beta (15 to 18) was enhanced. In addition, high beta (18 to 30 Hz) was inhibited as this bandwidth is associated with undesirable EMG artifact.

The qEEG reports and protocol recommendations were received shortly after all cohorts had begun the intervention. The recommendations for individualized neurofeedback protocols are listed in Table 13. These suggestions were analyzed and the theta/beta ratio training that all participants received at the beginning on the study were considered in developing the final protocols. It was decided that the intervention process for all participants would be subdivided into three phases: all students would receive the ten sessions of the theta/beta protocol followed by twenty sessions of qEEG-guided neurofeedback, and then receive ten additional sessions of a second qEEG-guided protocol. Students in all cohorts received the same protocol for the first phase, while the second and third phases were customized based on individual qEEG profiles (Table 14). Neurofeedback sessions were provided each school day until every participant had

received 40 sessions. Efforts were made to ensure that each participant received neurofeedback training at approximately the same time every day. Absences, field trips, and special events were accounted for and students who missed sessions continued with the intervention until they had completed 40 sessions.

*Progress monitoring*. Following completion of each 30-minute neurofeedback session, participants were administered the CNS-VS SAT, R-CBM Maze, and DIBELS ORF. Progress monitoring began with the SAT and included a 30-second practice test, followed by a 90-second assessment of attention and executive function. The practice test could not be disabled so all participants proceeded through that before taking the test.

Participants then completed the three-minute Maze assessment in which they were provided with a graded passage to read. All students were provided with fourth grade Maze and DIBELS materials with the exception of Webster, who was provided with eighth grade passages as his reading abilities were above grade level (discussed below). There are 24 Maze passages available from the publisher but the number of probes required during the study exceeded 40; these included the sessions required to establish baseline. To address this issue, the 24 passages were presented in sequence. They were then randomly reordered and repeated. All students were presented with the same passages in the same order.

Similarly, there are thirty DIBELS ORF reading passages available from the publisher. As the number of probes required for the study exceeded those available, two editions of the ORF were used (each contained a different set of 30 passages) with passages from each alternated every other session. Again, all participants received fourth

grade passage with the exception of Webster, who received the eighth grade set. Participants were asked to read for one minute and their results recorded. All participants were monitored using passages presented in the same order.

*Incentives*. Neurofeedback can be engaging, especially for motivated adults and adolescents who find that training is intrinsically rewarding and perceive it as a positive way to reduce symptoms and achieve control over unwanted behaviors (Rossiter, 2002). Others, particularly children who do not yet understand the implications of the disorder or the potential for long-term benefits associated with neurofeedback, can find that their interest in training wanes after the novelty of the invention dissipates and becomes routine. Although this phenomenon is not published in studies on neurofeedback, consultations with numerous experts in the field indicate that it is common practice to provide incentives to trainees in order to maintain motivation. Just one case study has been identified regarding this practice. Rossiter (2002) discussed the use of a point system that rewarded the participant for exceeding the median theta/beta ratio from the previous session. Given the limited documentation for this apparently wide-spread practice, a reward system was established that was non-contingent on performance but as an incentive to complete each daily session. Initially, students were provided with a chart and for each day that they responded in the affirmative to the question, "Did you try your best today?" were permitted to select a shiny metallic star sticker to record their participation. At the end of each week, students who received stars each day earned a "Friday Surprise" – a small reward valued at ≤ $1. This procedure was used throughout the study until the final two weeks. At that time, the school year was coming to an end

and each day was filled with special activities planned by the classroom teachers; these activities included parties, movies, picnics, school plays, concerts, and many other events. Given the large number of special events, it was difficult to keep students motivated to attend each session so the use of the star chart continued; however, participants also received a reward at the end of each session, as long as they attested to "trying their best." Unlike the Rossiter (2002) study, rewards were not contingent on performance during the intervention but on each participant's personal evaluation of effort.

**Data Analysis**. SCD traditionally relies on systematic visual analysis of data, in which relations between the independent and dependent variables are sought, as well as the strength of the relation between them (Horner et al., 2005; Kennedy, 2005; Kratochwill et al., 2010). As data are gathered, they are plotted and visually inspected to determine if a causal relation can be inferred by changes in the outcome that is attributable to manipulations of an intervention. Effects can be demonstrated when there are observable changes between consecutive phases (i.e., baseline and intervention) that differ from what is expected due to manipulation of the independent variable.

SCD begins with the observation of the dependent variable prior to the introduction of the intervention. This baseline phase serves to document the behavior(s) that will be examined and to establish stable patterns that permit a later comparison with the effect of the independent variable after it has been introduced during the intervention phase (Kratochwill et al., 2010). Thus, changes in outcomes can then be analyzed to determine the efficacy of the intervention. Horner et al. (2005) recommend that

establishment of a stable baseline requires five (sometimes fewer) data points for which there is not a "substantive trend." A baseline may also be established when there is a trend in the opposite direction than expected after the intervention has been introduced.

Once a stable baseline is established and the intervention phase begins, data are continuously plotted and visually analyzed to see if a causal relation can be inferred. Several features of the plot are examined including level, trend, and variability (Kennedy, 2005). Level refers to the mean score within each phase (i.e., baseline and intervention) and if different across phases, serves as in indicator that the invention is having an effect upon outcomes. Trend is a best-fit line overlaid on the data in each phase and contains two elements: slope and magnitude. Slope refers to the direction of the best-fit line and can be positive (the direction of the best-fit line increases over time), flat (the best-fit line remains static), or negative (the best-fit line decreases over time). Magnitude refers to the strength of the slope; a high-magnitude slope is one that increases rapidly, a low-magnitude slope is one that exhibits a subtle increase or decrease. Variability refers to how closely data points are clustered around either the level or trend in each phase (Horner et al., 2005).

Visual analysis of data in SCD also requires attention to the immediacy of the effect, consistency of data, and the proportion of data points that overlap between phases (Horner et al., 2005; Kratochwill et al., 2010). Immediacy of effect refers to the change in level that occurs between phases (e.g., baseline and intervention). In most cases, when rapid change is observed, the stronger the inference that the intervention is effective. However, in cases where effects are delayed, the length of the phase is taken into

consideration. Given that the operant conditioning of EEG often requires multiple sessions before changes are observed, and that 40 sessions are considered typical for neurofeedback training (Lofthouse et al., 2011), it is anticipated that effects will not be immediately observable (Kratochwill et al., 2010). Consistency of data refers to the examination of data across all phases that use the same intervention. Greater similarity is suggestive of a causal relation between the intervention and outcomes.

The proportion of data points that overlap between phases displays the percent of data between two phases that share the same values (Kennedy, 2005). In other words, the smaller the percentage, the more likely it is that the intervention has produced an effect. Overlap is observed by determining the percentage of nonoverlapping data (PND). It is calculated as the proportion of data points that exceed that most extreme data point (in the expected direction) observed during baseline. For example, if seven out of ten data points exceed the maximum value observed during baseline, PND would be calculated as 7/10; therefore, PND = 70% (Scruggs, Mastropieri, & Casto, 1987). As an estimation of the effectiveness of an intervention, Scruggs and Mastropieri (1998) suggest that PNDs > 90% are "very effective," between 70 to 90% are "effective," between 50 to 70% are "questionable," and < 50% are "ineffective."

## Chapter 4: Results

The amount of time each participant contributed to this research was extensive; between the onset of the baseline phase and completion of the intervention phase, participants received 43 to 49 daily sessions, the total was dependent on the cohort to which they were assigned. Variation in the number of sessions received was due to differential baseline phase lengths. During each of the baseline sessions, participants' EEG was recorded. The intervention was divided into three phases with all students receiving the same theta beta reduction protocol during Phase 1: inhibit theta (4 to 8 Hz) and enhance beta (15 to 18 Hz) for the first ten sessions. Phases 2 and 3 used qEEG-guided protocols and contained 20 sessions and 10 sessions, respectively.

Progress monitoring, using Maze, ORF, and SAT provided more data. Many additional days were required for screening, as well as pre- and posttesting. Given the amount of data gathered, results will be provided by individual participant, followed by between-participant comparisons and group results.

### Individual Results

**Participant 1: Mildred**. Students began screening procedures as soon as their signed parent consent forms were returned to the school. Mildred, age 9.6 years, was the first student and only girl to be referred as a participant. Although fluent in English, she also spoke Spanish in the home. From the beginning, she presented herself as an enthusiastic student who was eager to participate. Her health questionnaire indicated that there was a family history of ADHD, although she did not have an existing diagnosis. Both her parent and teacher gave her scores on the Conners 3AI that supported a

diagnosis of ADHD. IVA+Plus results suggested that her scores were consistent with a working diagnosis of the inattentive subtype. The WASI-II estimated her FSIQ at 102, with a VIQ of 109 and a PIQ of 94. Her WRMT-III Total Reading (standard) score was 87 and her Oral Reading (standard) score was 93. The school indicated that problems with inattention had been noted by teachers since first grade.

***qEEG/EEG results.***

*Pretest conclusions*. The preliminary qEEG report from BSI states,

> The background alpha is poorly organized and sustained, with rhythmicity seen at 8-9 Hz posteriorly with eyes closed, and with mu seen bi-centrally at 9-10 Hz. There are irregular sharper and slower changes seen bi-temporally, somewhat greater on the right at times. The theta/beta ratio was not increased significantly at the vertex. The mu noted is a normal neurological variant, though it is also reported disproportionately in those with mirror neuron disturbances frontally. The temporal slower content suggests a disturbance of comprehension as well as verbal memory. The lack of faster alpha suggests a poor semantic/declarative memory performance (Brain Science International, personal communication, April 1, 2013).

This report indicates that Mildred's EEG contained irregularities with "slower content" and with higher amplitudes of alpha (8 to 12 Hz) present, particularly at the lower end of the alpha bandwidth (8 to 10 Hz). "Slower content" also includes theta (4 to 8 Hz). It is noted that theta/beta ratios were not higher at Cz (on the top center of her head) when compared to the normative database (although they were higher in other scalp locations contained in the full qEEG report). In addition, higher amplitude alpha at the upper end of the bandwidth (10 to 12Hz) was not observed. To address these issues during neurofeedback training, Mildred was the only student who was trained to inhibit

theta and alpha (4 to 10 Hz); all others were trained to inhibit the full theta and alpha bandwidths (4 to 12 Hz).

Mu rhythms fall within the same frequency band as alpha but they are found over the sensorimotor cortex and behave differently (Demos, 2005) . Unlike alpha, which is sensitive to opening and closing of the eyes and easily observed during monitoring of EEG (e.g., the alpha-blocking response discussed earlier), mu remains steady when opening or closing the eyes.

*Posttest conclusions*. The final qEEG report from BSI states,

> The background alpha is seen at 8-10 Hz posteriorly with eyes closed, and with a peak alpha seen at 9 Hz and without the mu seen previously in the report of 4-1-2013. The irregular sharper and slower changes seen bi-temporally remain, though the significance of the divergence has been reduced substantially. The theta/beta ratio was not increased significantly at the vertex. The elimination of the mu suggests the mirror neuron system is now functional. Though the overall power is increased, the slow content has been reduced in significance. The somewhat slower nature of the EEG with the lack of faster alpha remains, suggesting a poor semantic/declarative memory performance, though generally this EEG is improved over the initial recording (Brain Science International, personal communication, June 12, 2013).

Following the intervention, some of the higher amplitude slower content (theta and alpha) was reduced but not eliminated. In addition, mu was reduced. Similar to what was noted at pretest, theta/beta ratios were not elevated at Cz. The overall findings, however, indicated that positive changes in EEG occurred.

*EEG Monitoring*. In order to calibrate the software, each daily session began with a three-minute EEG assessment. As these assessments preceded the neurofeedback training, they would be reflective, at least in part, of changes in EEG resulting from previous sessions. Measurements were taken during each phase for Mildred as follows

(Table 14): Baseline, active electrode at Cz, reference and ground used linked ears (i.e., reference placed at A1, ground placed at A2); Phase 1, active electrode at Cz, reference and ground used linked ears; Phase 2, active electrode at C4, reference at T5, ground at A2; Phase 3, active electrode at Fz, reference at Pz, ground at A2. During Phase 1, training was designed in enhance beta (15 to 18 Hz) and inhibit theta (4 to 8 Hz); Phase 2, enhance SMR (12 to 15 Hz), inhibit theta and alpha (4 to 10 Hz); Phase 3 used a dual inhibit protocol (no frequencies were enhanced), inhibit theta and alpha (4 to 10 Hz) and inhibit high beta (18 to 30 Hz). High beta was also inhibited across the other phases to reduce EMG artifact, which is associated with this bandwidth. Mildred received the same protocols as all other participants during baseline and Phase 1; Phases 2 and 3 were qEEG-guided (determined by the initial qEEG assessment).

As SCDs rely on the systematic visual analysis of data, EEG bandwidths were plotted to examine changes. However, it is important to recognize that across each phase, the neurofeedback sessions were qEEG-guided and individualized for each participant. As this entailed making changes in the location of electrode placements and the protocols used, caution must be advised when interpreting results. For EEG bandwidths that were trained to be enhanced, Mildred's beta (15 to 18 Hz) remained stable during Phase 1, and showed slight improvements in SMR and beta during Phases 2 and 3, respectively. For bandwidths that were trained to be inhibited, Mildred demonstrated decreases in theta (4 to 8 Hz) during Phase 1, as well as in theta and alpha (4 to 10 Hz) during Phases 2 and 3.

***Progress monitoring.***

*SAT results*. The CNS-VS Shifting Attention Test provides scores for the number of correct responses, the number of errors, and mean reaction time between the presentation of the target and correct responses in milliseconds. When trends are examined by phase, Mildred demonstrated improvements in correct responses during Phases 1 and 2, with a slight decrease in Phase 3. Trends for errors decreased in Phases 1 and 2 and remained stable in Phase 3 (Figure 10). When reaction time is examined, Mildred exhibited an increase in reaction time during each phase (Figure 11).

When trends for SAT scores are examined across all phases, Mildred's correct responses appear to be stable and neither increased nor decreased over 40 sessions. She demonstrated a decrease in the number of errors made (Figure 12). For reaction time, the trend indicated an increase (Table 15), meaning that she required more time to respond correctly to the target over the course of 40 sessions. When levels (means) of scores for each phase are examined, Mildred displayed an increase in correct responses and a decrease in errors (Figure 14); reaction time appears stable (Figure 15). While she demonstrated improved reaction time during Phases 1 and 2, these improvements disappeared in Phase 3 (Figure 15).

*DIBELS ORF results.* This measure produces a raw score for words correct per minute calculated from the total number of words read from a graded passage over a period of one minute minus the number of errors. In addition, an accuracy score can be calculated as a percentage by dividing words correct per minute by the total number of words read. Examining trends by phase, Mildred demonstrated an increase in the number

of words correct per minute read during Phase 1, a slight increase during Phase 2, and the trend line displayed a decrease during Phase 3 (Figure 16). However, when the trend line across all phases is examined, she displayed an increase across the 40 sessions (Figure 17). When means for words correct per minute are compared for each phase, the number of words read correctly increased (Figure 18). An examination of the trend line for accuracy indicates a decrease, opposite of the direction desired (Figure 19). Mildred was the only participant to exhibit a decrease in accuracy.

*AIMSweb Maze results*. The Maze is a multiple choice cloze task that produces raw scores based on the number of words correctly identified and the number of errors. Examining trends by phase, Mildred displayed a decrease in the number of correct word choices and an increase in the number of errors made during Phase 1, both trends where opposite of those desired. During Phases 2 and 3, words correct showed positive trends and number of errors displayed negative (Figure 20). When trend lines across all phases are examined, changes are observed in the desired directions; the raw scores for words correct increases and number of errors decreases (Figure 21). When means for correct words and number of errors are compared for each phase, the mean for words correct increases and the mean for number of errors decreases (Figure 22).

***Pre- and posttest results.***

*Conners 3AI results*. The Conners rating scales provide three scores: a raw score, a probability score, and a T-score. Both the parent and teacher scales provide the same scores. Mildred's pretest results (Table 15) were consistent with a profile of ADHD. Her parent gave her a raw score of 16 (maximum score = 20), a T-score ≥ 90 (cutoff ≥ 61),

and a probability score of 99 percent. The teacher rating produced similar scores: raw score = 18, T-Score = ≥ 90 (cutoff ≥ 61), and probability = 97. Decreases in the desired direction were noted on the posttest by both parent and teacher. The parent rating produced a raw score = 8, a T-score ≥ 90, and a probability score = 82 percent. As the publisher's maximum T-score is ≥ 90, no changes could be noted although all other scores improved. The posttest teacher ratings (Table 15) also produced changes in the desired direction: raw score = 13, T-score = ≥ 90, and probability = 91 percent.

*IVA+Plus results*. The IVA+Plus CPT generates multiple scores pertaining to attention, and hyperactivity/impulsivity; the tests also suggests if scores support a diagnosis of ADHD. Results for the three primary indices are reported in Table 6; subtests for these indices are found on Tables 7 to 10. As this study examined attention, two scores are particularly relevant; the Full Scale Attention Quotient (FS-AQ) and the Combined Sustained Attention (C-SA) score. All results are expressed as standard scores.

At pretest, Mildred's scores supported a diagnosis of an attention deficit. She had a FS-AQ of 61 and a C-SA = 42; both indicating a significant impairment. At posttest, she demonstrated gains across all measures (Figure 6) with her FS-AQ = 77 and C-SA = 70. The IVA+Plus continued to support a diagnosis of an attention deficit.

*GORT-5 results*. The GORT-5 provides several measures of oral reading skills. The scores examined here include fluency, comprehension, and an Oral Reading Index (ORI), a composite score derived from the fluency and comprehension scores (Table 16). Mildred demonstrated improved scores on all measures between pre- and posttesting. At pretest, she obtained a scaled score on fluency = 6, a scaled score on comprehension = 7,

and an ORI standard score = 81. Her posttest scores included fluency = 7, comprehension = 9, and an ORI score = 89.

**Participant 2: Dudley**. At age 10.6 years, Dudley was the one of the oldest participants. His health questionnaire indicated that there was not a family history of ADHD, although he had been diagnosed by medical professionals with the inattentive subtype on two different occasions. Both his parent and teacher gave him scores on the Conners 3AI that supported a diagnosis of ADHD; these were consistent with his educational history. Dudley had transferred to Sunny Shoals Elementary School at the beginning of the 2012/2013 school year from an out-of-state school. Both schools reported persistent problems with attention and he was the only student in the sample with a Section 504 plan. His IVA+Plus results indicated significant impairments that were consistent with a working diagnosis of the inattentive subtype. The WASI-II estimated his FSIQ at 101, with a VIQ of 109 and a PIQ of 93. His WRMT-III Total Reading (standard) score was 84 and his Oral Reading (standard) score was 85.

As a participant, Dudley presented several unique challenges. While his health history indicated problems with attention, headaches, and school performance, there were no indications of anxiety or oppositional behaviors. His teacher and a parent both reported that his favorite pastimes were watching zombie movies and playing computer video games. However, he expressed concern on several occasions during the beginning of the study that neurofeedback was going to "erase his brain." It would often take two or three times longer to set up his sessions as he was inquisitive and would ask many questions. Quite often, he would simply come to the session and stand silently next to the

equipment for a considerable period of time before engaging with the researcher. Once the neurofeedback had begun, his demeanor would usually change and he would actively participate in the process.

***qEEG/EEG results.***

*Pretest conclusions*. The preliminary qEEG report from BSI states,

> The background alpha is seen at 10-12 Hz, with alpha seen at 8-9 Hz right temporally, and with less SMR band activity than expected and with mild slower content with a widespread distribution. The theta/beta ratio is slightly increased along the midline. The frontal alpha and widespread alpha hypercoherence suggest an affective regulatory disturbance, with the faster alpha suggesting a mild CNS over-arousal. The right temporal slower alpha focus suggests a local disturbance in areas involved in prosodic and spatial comprehension as well as non-verbal memory (Brain Science International, personal communication, April 1, 2013).

Dudley's pretest qEEG results indicate the presence of higher amplitude alpha (10 to 12 Hz) at various locations on the cortex and that his theta/beta ratio, as recorded at the midline (Fz, Cz, and Pz) was elevated. It is noted that his EEG exhibited alpha "hypercoherence." This means that when the readings from each of the 19 electrodes used for the qEEG assessment are compared with each of the other sites, there is more connectivity of EEG between these locations when compared to the normative database. Although this will be discussed in greater detail later, Chabot and Serfontein (1996) found that hypercoherence and hypocoherence can be present in children with ADHD, as well as with learning disabilities. This initial assessment also noted that the amplitude of SMR (12 to 15 Hz) was lower when compared to norms.

*Posttest conclusions*. The final qEEG report from BSI states,

> The background alpha is seen at 9-12 Hz, with low voltage alpha seen at 8-9 Hz temporally, though without the right temporal intensity seen previously and with less slow content right temporally than initially seen. There is still less SMR band activity than expected. The theta/beta ratio remains increased at the vertex, though the parietal involvement has waned. The alpha hypercoherence is no longer seen with eyes open, though the eyes closed hypercoherence remains. The alpha is now seen at 9-11 Hz parietally, about 1 Hz slower than previously, suggesting a mildly improved alpha frequency tuning with less over-arousal. The right temporal slower alpha focus has improved significantly (Brain Science International, personal communication, June 13, 2013).

Although there was a reduction of alpha frequency following completion of the intervention, improvements were observed. Dudley's theta/beta ratio remained high and insufficient amplitude of SMR remained. However, the alpha hypercoherence, especially with eyes open, was reduced. As coherence training protocols were not used during this study, the reduction of hypercoherence will be discussed in great detail later. Demos (2005) notes that coherence training does not have to occur in order for changes to be observed because it is often improved with amplitude neurofeedback (that used in this study); this appears to be the case with Dudley.

*EEG Monitoring*. Measurements were taken during each phase for Dudley as follows (Table 14): Baseline, active electrode at Cz, reference and ground used linked ears (i.e., reference placed at A1 and ground placed at A2); Phase 1, active electrode at Cz, reference and ground used linked ears; Phase 2, active electrode at T6, reference at Cz, ground at A2; Phase 3, active electrode at Fz with linked ears. During Phase 1, training was designed in enhance beta (15 to 18 Hz) and inhibit theta (4 to 8 Hz); Phase 2, enhance SMR and inhibit theta and alpha (4 to 12 Hz); Phase 3 used a dual inhibit

protocol - inhibit theta and alpha (4 to 12 Hz), and inhibit high beta (18 to 30 Hz). High beta was also inhibited across the other phases to reduce EMG artifact.

For EEG bandwidths that were trained to be enhanced, Dudley's beta (15 to 18 Hz) exhibited a decrease (in the direction that was contrary to what was expected) during Phase 1, and slight improvements in SMR and beta during Phases 2 and 3. For bandwidths that were trained to be inhibited, Dudley demonstrated a decrease in theta (4 to 8 Hz) during Phase 1, a decrease in theta and alpha (4 to 12 Hz) during Phase 2, and a slight increase theta and alpha (opposite direction of that expected) during Phase 3.

***Progress monitoring.***

*SAT results*. When trends are examined by phase, Dudley demonstrated a slight decrease in correct responses during Phase 1; during Phases 2 and 3, increases in correct responses were observed. Trends for errors decreased in Phases 1 and 2 and remained stable in Phase 3 (Figure 10). When reaction time is examined, Dudley exhibited an increase in reaction time during Phase 1 and slight decreases in Phases 2 and 3 (Figure 11).

When trends for SAT scores are examined across all phases, Dudley's correct responses increased over 40 sessions. He also demonstrated a decrease in the number of errors made (Figure 12). For reaction time, the trend indicates a decrease (Figure 13) across all phases. When levels (means) of scores for each phase are examined, Dudley displayed an increase in correct responses and a decrease in errors (Figure 14). While the trend line indicates that reaction time appears stable (Figure 15), the changes in means

between Baseline and Phase 1 indicate a large increase, while much of the gains were lost in Phases 2 and 3 (Figure 15).

Dudley's scores on the SAT, particularly those obtained during Baseline and Phase 1 must be interpreted with caution. All participants received verbal instructions prior to the first administration and the SAT also provides an online practice test prior to every administration. Despite this, Dudley's baseline reaction time scores are considerably faster than the other participants (Figure 13); for the first three sessions of baseline, Dudley had a mean reaction time of 736.00 ms, while the mean reaction times for the other participants ranged from 1194.00 to 1336.0 ms. His baseline scores appear to be outliers and the result of carelessly responding to the target rather than a reflection of actual performance; his scores continued to express considerable variability with reaction time stabilizing after session 27 of the intervention. Another observation is that a substantial number of sessions included those where the number of errors he made, exceeded the number of correct responses. Indeed, when compared with all of the other participants, this only occurred one other time across the sample. Specifically, this happened once during session 12 with Mildred and in that case, her score appears to be an outlier. While observing Dudley, the precise reasons for these results could not be ascertained. It is conceivable that motivation was a factor as a distinct change in behavior was noted during session five of neurofeedback training. The situation with error scores exceeding correct responses continued until session 27 of the intervention when a distinct change is observed. While no changes in his external behaviors were noted at that time, his scores for correct responses and errors appeared to normalize (Figure 12) and a

decrease in the variability of his reaction time to obtain correct responses was evident (Figure 13).

*DIBELS ORF results*. Examining trends by phase, Dudley demonstrated an increase in the number of words correct per minute read during Phase 1 and decreases during Phases 2 and 3 (Figure 16). Visual examination of his scores indicates considerable variation between individual sessions, particularly during Baseline, Phase 1, and Phase 2. The trend line across all phases is flat with no increase or decrease in words correct per minute observed over time (Figure 17). When means for words correct per minute are compared for each phase, a decrease is noted, however, no patterns are found between phases (Figure 18). An examination of the trend line for accuracy indicates an increase in performance over time (Figure 19). Similar to his SAT results, there appears to be less variability in his performance that occurs around session 27, with the exception of sessions 34 and 35 where a temporary drop in accuracy is observed.

*AIMSweb Maze results*. Examining trends by phase, Dudley displayed a decrease in the number of words correct and in the number of errors during Phase 1. In Phases 2 and 3, words correct showed positive trends; while the number of errors showed a decrease in Phase 2 and an increase in Phase 3 (Figure 20). When trend lines across all phases are examined, changes are observed in the desired directions; the raw scores for words correct increases and the scores for number of errors decreases (Figure 21). When means for correct words and number of errors are compared for each phase, the means for words correct increases, except for a decrease between Phases 1 and 2, and the mean for number of errors decreases, with an increase between Phases 1 and 2 (Figure 22).

***Pre- and posttest results.***

*Conners 3AI results*. Dudley's pretest results (Table 15) were consistent with a profile of ADHD. His parent gave him a raw score of 10 (maximum score = 20), a T-score ≥ 90 (cutoff ≥ 61), and a probability score of 91 percent. The teacher rating produced similar scores: raw score = 12, T-Score = ≥ 90 (cutoff ≥ 61), and probability = 89. Decreases in the desired direction were noted on the posttest by both parent and teacher. The parent rating produced a raw score = 9, a T-score ≥ 90, and a probability score = 87 percent. The posttest teacher ratings (Table 15) also produced changes in the desired direction: raw score = 10, T-score = 86, and probability = 84 percent.

*IVA+Plus results*. At pretest, Dudley's scores supported a diagnosis of an attention deficit with standard scores across all subscales indicating significant impairment; scores ranged from 19 to 79. He had a FS-AQ of 59 and a C-SA = 28. At posttest, he demonstrated considerable variation from pretest results with many of his scores declining (Table 6). He had a posttest FS-AQ = 32 and C-SA = 7. Although Dudley did not express symptoms of hyperactivity, it is notable that his FS-RCQ showed an increase in his pretest standard score of 19 to 63 on the posttest. Both the Auditory and Visual Response Control Quotients also showed large gains (Table 6). The IVA+Plus continued to support a diagnosis of an attention deficit.

Dudley's results on the posttest, however, are suspect. During the first administration of the posttest, a group of noisy students unexpectedly entered the room and caused considerable distraction; these clearly influenced this participant's results. Indeed, he received a standard score of 0 on the measure of A-AQ (auditory) vigilance.

The vigilance score examines errors of omission and thus serves as an indicator of problems with inattention. In addition, it serves as a tool to examine motivation and effort. Given the unexpected noise, and the fact that Dudley performed considerably worse on several of the other scores obtained during the pretest, it was evident that the testing conditions interfered with outcomes and were, therefore, not valid.

Based on this situation and Dudley's poor performance, the decision was made to conduct a second posttest, three days later. This time, the testing conditions were optimal and the participant was observed throughout. It was noted, however, that while the participant appeared engaged, he was observed responding very quickly to the target. At the conclusion of the test, the participant was asked if he had "tried his best," to which he responded in the affirmative. His scores on this second attempt, however, were inconsistent not only from those obtained three days previously, but also from those obtained at pretest (Table 6). When compared with his pretest results, FS-RCQ standard scores increased from 19 to 63, FS-AQ declined from 59 to 32, and C-SA declined from 28 to 7. An examination of his subscores (Tables 9 and 10) also reveal tremendous variability with standard scores ranging from 0 (for A-AQ auditory and visual scores for vigilance) to 157 (RCQ score for Stamina). The two vigilance scores of 0 suggest that this participant wasn't motivated to do his best and therefore the IVA+Plus scores for the second posttest administration must be viewed with caution. As the second posttest administration occurred on the last day that data could be gathered from participants prior to the end of the school year, it was impossible to re-administer again.

*GORT-5 results* Dudley demonstrated improved scores on all measures between pre- and posttesting (Table 12). At pretest, he obtained a scaled score on fluency = 4, a scaled score on comprehension = 9, and an ORI standard score = 73. His posttest scores included fluency = 7, comprehension = 8, and an ORI score = 86.

**Participant 3: Nimrod**. This student, age 9.4 years, was the youngest in the sample. Nimrod's health questionnaire indicated that there was no known family history of ADHD and that he did not have an existing diagnosis. Fluent in English, this participant also spoke Vietnamese at home. On the Conners 3AI, the teacher's rating resulted in a T-score ≥ 90 (the highest possible score) and supported a diagnosis of ADHD. His parent, however gave him a raw score of zero (i.e., Nimrod expressed no symptoms of ADHD) that represented a T-score of 45. The school was concerned with consistent low academic performance and low test scores. He had been previously referred to the school's Student Study Team (SST) but was not found eligible for services. IVA+Plus results suggested that his scores were consistent with a diagnosis of ADHD. The WASI-II estimated his FSIQ at 90, with a VIQ of 104 and a PIQ of 81. His WRMT-III Total Reading (standard) score was 93 and his Oral Reading (standard) score was 100.

***qEEG/EEG results.***

*Pretest conclusions*. The preliminary qEEG report from BSI states,

> The background alpha is seen at 9-12 Hz, with mu seen bi-centrally, greater on the right at 11 Hz. The alpha peak seen at 10-11 Hz, with excess alpha noted frontally and temporally. The theta/beta ratio was not increased significantly. The mu noted is a normal neurological variant, though it is also reported disproportionately in those with mirror neuron disturbances frontally. The temporal alpha suggests a local disturbance in

> cortical areas involved in comprehension as well as memory. The hypercoherent alpha is noted with eyes open and closed (Brain Science International, personal communication, April 2, 2013).

Nimrod's pretest qEEG indicates the presence of higher amplitude alpha, as well as mu. Theta/beta ratios, recorded at Cz, was not elevated. However, like Dudley, alpha hypercoherence was present.

*Posttest conclusions*. The final qEEG report from BSI states,

> The background alpha is seen at 9-12 Hz, with mu seen bi-centrally, greater on the right at 10-11 Hz. The alpha peak is now seen at 9-11 Hz, with a more posterior distribution. The theta/beta ratio was not increased significantly. The mu noted is a normal neurological variant, though it is also reported disproportionately in those with mirror neuron disturbances frontally. The alpha distribution is now in a more traditional posterior prominence. The slower asymmetry is no longer showing a left frontal-temporal prominence. The hypercoherent alpha is still noted with eyes open and closed, though the hypercoherence is less widely distributed, especially with eyes open. These results are generally improved over the initial report dated 4-2-2013 (Brain Science International, personal communication, June 14, 2013).

Nimrod exhibited some changes in alpha; mu continued to be observed with the general finding that the EEG had improved. However, there was a reduction in hypercoherence with eyes open that resulted in the dispersion of alpha. This will be discussed in greater detail later.

*EEG Monitoring*. Measurements were taken during each phase for Nimrod as follows (Table 14): Baseline, active electrode at Cz, reference and ground used linked ears (i.e., reference placed at A1 and ground placed at A2); Phase 1, active electrode at Cz, reference and ground used linked ears; Phase 2, active electrode at C4, reference at T5, ground at A2; Phase 3, active electrode at Fz with linked ears. During Phase 1, training was designed in enhance beta (15 to 18 Hz) and inhibit theta (4 to 8 Hz); Phase

2, enhance SMR, inhibit theta and alpha (4 to 12 Hz); Phase 3, enhance beta (15 to 18 Hz) and inhibit theta and alpha (4 to 12 Hz). High beta was also inhibited across all phases to reduce EMG artifact.

For EEG bandwidths that were trained to be enhanced, Nimrod's beta (15 to 18 Hz) displayed a slight increase during Phase 1, and decrease in SMR (opposite of the direction expected) during Phase 2, and an increase in beta during Phase 3. For bandwidths that were trained to be inhibited, Nimrod demonstrated increases in theta (4 to 8 Hz) during Phase 1, and increases theta and alpha (4 to 12 Hz) during Phases 2 and 3. These increases are in the opposite direction of those expected.

***Progress monitoring.***

*SAT results*. When trends are examined by phase, Nimrod demonstrated improvements in correct responses across all three phases. Trends for errors decreased in Phases 1 and 2 and displayed an increase in Phase 3, contrary to what was expected (Figure 10). When reaction time is examined, Nimrod exhibited an increase in reaction time during Phases 1 and 2; in Phase three, the trend line decreases (Figure 11).

When trends for SAT scores are examined across all phases, Nimrod's correct responses appear to be stable and neither increased nor decreased over 40 sessions. He demonstrated a decrease in the number of errors made (Figure 12). For reaction time, the trend indicates an increase (Table 15), meaning that he required more time to respond correctly to the target over the course of 40 sessions. When levels (means) of scores for each phase are examined, Nimrod displayed an increase in correct responses and a

decrease in errors (Figure 14); reaction time appears stable with a decline following Baseline and an increase between Phases 1 and 3 (Figure 15).

*DIBELS ORF results.* Examining trends by phase, Nimrod demonstrated an increase in the number of words correct per minute read during each phase (Figure 16). The trend line across all phases indicates an increase in words correct per minute over time (Figure 17). When means for words correct per minute are compared for each phase, an increase is observed over time with a slight decrease noted between Phases 2 and 3 (Figure 18). An examination of the trend line for accuracy indicates an improvement in performance over time (Figure 19).

*AIMSweb Maze results*. Examining trends by phase, Nimrod displayed a decrease in the number of words correct during Phase 1. The trend lines for number of words correct showed increases during Phases 2 and 3. The number of errors decreases in Phases 1 and 2 and increases in Phase 3 (Figure 20). When trend lines across all phases are examined, changes are observed in the desired directions; the raw scores for words correct increased and the scores for number of errors decreases (Figure 21). When means for words correct and number of errors are compared for each phase, the means for words correct increases, and the mean for number of errors decreases, with an increase in between Phases 1 and 2 (Figure 22).

***Pre- and posttest results.***

*Conners 3AI results*. Nimrod's parent pretest results (Table 15) were not consistent with a profile of ADHD. His parent gave him a raw score of 0 (maximum score = 20), a T-score ≥ 45 (cutoff ≥ 61), and a probability score of 11 percent. The

teacher rating produced a score that was consistent with a profile of ADHD: raw score = 18, T-Score = ≥ 90 (cutoff ≥ 61), and probability = 97. The parent posttest rating was similar to the pretest: raw score = 0, a T-score = 45, and a probability score = 11 percent. Large decreases in the desired direction were noted on the posttest teacher ratings (Table 15): raw score = 0, T-score = 45, and probability = 19 percent. Based on Nimrod's posttest results, Nimrod profile no longer suggests a profile consistent with ADHD.

*IVA+Plus results*. At pretest, Nimrod's scores supported a diagnosis of an attention deficit. He had a FS-AQ of 99 and a C-SA = 91. At posttest, he demonstrated gains across most measures (Figure 6) with his FS-AQ = 103 and C-SA = 96. The IVA+Plus no longer supports a diagnosis of an attention deficit.

*GORT-5 results*. Nimrod demonstrated improved scores on all measures between pre- and posttesting (Table 16). At pretest, he obtained a scaled score on fluency = 7, a scaled score on comprehension = 5, and an ORI score = 78. His posttest scores included fluency = 8, comprehension = 8, and an ORI score = 89.

**Participant 4: Webster**. Prior to enrolling at Sunny Shoals Elementary School, Webster (age 10.6) had attended a local private school for several years. From the beginning of this study, he presented himself as a very polite student and would shake hands with the researcher at the beginning of each session. Webster's health questionnaire indicated that there was a family history of ADHD, although he did not have an existing diagnosis. Both his parent and teacher gave him scores on the Conners 3AI that supported a diagnosis of ADHD. Despite a history of demonstrated good school performance, attention problems had been noted by both his former and present school,

as well as by his parent, since first grade. His current teacher noted persistent problems with organization, distractibility, and with work completion. IVA+Plus results indicated that his scores were consistent with a diagnosis of ADHD, inattentive subtype. The WASI-II estimated his FSIQ at 107, with a VIQ of 116 and a PIQ of 96. His WRMT-III Total Reading (standard) score was 112 and his Oral Reading (standard) score was 96. Several of his WRMT-III subtest scores were high, including: Reading comprehension cluster score = 124, Word Comprehension = 118, Passage Comprehension = 126, and Listening Comprehension = 135.

***qEEG/EEG results.***

*Pretest conclusions*. The preliminary qEEG report from BSI states,

> The background alpha is seen at 9-11 Hz, with mu seen more right centrally at 11-12 Hz and the alpha peak seen at 10 Hz with eyes closed. There is irregular sharper and slower changes seen frontally at the midline and at the vertex. The theta/beta ratio is increased significantly at the vertex. The mu noted is a normal neurological variant, though it is also reported disproportionately in those with mirror neuron disturbances frontally. The right temporal alpha suggests a local disturbance in areas involved in prosodic processing and comprehension as well as non-verbal memory (Brain Science International, personal communication, March 29, 2013).

Webster's qEEG indicated the presence of higher amplitude alpha, as well as the presence of mu. His theta/beta ratio was elevated at Cz.

*Posttest conclusions*. The final qEEG report from BSI states,

> The background alpha is seen at 9-11 Hz, with mu seen centrally at 11 Hz and the alpha peak seen at 10.5 Hz with eyes closed. Though the irregular sharper and slower changes are still seen frontally at the midline and at the vertex, the theta/beta ratio is no longer increased significantly at the vertex, being reduced by 50% from a ratio of 8:1 to 4:1. The mu remains though it has been reduced relative to the rhythmic background activity, which has increased in power. The right temporal alpha and slower

> content have been largely normalized. These findings are substantially improved over the initial quantitative findings (Brain Science International, personal communication, June 19, 2013).

Although higher amplitude alpha remained present in some locations, improvements were observed in others. Mu remained but was reduced (improved) in power. Webster's theta/beta ratio was reduced and is now comparable to typically developing others when compared to the normative database.

*EEG Monitoring*. Measurements were taken during each phase for Webster as follows (Table 14): Baseline, active electrode at Cz, reference and ground used linked ears (i.e., reference placed at A1 and ground placed at A2); Phase 1, active electrode at Cz, reference and ground used linked ears; Phase 2, active electrode at T6, reference at Cz, ground at A2; Phase 3, active electrode at Fz with linked ears. During Phase 1, training was designed in enhance beta (15 to 18 Hz) and inhibit theta (4 to 8 Hz); Phase 2, enhance SMR, inhibit theta and alpha (4 to 12 Hz); Phase 3, enhance beta (15 to 18 Hz) and inhibit theta and alpha (4 to 12 Hz). High beta was also inhibited across the other phases to reduce EMG artifact.

For EEG bandwidths that were trained to be enhanced, Webster's beta (15 to 18 Hz) remained stable during Phases 1, and SMR remained stable during Phase 2, beta demonstrated improvement in Phase 3. For bandwidths that were trained to be inhibited, Webster' theta (4 to 8 Hz) remained stable during Phase 1; theta and alpha (4 to 12 Hz) decreased in Phases 2, and displayed a slight increase in Phase 3.

***Progress monitoring.***

*SAT results*. When trends are examined by phase, Webster demonstrated improvements in correct responses across all three phases. Trends for errors increased in Phases 1, contrary to what was expected, and decreased in Phases 2 and 3 (Figure 10). When reaction time is examined, Webster exhibited an increase in reaction time during Phases 1 and 2; in Phase three, the trend line decreases (Figure 11). Between sessions 10 and 13, Webster's correct responses did not deviate much from previous performance (Figure 10), however, the number of errors he obtained increased and yet his reaction time decreased (Figure 11). Given his typically placid demeanor, no changes in external behaviors were observed over these four sessions and a cause cannot be ascribed.

When trends for SAT scores are examined across all phases, Webster's correct responses demonstrated a steady increase over 40 sessions. Other than the aberrant error scores between sessions 10 and 13, there was a decrease in the number of errors made (Figure 12). For reaction time, the trend suggests a decrease across all phases, however, closer visual inspection of the data indicate that this decrease disappeared during the latter part of Phase 2 and Phase 3, with most of the decline occurring earlier in the study (Table 15). When levels (means) of scores for each phase are examined, Webster displayed an increase in correct responses and after an increase in errors between Phases 1 and 2, a decrease in errors occurs in Phase 3 (Figure 14); reaction time decreases between Baseline and Phase 2, with an increase observed in Phase 3 (Figure 15).

*DIBELS ORF results*. Given Webster's strong performance on the WRMT, the decision was made to identify appropriate graded materials for progress monitoring,

especially in light of his profile that was consistent ADHD, inattentive subtype. While the other participants read from measures developed for students in fourth grade, screening determined that Webster should use DIBELS ORF eighth grade passages. Examining trends by phase, Webster demonstrated stable trend lines for the number of words correct per minute read during Phases 1 and 2, an increase during Phase 3 (Figure 16). When the trend line across all phases is examined, only a slight increase in words correct per minute is evident over time (Figure 17). When means for words correct per minute read are compared for each phase, a slight decrease is noted, however, no patterns are noted between phases (Figure 18). An examination of the trend line for accuracy indicates an increase in performance over time (Figure 19). In addition to improved accuracy, Webster's performance exhibits the least variability of the five participants.

*AIMSweb Maze results*. Examining trends by phase, Webster displayed increases in the number of words correct in each phase. The number of errors also showed changes in the desired direction with decreases observed in all phases (Figure 20). When trend lines across all phases are examined, changes are observed in the desired directions; the raw scores for words correct increases and the scores for number of errors decreases (Figure 21). When means for words correct and number of errors are compared for each phase, the means for words correct increases, and the mean for number of errors decreases (Figure 22).

***Pre- and posttest results.***

*Conners 3AI results*. Webster's pretest results (Table 15) were consistent with a profile of ADHD. His parent gave him a raw score of 16 (maximum score = 20), a T-score ≥ 90 (cutoff ≥ 61), and a probability score of 99 percent. The teacher rating produced similar scores: raw score = 13, T-Score = ≥ 90 (cutoff ≥ 61), and probability = 91. Decreases in the desired direction were noted on the posttest by both parent and teacher. The parent rating produced a raw score = 3, a T-score = 61, and a probability score = 51 percent. The posttest teacher ratings (Table 15) also produced changes in the desired direction: raw score = 5, T-score = 65, and probability = 64 percent. Webster's parent posttest scores no longer suggests a profile of ADHD and his teacher posttest rating of 61 is at the cutoff for the test's criteria.

*IVA+Plus results*. At pretest, Webster's scores supported a diagnosis of an attention deficit. He had a FS-AQ of 83 and a C-SA = 84. At posttest, he demonstrated gains across most measures (Figure 6) with his FS-AQ = 95 and C-SA = 87. The IVA+Plus no longer supports a diagnosis of an attention deficit.

*GORT-5 results*. Webster demonstrated improved scores on all measures between pre- and posttesting except for rate (Table 16). At pretest, he obtained a scaled score on fluency = 9, a scaled score on comprehension = 10, and an ORI score = 97. His posttest scores included fluency = 10, comprehension = 12, and an ORI score = 105.

**Participant 5: Egbert**. This participant consistently presented himself as an affable student. Egbert, age 10, was fluent in English and spoke Spanish at home. His health questionnaire stated that he had an existing diagnosis of ADHD but also indicated

there was not a family history of the disorder. Both his parent and teacher gave him scores on the Conners 3AI that supported a diagnosis of ADHD. IVA+Plus results suggested that his scores were consistent with a diagnosis of ADHD. The WASI-II estimated his FSIQ at 105, with a VIQ of 104 and a PIQ of 104. Egbert's WRMT-III Total Reading (standard) score was 94 and his Oral Reading (standard) score was 93.

Egbert had a history of poor academic progress, distractibility, and inattentiveness. He had received a reading intervention in first grade and had been referred on two different occasions to the Student Study Team, the most recent of which was held concurrently with the beginning of this study's screening process. While Egbert was characterized as being talkative but polite, consistent problems with work were reported at both school and home. The parent indicated that a doctor had been consulted about medications but was told that they "were not needed." His teacher also indicated that there appeared to be significant problems with motivation and that while Egbert worked well with adults, there were often interpersonal conflicts with other children.

***qEEG/EEG results.***

*Pretest conclusions*. The preliminary qEEG report from BSI states,

> The background alpha is seen at 9-12 Hz, with mu seen bicentrally at 11-12 Hz and the alpha peak seen parietally at 10-11 Hz. There is mild frontal slower content at the midline, with frontal beta spindles seen from 18-25 Hz. The theta/beta ratio was not increased significantly due to the presence of the beta spindles. The mu noted is a normal neurological variant, though it is also reported disproportionately in those with mirror neuron disturbances frontally. The frontal beta spindles suggest an easily kindled cortex or cortical irritability, with the frontal lobe involved in both attentional and affective regulation (Brain Science International, personal communication, March 29, 2013).

Similar to the other participants, Egbert exhibited higher amplitude alpha, with higher alpha and theta present, particularly in the frontal region. Mu is also noted. Although his theta/beta ratio was not elevated at Cz, this may have been due to intrusion of beta spindles (the sudden appearance of fast beta brainwaves that quickly disappear).

*Posttest conclusions*. The final report qEEG from BSI states,

> The background alpha is seen at 9-12 Hz, with mu seen bicentrally at 11-12 Hz and the alpha peak seen parietally at 10 Hz. The mu is reduced in magnitude by more than half with eyes open and closed. There is mild frontal slower content at the midline, with frontal beta spindles still seen from 18-25 Hz. The theta/beta ratio was not increased significantly due to the presence of the beta spindles. The left temporal alpha has been reduced in absolute and relative power during eyes open. Though the beta spindles remain, the mu reductions and reduced eyes open temporal alpha on the left are noted, with further reduction possible with additional training time (Brain Science International, personal communication, June 19, 2013).

Egbert continued to exhibit the presence of higher amplitude alpha, with reductions of mu noted. His theta/beta ratio remained not elevated, but similar to the pretest qEEG, beta spindles were noted.

*EEG Monitoring*. Measurements were taken during each phase for Egbert as follows (Table 14): Baseline, active electrode at Cz, reference and ground used linked ears (i.e., reference placed at A1 and ground placed at A2); Phase 1, active electrode at Cz, reference and ground used linked ears; Phase 2, active electrode at Cz with linked ears; Phase 3, active electrode at Fz with linked ears. During Phase 1, training was designed in enhance beta (15 to 18 Hz) and inhibit theta (4 to 8 Hz); Phase 2, enhance SMR, inhibit theta and alpha (4 to 12 Hz); Phase 3 used a dual inhibit protocol - inhibit theta and alpha (4 to 12 Hz), and inhibit high beta (18 to 30 Hz). High beta was also inhibited across the other phases to reduce EMG artifact. For EEG bandwidths that were

trained to be enhanced, Egbert's beta (15 to 18 Hz) demonstrated increases in all three Phases. For bandwidths that were trained to be inhibited, Egbert demonstrated an increase in theta (4 to 8 Hz) during Phase 1, a decrease in theta and alpha (4 to 12 Hz) during Phase 2, and theta and alpha (4 to 12 Hz) was stable in Phase 3.

***Progress monitoring.***

*CNS-VS SAT results*. When trends are examined by phase, Egbert demonstrated improvements in correct responses across all three phases. Trends for errors also displayed changes in the desired direction with decreases noted across all phases (Figure 10). When reaction time is examined, Egbert demonstrated a decrease in reaction time in each phase (Figure 11).

When trends for SAT scores are examined across all phases, Egbert demonstrated a steady increase in correct responses over 40 sessions. Likewise, there was a steady decrease in the number of errors made (Figure 12). For reaction time, the trend demonstrates a decrease across all phases (Table 15). When levels (means) of scores for each phase are examined, Egbert displayed an increase in correct responses and after a slight decline in Phase 1; this was accompanied by a decrease in errors across phases (Figure 14). Reaction time decreased between Baseline and Phase 3 (Figure 15).

*DIBELS ORF results.* Examining trends by phase, Egbert demonstrated a decrease in the number of words correct per minute read during Phases 1 and 2, with an increase observed in Phase 3 (Figure 16). The trend line across all phases is static with little change in words correct per minute evident over time (Figure 17). When means for words correct per minute read are compared for each phase, an increase is noted between

Baseline, Phase 1, and 2, with a decrease in Phase 3 (Figure 18). An examination of the Egbert's trend line for accuracy indicates a slight increase in performance over time (Figure 19).

*AIMSweb Maze results*. Examining trends by phase, Egbert displayed a decrease in the number of words correct and in the number of errors during Phase 1, an increase in words correct and a decrease in errors during Phases 2 and 3 (Figure 20). When trend lines across all phases are examined, changes are observed in the desired directions; the raw scores for words correct increases and the scores for number of errors decreases (Figure 21). When means for words correct and number of errors are compared for each phase, the means for words correct displays no patterns and the mean for number of errors decreases (Figure 22).

***Pre- and posttest results.***

*Conners 3AI results*. Egbert's pretest results (Table 15) were consistent with a profile of ADHD. His parent gave him a raw score of 14 (maximum score = 20), a T-score ≥ 90 (cutoff ≥ 61), and a probability score of 99 percent. The teacher rating produced similar scores: raw score = 17, T-Score = ≥ 90 (cutoff ≥ 61), and probability = 96. Decreases in the desired direction were noted on the posttest by both parent and teacher. The parent rating produced a raw score = 11, a T-score ≥ 90, and a probability score = 94 percent. The posttest teacher ratings (Table 15) also produced changes in the desired direction: raw score = 14, T-score ≥ 90, and probability = 92 percent.

*IVA+Plus results*. At pretest, Egbert's scores supported a diagnosis of an attention deficit. He had a FS-AQ of 54 and a C-SA = 48; both indicating a significant impairment. At posttest, he demonstrated (often large) gains across all measures (Figure 6) with his FS-AQ = 90 and C-SA = 82. The IVA+Plus continued to support a diagnosis of an attention deficit.

*GORT-5 results*. Egbert demonstrated increases only on his comprehension scores between pre- and posttesting, other scores decreased (Table 16). At pretest, he obtained a scaled score on fluency = 9, a scaled score on comprehension = 6, and an ORI score = 86. His posttest scores included fluency = 6, comprehension = 8, and an ORI score = 84.

**Group Results**

When examining results from research using SCDs, caution is advised regarding the generalizability of findings to the general population due to the small sample sizes used by this experimental design. The emphasis in SCD research focuses on determining if experimental control of the independent variable produces consistent effects on the dependent variables (Kennedy, 2005). Acknowledging the limitations inherent in SCDs, descriptions of results will be reported as observed changes in EEG, attention, reading fluency, and reading comprehension.

**qEEG/EEG results**. The neurofeedback protocols used in this research were qEEG-guided and, therefore, individualized for each participant. Due to this customization, as well as limits placed on the number of bandwidths that could be monitored at once by the neurofeedback software, it was not possible to monitor all of the bandwidths observed across all phases. Thus, only general results can be reported. Across

all participants, just two bandwidths were enhanced during training (Table 14), SMR (12 to 15 Hz) or beta (15 to 18 Hz). As each of the five participants received neurofeedback training across three different phases, with protocols determined by their individual qEEG assessments, examining data across all 15 phases reveals that changes in desired direction for these bandwidths occurred during 11 of these phases, decreases were observed during one phase, and no changes were observed in three phases. Similarly, all participants were trained inhibit two bandwidths, although three bandwidths were inhibited across all participants occurred during training (Table 14), theta (4 to 8 Hz), theta and alpha (4 to 10 Hz), and theta and alpha (4 to 12 Hz). Only one participant, Mildred, was trained to inhibit theta and alpha (4 to 10 Hz), while all other participants were trained to inhibit alpha and theta (4 to 12 Hz). Changes in the desired direction (i.e., decreased) were observed in six of the 15 phases, increases (not in the desired direction) were observed in 7, and no changes were observed in three phases.

The qEEG results for each participant, described above under Individual Results, report that there were general improvements observed in each participant's EEG, with the exception of Egbert's. Pre- and posttest qEEG theta/beta power ratios exhibited changes in the desired direction for all participants except for Dudley (Table 17). Power ratios are calculated by dividing the amplitude (μV) of theta squared by the amplitude of beta squared: $theta^2/beta^2$.

Although not explicitly trained during the neurofeedback sessions, the qEEG reports revealed that two participants, Dudley and Nimrod, exhibited reductions in hypercoherence in alpha during the eyes open condition. Issues with coherence can be

observed in qEEGs when data from each electrode site, using the International 10/20 system (Figure 1), are compared with each other. This process involves the examination of the waveforms (not amplitudes) of EEG bandwidths, in 1 Hz increments, at the two sites being compared (Demos, 2005). Hypercoherence concerns arise as correlation coefficients approach 1 (perfectly correlated), and hypo-coherence concerns arise as correlation coefficients approach -1 (not correlated) when compared with age-matched norms. Excessive hypercoherence, particularly within theta and/or alpha bandwidths is observed in many children with ADHD. Chabot and Serfontein (1996) found in a large study that examined the qEEGs of 407 non-medicated ADHD children that interhemispheric hypocoherence was present in 26.5 percent of the sample and intrahemispheric hypocoherence was present in 32.4 percent. Similarly, interhemispheric hypercoherence was present in 35.1 percent and intrahemispheric hypercoherence was present in 26.3 percent. In addition, stronger correlations with either hyper- or hypocoherence were associated with learning disabilities.

The qEEGs of two participants in this study, Dudley and Nimrod, revealed hypercoherent alpha under both eyes open and eyes closed conditions. Coherence issues were not observed in the other participants. For Dudley, hypercoherence was noted at pretest under eyes open condition at 10 to 11 Hz and 11 to 12 Hz (Figure 23). At pretest, hypercoherent alpha was evident at 10 to 11 Hz for Nimrod (Figure 24). At posttest, both participants revealed greatly reduced hypercoherence under the eyes open condition. Dudley's was eliminated entirely and Nimrod's was reduced, particularly at 10 to 11 Hz.

## Attention Measures

**CNS-VS SAT results**. Visual examination of the results for the CNS-VS SAT across all phases revealed that three participants displayed an increase in the number of correct responses over the 40 sessions of neurofeedback and two participants (Mildred and Nimrod) neither increased nor decreased their performance (Figure 12). All five participants, however, reduced the number of errors over the same period. Group performance pertaining to reaction time was mixed; three participants, Dudley, Webster, and Egbert demonstrated improved (faster) performance, while Mildred and Nimrod performed slower over time.

When examining trends by phase for the number of correct responses (Figure 10), changes in treatment protocols appear to be associated with differential performance. Specially, four participants exhibited changes in the positive direction for number of correct responses during Phase 1, although the increase in slope for two students (Webster and Egbert) is slight. Beginning with Phase 2, all participants display increases in the positive direction for number of correct responses. This trend continues in Phase 3 although one participant, Mildred, does display a slight decrease. When all three phases are considered every participant (including Mildred) exhibits increases in the number of correct responses (Figure 12). These results suggest that qEEG-guided training protocols are more efficacious than the generic theta/beta protocol used during Phase 1.

The PND scores ranged from 23% to 75% on number of correct responses (Figure 25); four participants had PND scores ≥ 73% ("effective"), and one participant, Egbert had a PND score of 23% ("ineffective"). PND scores for number of errors ranged from

0% to 68% (Figure 27); two participants (Webster and Egbert) had PND scores of 0% (reflecting the Webster's lowest baseline score was 3 errors and Egbert's lowest baseline score of zero) and the PND scores for the remaining participants ranged from 55 to 68% ("questionable"). The PND scores for reaction time ranged from 8 to 83% (Figure 27); three participants had PND scores between 8 and 18% ("ineffective") and two participants had PND scores between 80 and 83% ("very effective").

**Conners 3AI results**. Both parent and teacher ratings on the Conners 3AI showed improvements for all participants, on all measures (Table 15). The one exception was Nimrod, whose parent gave him a raw score of zero at pre- and posttest. Nimrod's teacher, however, indicated a large improvement with his raw score dropping from 18 on the pretest, to 0 on the posttest. The mean raw score for all participants on the parent scale was 11.20, with a SD of 6.72. These results were much improved from those on the pretest, which had a mean of 6.20 and a SD of 4.55. Similar declines in scores were noted on the teacher ratings; the mean raw score pretest was 15.60 with SD = 2.88. At posttest, the mean = 8.40 and SD = 5.86.

**IVA+Plus Results**. Nearly all participants demonstrated improvement on most, if not all measures on the IVA+Plus (Table 6). Mildred and Egbert demonstrated improvements on all subtests, with large improvements in scores pertaining to attention (and not hyperactivity/impulsivity). Mildred's Full Scale Attention Quotient (FS-AQ) standard score increased from 61 at pretest to 77 on posttest; Egbert's improved from 54 to 90. Similar results for both participants also occurred on their Combined Sustained Attention (CSA) score; Mildred's CSA standard scored increased from 42 to 70 and

Egbert's increased from 48 to 82. Nimrod improved on all measures except for the V-AQ, which declined from a standard score of 101 to 98 and the V-SA, showed no change (standard score = 100) between pre- and posttests. Webster also demonstrated improvements on all scores, except for V-RCQ, which declined from 98 to 88 and A-SA, which declined from 105 to 92. Dudley was the only participant to demonstrate decreases on more than two subtests although as previously discussed, his posttest results are suspect.

Even when Dudley's scores are considered, group results are positive (Table 6). However, when Dudley's scores are removed from the group (Table 18), the increases on the primary indices not only continue to show gains in the proper direction but the increases on the two standard scores that reflect attention, FS-AQ and C-SA, are even larger, between the pre-test and posttest, FS-RCQ increases by 8 points (SD = 0.53), the FS-AQ increases by 17 points (SD = 1.13), and C-SA increases by 17.5 points (SD = 1.17). The attention scores, therefore, increase by more than full standard deviation over the course of the intervention. At posttest, the algorithms used by the IVA+Plus Interpretive Flowchart no longer suggests a diagnosis for ADHD for two students, Nimrod and Webster, while a diagnosis continues to be suggested for Mildred and Egbert (Dudley's also suggests a diagnosis).

**Reading Measures**

**DIBLES ORF results**. Trend lines for three participants (Mildred, Nimrod, and Webster) demonstrated an increased number of words correct per minute while the trend lines for two students (Dudley and Egbert) remained flat (Figure 17). When all

participants' scores are combined and the mean number of words correct per minute during each phase is examined, an increase is observed from 85.04 words correct at baseline to 88.64 at Phase 3 (Figure 28), which is less than expected for fourth graders. PND scores range from 8 to 68% (Figure 30). Four participants had PND scores between 8 and 30% ("ineffective") and one participant, Mildred, had a PND of 68% "questionable."

When trend lines for accuracy are examined (Figure 19) all participants except Mildred exhibited some improvement in the percentage of words read correctly per minute, which means that most participants made fewer errors as the study progressed. The decline in Mildred's accuracy cannot be explained.

**AIMSweb Maze results**. All five participants exhibited changes in the desired direction on both AIMSweb Maze scores; the number of words correct increased and the number of errors decreased (Figure 21). When all participants' scores are combined and the mean number of correct word choices during each phase is examined, an increase is observed from 15.04 correct word choices at baseline to 18.18 at Phase 3 (Figure 29). PND scores for correct word choices (Figure 31) ranged from 5 to 65%. Dudley's PND score was 65% and the other participants' scores ranged from 5 to 48% ("ineffective"). For number of errors, all participants' PND scores (Figure 32) ranged from 0 to 23% ("ineffective").

When examining trends by phase for correct word choices (Figure 20), four participants exhibited changes in the negative direction for number of words correct during Phase 1, with just one participant (Webster) showing an increase. During Phases 2

and 3, all participants display increases in the positive direction for words correct. These results also suggest that qEEG-guided training protocols are more efficacious than the generic theta/beta protocol used for all participants during Phase 1.

**GORT-5 results**. All participants except Egbert increased their ORI standard scores between pre- and posttests (Table 16). The mean standard score for all participants increased from 83 (SD = 9.14) to 90.60 (SD = 8.32). Egbert's ORI had a slight drop from 86 to 84; as the standard error of measurement (SEM) on the ORI is 3 (Wiederholt & Bryant, 2012b), this decline does not appear to be meaningful. Similar results were obtained on the fluency score; four participants increased their scaled scores, while Egbert had a decrease (from 9 to 6). The mean fluency scaled score for all participants increased from 7.00 (SD = 2.12) to 7.60 (SD = 1.52). The fluency score is derived from two additional scaled scores, rate and accuracy. The mean rate score for all participants showed a slight decline, from 7.80 at pretest to 7.60 at posttest. The SEM for both the rate and fluency scores is 1. As no participant expressed increases or decreases ± 1 point in their rate score at posttest suggests that no meaningful changes in occurred in rate following the intervention. The group accuracy score, however, showed an increase, from 7.00 to 8.60, with all participants expressing gains of 1 point (Mildred), 2 points (Webster), 3 points (Nimrod), and 4 points (Dudley), except Egbert whose accuracy dropped 2 points. All five participants increased their comprehension scaled scores; the mean increased from 6.80 (SD = 1.92) at pretest to 9.00 (SD = 1.73) at posttest. All participants increased their posttest score by 2 points, with the exception of Nimrod, who had a 3 point increase.

**Follow-up Assessments**

Follow-up assessments were conducted near the beginning of the next school year (November 2013), approximately five and a half months following the completion of posttest assessments. The Conners 3AI was again completed by parents and teachers, although teacher ratings were completed by each participant's fifth grade teacher (thus, follow-up Conners 3AI-T ratings are subject to inter-rater reliability issues). On the Conners 3AI-P, results (Table 15) indicate that Webster's and Egbert's raw scores continued to improve, Nimrod's score exhibited no change, and Mildred's and Dudley's raw scores declined from posttest (as noted previously, Dudley's posttest scores are suspect). Overall, teachers' ratings on the Conners 3AI-T showed improvement for four participants, with one participant (Nimrod) maintaining the raw score observed at posttest.

Four of the five participants made gains at follow-up on the C-SA (Combined Sustained Attention) score (Table 2), the primary index of attention on the IVA+Plus. Nimrod and Egbert had decreases, although their scores remained above those originally obtained at pretest. Contrary to his performance at posttest, Dudley's results are not suspect at follow-up.

Positive performance was also observed on the GORT-5 at follow-up (Table 16). Four of the five participants obtained higher scores on ORI and one student maintained the score obtained at posttest. Accuracy scores remained the same for one participant, three participants had a decline of one scaled score although these scores remained higher than observed at pretest, and one participant (Egbert) had an increase of one scaled score

although his score remained lower than at pretest. Similar to the ORI, four of the five participants improved performance while one student (Webster) maintained his score at posttest. As a sufficient period of time had elapsed between posttest and follow-up, GORT-5 scores for all participants are based on the normative data for fifth grade students, rather than fourth grade.

## Chapter 5: Discussion

This study sought answers to three research questions: 1) Will neurofeedback enhance attention as measured by CPTs?, 2) Will neurofeedback improve performance on measures of reading fluency?, and 3) Will neurofeedback improve performance on measures of reading comprehension? Of these, only the first was based on a one-tailed hypothesis; specifically, 40 sessions of neurofeedback would improve attention. The other questions were based on two-tailed hypotheses as no studies had yet explicitly examined the effects of neurofeedback to improve either reading fluency or comprehension. Thus, no predications were made regarding the effects of neurofeedback on these components of reading achievement.

### Research Question 1

CPTs have long been used as a diagnostic tool for ADHD, as a measure of attention, to monitor changes in behavior resulting from an intervention, and to assist in the titration of pharmaceutical interventions (Halperin et al., 1992; Loew, 2001; Tinius, 2003). Two measures were used to monitor changes in attention during this study; the SAT and the IVA+Plus. The SAT served as a brief measure of sustained attention and also executive function. The IVA+Plus was used as a pre- and posttest measure of auditory and visual attention; it is considerably longer than the SAT. The SAT does not have an auditory component and all scores reflect visual attention. Despite these differences, both tests found that, with the possible exception of Dudley, students made gains on most measures.

Results on the SAT suggest that participants made consistent gains on correctly identifying targets throughout the study. In many ways, the test is a hybrid of traditional CPTs (such as the IVA+Plus) and a Stroop color test. As such, participants must not only select the correct response to the target, but they must read and make a decision concerning which choice is correct based on the written instructions provided with every presentation of a target (Figure 7). All participants demonstrated an increase in the number of correct responses made throughout the study. Visual examination of the number of correct responses and number of errors made (Figure 14) reveal improvements in the desired directions. These results suggest that not only did attention improve but so did executive function.

Although pre- and posttesting of the study's participants spanned from three and one-half to nearly four months, substantial gains were observed in the IVA+Plus standard score means for the three major indices. When Dudley's scores are removed (as discussed previously); the mean FS-RCQ score increased by 8 points (SD = 0.53), the mean FS-AQ increased by 17 points (SD = 1.13), and the mean C-SA scored increased by 17.5 points (SD = 1.17). However, even when Dudley's scores are included, increases on all three scores are still observed (Table 6). These findings, therefore, indicate that 40 sessions of neurofeedback improved attention as predicted.

**Research Question 2**

The second research question examined whether neurofeedback would improve performance on measures of reading fluency. To date, this has not been examined in the scientific literature. While this study used a single-case design with a small sample, it

should be noted that results cannot be generalized. However, few changes, if any were observed in reading fluency as measured at pre- and posttest, as well as during progress monitoring.

DIBELS ORF trend lines (Figure 17) indicate that most participants made few changes in words correct per minute read on this measure of fluency. Mildred and Nimrod showed growth in the desired direction but the trend lines for the others remained relatively static. An inspection of the means for words correct per minute displays inconsistent results when examined by phase (Figure 16). It is not until the combined scores of all participants are examined by phase that a pattern emerges; the mean number of words correct per minute by all participants displays an increase across phases (Figure 28). The increase in fluency was 3.06 words per minute over a period of two and a half months (the span during with the intervention was administered) suggesting that this increase is likely the result of a maturation effect.

The GORT-5, as a measure of oral reading skills, requires participants to read from multiple graded passage and several scales are provided for reading fluency and comprehension. While the DIBELS ORF has participants read for just one minute in order to record a reading rate, the GORT-5 passages are considerably longer as the test typically requires 15 to 45 minutes to administer (Wiederholt & Bryant, 2012b). It is notable that from pretest to posttest, the mean score for rate (words per minute) declined (7.80 to 7.60) while accuracy (the number of words read correctly) increased from 7.00 to 8.60 (Table 16). This combination of rate plus accuracy generates the GORT-5 fluency score, which increased for all participants except Egbert. These results suggest that while

the participants, as a group, did not read faster after 40 sessions of neurofeedback, their accuracy improved. Thus, it appears that the intervention may have helped participants to read with more focused attention to content.

**Research Question 3**

The third research question examined whether neurofeedback would improve performance on measures of reading comprehension. Although previous research has reported improvements on comprehension incidental to the dependent variables, none have explicitly examined the issue. Two measures were used in this study to examine comprehension: AIMSweb Maze was used for progress monitoring and the GORT-5 provided a pre- and posttest measure of comprehension. The two tests, however, are dissimilar in that the Maze uses a cloze technique that focuses attention primarily at the sentence level. Specifically, words are removed from the text, at regular intervals, and participants are required to insert the correct word before continuing. The GORT-5, reflects reading of longer, more school-like passages. After each story is read, participants answer passage-dependent questions that not only rely on the content of the text, but also require them to recall what has just been read.

The Maze was used to evaluate potential changes in comprehension following every neurofeedback session. The results suggest that the intervention was responsible for growth beyond what would be expected. When the means of correct word choices for all participants across phases is examined, an increase is observed in the number of correct word choices identified over time (Figure 29). The PND scores for the number of words correctly identified suggest that these fall within the range of "ineffective" (except for

one student, Dudley, who obtained a score that suggests changes were "questionable" PND scores also suggest that changes observed in the reduction of errors made for all participants were "ineffective." However, when the increases for all participants (as a group) are compared to the AIMSweb National Norms Table (NCS Pearson, 2013), which was developed with a large sample of fourth graders (n = 24,881) and provides norms calculated at three intervals across the school year (fall, winter, and spring), participants' gains appear to be larger than expected. Specially, the normative sample indicates that no changes are observed typically between winter and spring (e.g., the mean raw score for winter and spring are 21 correct word choices). The mean of participants' scores, between baseline (m = 15.04 correct word choices) and Phase 3 (m = 18.18 correct word choices) increased by 3.14 correct word choices. Given that the study commenced on March 18, 2013 and concluded on June 5, 2013 (when the last student, Egbert, completed the intervention), suggests that neurofeedback training may have improved comprehension as measured on the Maze.

The GORT-5 provides a different view of reading comprehension, one that requires participants to retain what they have read and rely on memory to answer open-ended passage-dependent questions. It is more reflective of the reading found in schools. When viewed in this context, the gains made by all students suggest that given longer passages, reading comprehension improves following 40 sessions of neurofeedback. Of the five participants in this study, four demonstrated meaningful improvements in either a reduction of theta/beta ratios or normalization of EEG through improved coherence.

Egbert was the only one with limited changes in his EEG and this may have been reflected in his performance on some of the reading tasks.

Several issues arise in relation to changes in reading comprehension scores. For example, the Maze assessment requires that participants read silently. This presents a problem as it is difficult to monitor student engagement with the text. Schuck (2008) observed that students with ADHD appear to read more slowly when reading silently than when reading orally. That study also noted that some participants appeared to rush through passages while reading silently and that prompting was required to keep them engaged. She concluded that participants performed significantly better on measures of comprehension while reading orally, rather than silently.

The results of this present study, do not necessarily support those of Schuck, although there are similarities. For example, during the Maze task participants in this research did not appear to rush through the task; if anything, the opposite occurred. Students were observed diverting their attention elsewhere; they would look about the room or play with the pencil used for their responses. When these behaviors were evident, students were guided back to the reading task. Similar to Schuck, participants performed better on the oral reading assessment of reading comprehension although the reasons for this remain unclear. The overall findings of this study suggest that neurofeedback training improves reading comprehension when given tasks that most resemble those that reflect of reading for content.

## Limitations

Single-case research is, by design, intended to observe the effectiveness of an intervention to alter behavior; it seeks to establish a causal relationship between an independent variable and the dependent variables. Thus, small sample sizes are permissible and the emphasis is on the observation of effects. In keeping with SCD guidelines, this study used a sample of five students. Although effects were clearly observed, caution is advised as these results cannot be generalized to larger populations. Further research is warranted, especially since no other studies have yet directly examined the effects of neurofeedback on reading fluency and comprehension.

**Time constraints**. Although this study was ready to begin during fall 2012, bureaucratic delays pertaining to the final approval of this research prevented data collection from beginning until February 2013; neurofeedback sessions could not begin until March. As a result, several constraints were imposed on the study's timeline. These delays imposed several restrictions on the research and nearly resulted in delaying commencement of the study until the next school year. An integral component of this study was that 40 sessions of neurofeedback were required of all participants. Although some studies have reported that fewer sessions have produced significant results (Rossiter & La Vaque, 1995), research often suggests that 40 sessions is appropriate to operantly condition EEG in individuals with ADHD (Lofthouse et al., 2011). Given the requirement to complete a minimum number of sessions, alterations to the original design had to occur; had the study commenced just one day later, this study would not have been completed by the end of the school year. Some of the areas most impacted included

participant selection, establishment of baseline, scheduling of sessions, and the role of qEEG assessments to guide intervention protocols.

***qEEG-guided protocols***. Initially, this study was designed to use generic theta/beta ratio reduction protocols as these may be more practical for others to replicate this research in different public school settings. However, the addition of qEEGs as pre- and posttest assessments were a considerable benefit and permitted each participant's neurofeedback protocols to be individualized. As this research began relatively late in the school year, the intervention phase had to begin the day after the pretest qEEGs were completed; had this not occurred, the study would have had to be postponed until the following school year. Given that the qEEG-guided neurofeedback protocols were not be available prior to the commencement of the intervention; the decision was made to begin the study using theta/beta ratio reduction protocols with all five participants for the first ten sessions. Although this was not optimal, it permitted to study to begin. Visual inspection of trend lines for both the SAT (Figure 10) and the Maze (Figure 20) also indicate that the qEEG-guided training protocols used during Phases 2 and 3 produce greater improvements. If this is the case, it is conceivable that the use of qEEG-guided protocols for all phases may have resulted in even more growth.

Upon receipt of the qEEG reports from the lab, recommendations for treatment protocols (Table 13) were evaluated and adapted so that they could be integrated into the final 30 sessions of the intervention phase. Adaptions were made (Table 14) based on the recommendations of the clinical psychologist (an expert in qEEG-guided protocols) who

served as a consultant for this study at the behest of the International Society for Neurofeedback and Research.

***Establishment of baseline***. It was not known if one or both participants in each cohort would be non-responders to neurofeedback. To address this issue, the decision was made to proceed to the intervention phase when at least one participant in each cohort had established a stable baseline based on the theta/beta ratio. Additional measures (e.g., the Maze, ORF, or SAT) were not used to determine baseline.

***Follow-up assessments***. This study originally intended to conduct follow-up assessments several weeks after the intervention to examine maintenance of any changes in the dependent variables. Due to the time constraints that resulted in the completion of posttest assessments on the last available day prior to the end of the school year, this was not possible. In order to address this situation, follow-up data were collected near the beginning of the subsequent school year.

***School schedules***. Under the best of circumstances, schools are busy places and days are filled with many activities. Schedules are subject to many changes, some planned and others not. It is against this backdrop that the intensive intervention schedule of this study was overlaid. Significant events included Spring Break, as well as a week of standardized testing. Special activities included concerts, field trips, fire alarms, movies, plays, picnics, a "Fun Run" (school-wide fitness program), and many other events. Although this study was able to adapt to changes in the schedule, there were times when participants' neurofeedback sessions had to be rearranged to accommodate activities. When possible, students were scheduled as close to their normal times as possible.

**Social Validity**

The intensity of conducting forty sessions of neurofeedback, particularly when training was scheduled on a daily basis, was an issue that was researched and embedded into the design of this study. The star charts and use of incentives, as described earlier, appeared to work well. As a group, participants (with the exception of Dudley) regularly expressed satisfaction with the training sessions with several commenting that participation in the study was "awesome." Three students, Mildred, Nimrod, and Egbert, asked if they were going to continue neurofeedback during the next school year. All expressed disappointment when they were told that the study would not continue after summer vacation. Participants would often show up before their scheduled time; Mildred, who was the last student to receive the intervention each day, often droped by in the morning (a few hours before her scheduled time) and ask if she could begin her session early. Even Dudley showed up early on a few occasions.

Although the overall enthusiasm of the participants was beneficial, it was evident that at least two participants (Mildred and Egbert) also enjoyed coming to sessions because they missed class. As both of these students were generally affable and congenial, it appeared as if they especially enjoyed the individual attention received throughout the study. With both of these students, however, encouragement was regularly provided to keep them focused on doing their best during training.

**Implications and Future Research**

To date, only a handful of studies have examined the use of neurofeedback in public schools. Wadhwani, Radvanski, and Carmody (1998) may have been the first to

conduct a case study of a single middle school student in a public school. Their participant received 37 sessions of neurofeedback during the latter half of a school year. They noted that it was possible to conduct neurofeedback within an educational milieu and the researchers described improvements on standardized tests. Boyd and Campbell (1998) reported on six students who received no more than 20 sessions of neurofeedback. Five of these participants exhibited improvements on a CPT (the TOVA). Carmody et al. (2001) conducted a study of 16 students enrolled in fourth and fifth grade at a public school. Participants included eight students who exhibited behavior problems and had been diagnosed with ADHD by a school psychologist and eight students who were not diagnosed. Each set of students was equally divided and randomly assigned to either an experimental group or a wait-list control group. Participants were evaluated using an ADHD rating scale and the TOVA. Results were inconclusive. As previously discussed, the Orlando and Rivera (2004) study was the only one conducted in a public school to examine reading performance and IQ scores. However, that study was beset with design and methodological problems that prevent meaningful conclusions from being drawn.

This study is the first to explicitly explore the utility of neurofeedback as an intervention to improve reading achievement, following 40 sessions of training. It is also unique in that it focused on symptoms of inattention and not hyperactivity (the samples of the other studies conducted in public schools all appear to have included children with hyperactivity/impulsivity). Specifically, this study examined what impact, if any, conditioning of EEG has on reading fluency and comprehension.

Measures of reading fluency demonstrated mixed or limited results. Other than a slight increase in accuracy, the changes in DIBELS ORF results were negligible. It is not until rate, accuracy, and fluency are examined on the longer passages found on the GORT-5 that a possible pattern emerges; rate remained relatively static while accuracy increased. This suggests that participants became more attentive to the text and thus read with improved accuracy (therefore, they also made fewer errors) resulting in little or no change in rate.

The results indicate that all participants displayed increases in reading comprehension when asked to read the longer passages on the GORT-5. Similar findings were also evident during progress monitoring using the Maze; however, this may have been due to the use of considerably shorter passages as well as an assessment that does not rely on memory. Future research may wish to examine differential performance on reading comprehension measures that rely on memory versus those that permit text to be reviewed, especially since both of these conditions are found in academic settings. For example, memory-dependent reading comprehension skills are necessary when reading for content that must be retained, while text-dependent reading is used for assessments in the classroom.

Results from follow-up assessments indicate three of the five participants exhibited improvements on the primary measure of attention (C-SA) on the IVA+Plus. Furthermore, gains observed on the GORT-5 measure of reading achievement, also appear to be robust. Specifically, four of the five participants achieved higher ORI and Reading Comprehension standardized scores at follow-up than observed at posttest; the

remaining participant (Webster) maintained the same score on both indices as obtained at posttest. These findings imply that neurofeedback may be a viable option to assist children with attention deficits as an intervention strategy for improving both attention and reading comprehension.

While the experimental design required the use of a small sample and findings cannot be generalized to a larger population, this study has demonstrated potential for neurofeedback to improve educational opportunities for school children. Findings that attention improved, as measured by CPTs, are consistent with existing literature. Even more importantly, four of the five participants made positive gains on the GORT-5 Oral Reading Index; the measure of reading achievement. The one student who did not show gains on the ORI also displayed the least change in EEG; he may have been a non- or slow-responder to neurofeedback, or perhaps other issues, such as motivation, may have been involved. The overall findings of this study suggest that the use of neurofeedback in a public school setting is worthy of continued exploration. Future studies that replicate this one, or use randomized controlled trials with considerably larger samples, are justified.

The body of scientific literature on the efficacy of neurofeedback as an intervention strategy to improve the lives of individuals with attention deficits, as well as many other disorders, continues to grow. Currently, nearly all studies on neurofeedback are conducted within clinical settings; there remains a need for research in school settings. The American Academy of Pediatrics' recognition of neurofeedback as an evidence-based practice (American Academy of Pediatrics, 2012), as well as recent meta-

analyses that indicate it is a promising intervention (Arns et al., 2009; Hodgson, Hutchinson, & Denson, 2012), lend support to the need for additional research. This study provides one of the first glimpses on the use of neurofeedback in a public school setting and therefore contributes to a literature that deserves additional research.

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**Figures**

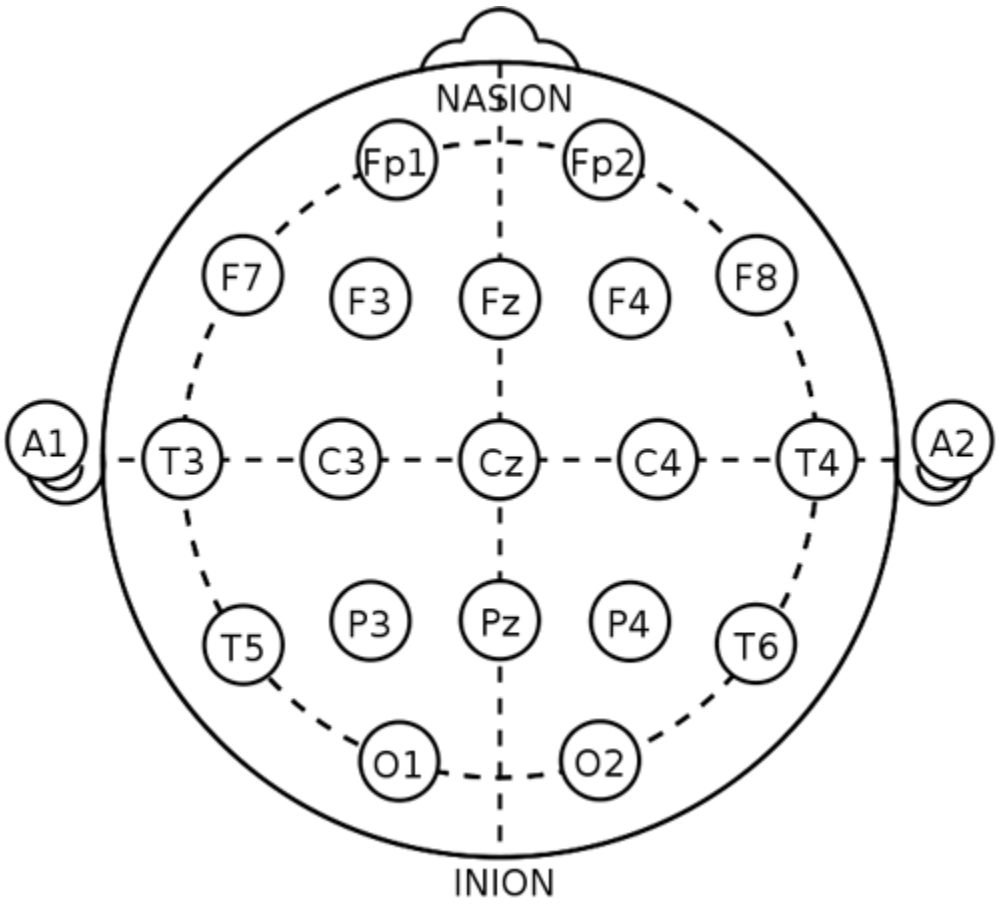



*Figure 1*. International 10/20 System for EEG electrode placement (Asanagi, 2010). Nasion = depressed area between the eyes and above the bridge of the nose; Inion = slight protrusion on the back of the head at the base of the skull over the occipital lobes; Fp = Frontal poles; F = Frontal lobe areas; T = Temporal lobes; C = Sensorimotor cortex; P = Parietal lobes; O = Occipital lobes; z = area above midline; A = location for auricular electrodes (these do not measure EEG but serve as locations for reference and ground placement); odd numbers = electrode sites over left hemisphere; even numbers = electrode sites over right hemisphere.

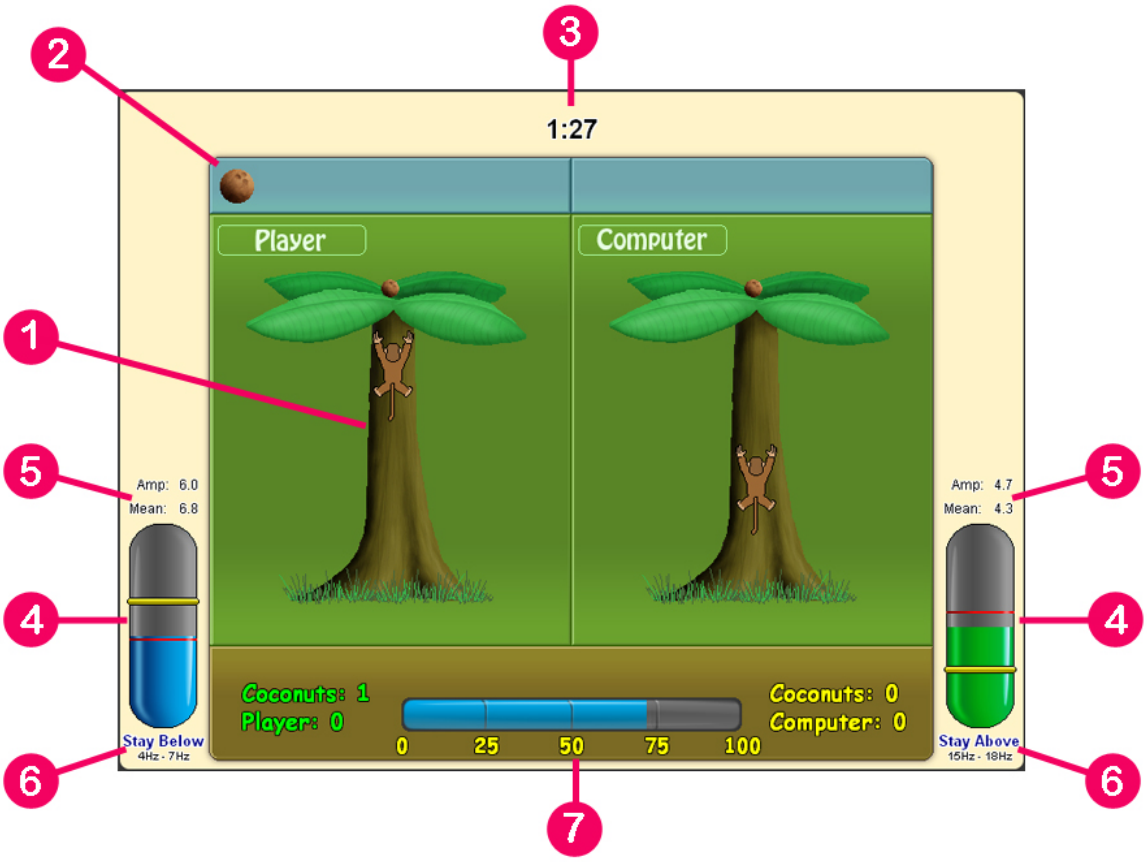



*Figure 2.* SmartMind Pro game example (Sandford, 2012). The object is for the player to meet pre-established target EEG goals to permit the player's monkey to reach the coconut first. The degree to which target EEG amplitudes are exceeded determines how quickly the monkey moves. This example has two targets (inhibit 4 to 7 Hz and enhance 15 to 18 Hz). Success on either will cause the animated figure to move, success on both result in faster movement. Targets are based on an assessment of mean EEG amplitudes prior to each daily session. The player's success rate against the computer is also contingent on meeting targets. 1 = animated figure controlled by player's EEG; 2 = number of successful attempts to reach coconut during game; 3 = Time remaining in current game (the length and number of games can be set prior to each session); 4 = EEG filter indicator. The colored bar moves continuously in response to the amplitude of the bandwidth being trained (the filter of the left is set to inhibit theta [4 to 7 Hz], and the right is set to enhance beta [12 to 20 Hz]). The yellow horizontal line indicates the minimum target threshold (0.3 SD from mean amplitude of EEG bandwidth set during the assessment) for success. The red horizontal line indicates the trainee's current goal (by default, this is set to 1.0 SD from the mean amplitude); 5 = current EEG amplitude and mean amplitude during session; 6 = current instructions; 7 = "Power Bar" – indicates current speed of animation.

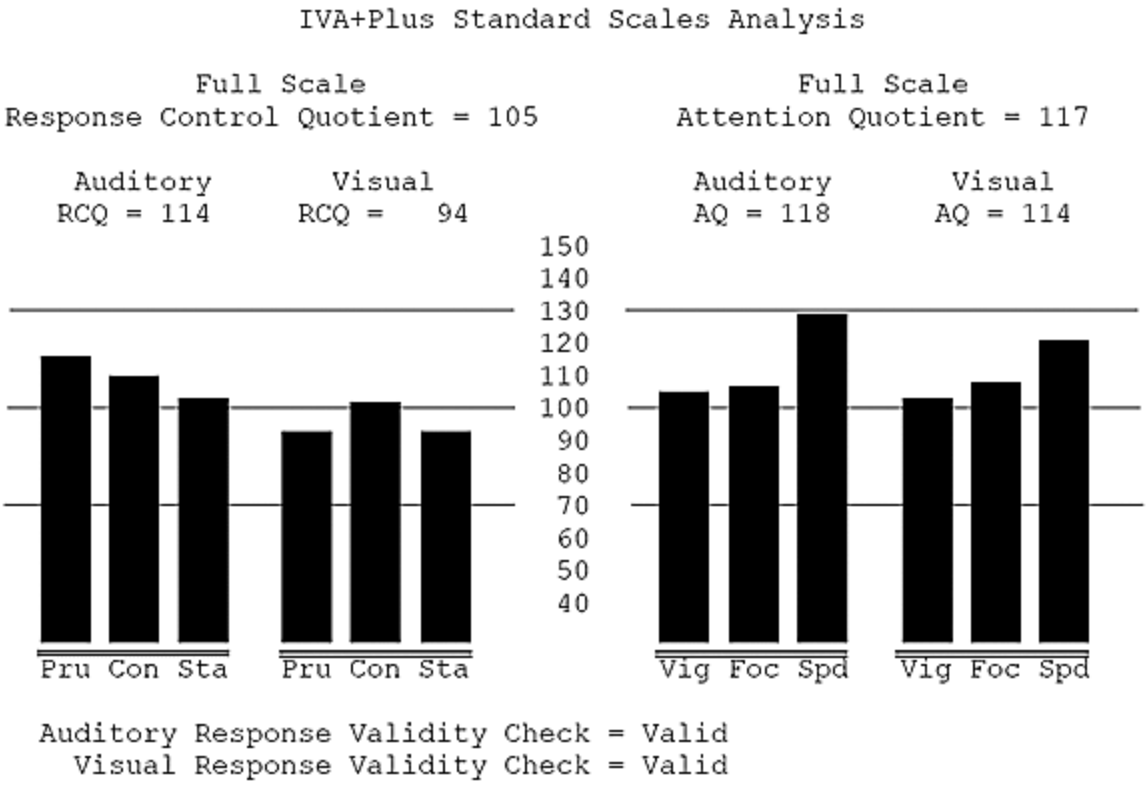



*Figure 3*. IVA+Plus output example (Sandford & Turner, 2007). RCQ = Response Control Quotient; AC = Attention Quotient; Pru = Prudence; Con = Consistency; Sta = Stamina; Vig = Vigilance; Foc = Focus; Spd = Speed.

Cam was a clam. He lived in the shallow waters (one, for, of) the sea with his parents. Cam (all, had, was) many friends. He had fresh, clear (bottom, next, water). He had a nice hard shell. (Thing, Take, Still), he was not happy. Cam was (sad, what, cry) because he did not like (him, out, his) shell.

*Figure 4.* Example (excerpt) of Maze task from R-CBM (Shinn & Shinn, 2002b).

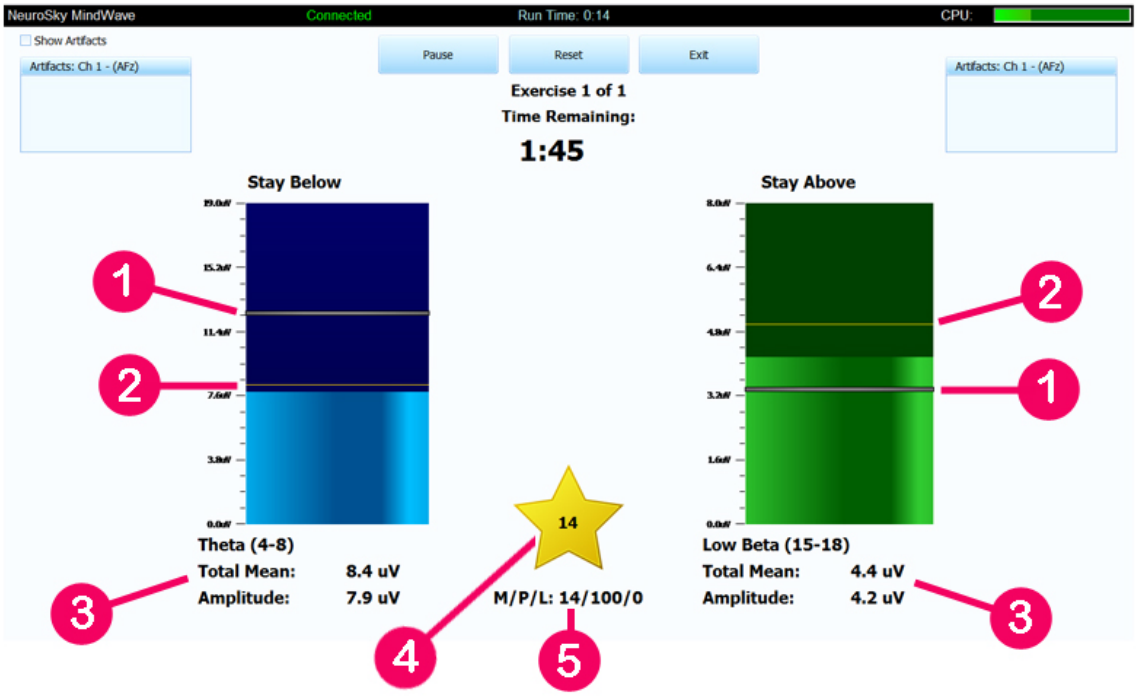



*Figure 5.* SmartMind clinical screen (Sandford, 2012). This is an example of one screen that may be used for neurofeedback training. Two bar graphs are provided with each displaying the current amplitude, in μVs, of the bandwidths being trained (e.g., theta [blue] and beta [green]); 1 = Target line. This line represents the target (threshold) goal for the current session. By default, it is set at 1.0 SD from the mean amplitude of each bandwidth that is established during an automated assessment of EEG conducted at the beginning of each daily session. The target can also be adjusted manually to make the session easier or more difficult; 2 = Goal line. The gray goal line represents the EEG amplitude that is required to be enhanced during the session. The default is set at 0.3 SD from the mean amplitude of each bandwidth established during the initial daily assessment of EEG and can be changed manually. In the above example, the goal is to inhibit the amplitude of theta and therefore the blue bar must fall below the goal line for the behavior to be rewarded. As the goal for beta is to increase the amplitude, the behavior is rewarded when the green bar is higher than the goal line; 3 = Visual display of: a) bandwidth being trained as represented by the bar graph, b) Total Mean = mean of the bandwidth's amplitude, in μVs, during the current session, and c) the current amplitude of the bandwidth in μVs; 4 = Goal star. The size and color of the star changes in real time to indicate when goals are met. In this example, goals for both theta and beta have been met for the preceding four seconds. Thus, the star is at its maximum size and is gold. If the goal is being met for just one of the bandwidths, the color of the star will reflect the same color that represents those frequencies on their respective bar graphs and will be smaller. If neither goal is met, the star will be small and red in color; 5 = M/P/L. M = Maximum number of seconds that the goal has been sustained during the current session. P = Percent of time during the session that the goal was maintained. L = Length of time that the goal was sustained during the last time it was reached.

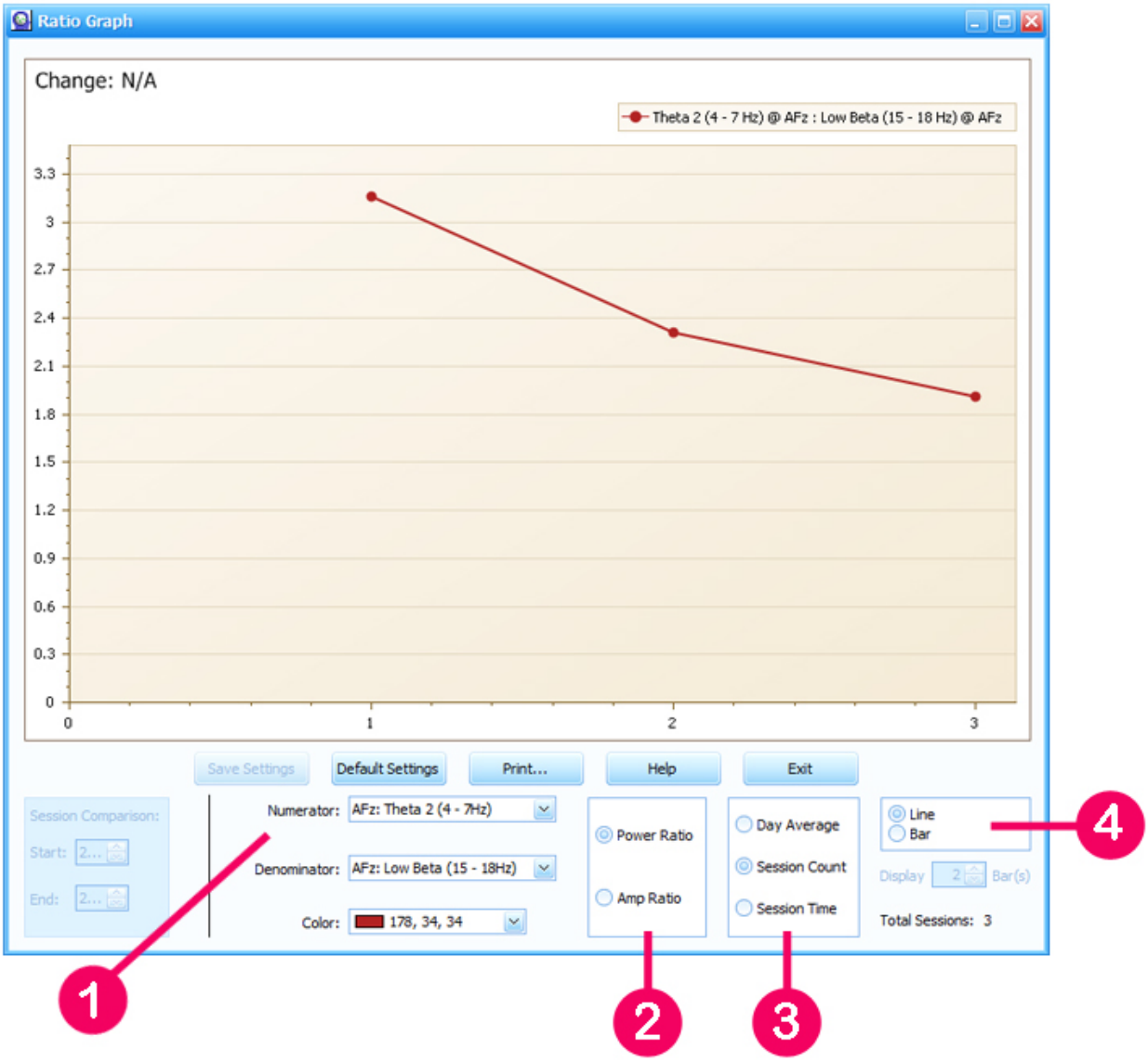



*Figure 6.* Example of theta/beta ratio chart created by SmartMind (Sandford, 2012). 1 = Ratio numerator and denominator settings; 2 = Type of ratio (Amp Ratio = mean of theta amplitude in μVs divided by mean of beta amplitude in μVs, Power Ratio = mean of theta amplitude in μVs squared divided by mean of beta amplitude in μVs squared.) Monastra et al. (1999) report the the power ratio is more sensitive as a diagnostic measure of ADHD and will be used in this study; 3= scale of the graph's abscissa; 4 = Selector for type of graph.

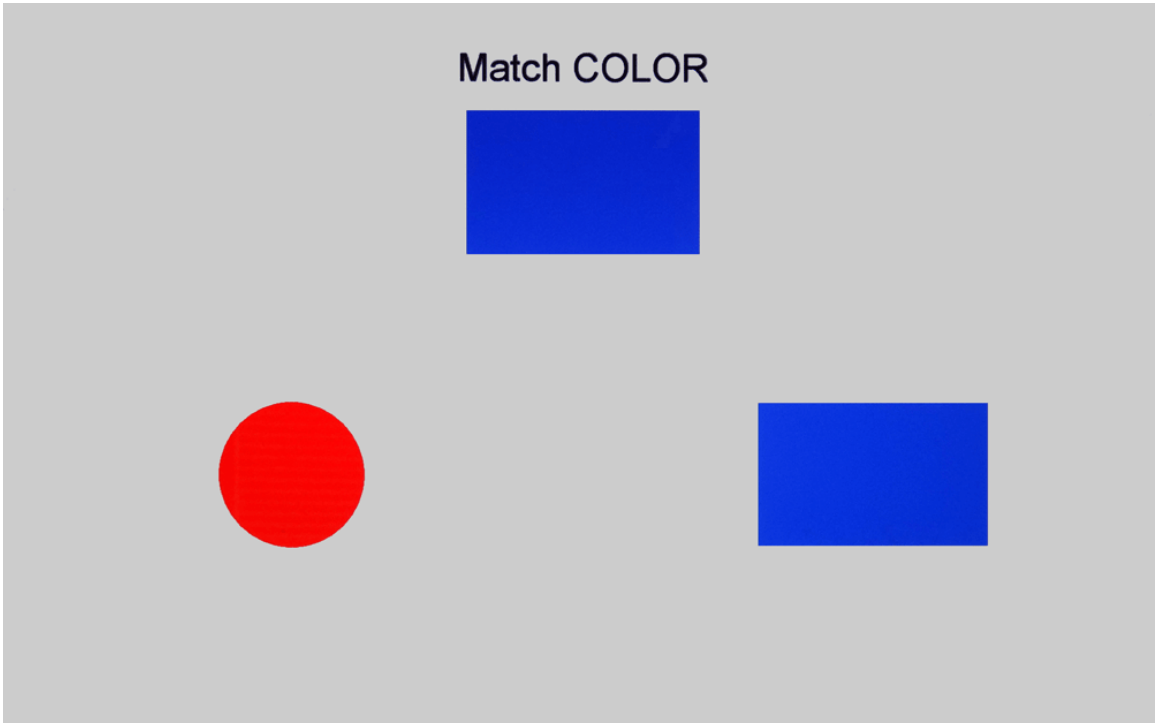



*Figure 7.* Example of CNS-VS SAT task (SAT; Gualtieri & Johnson, 2006). Participants are exposed to two shapes (i.e., circle and rectangle) in three positions. The shape on the top is the prompt, and the shapes on the bottom represent the possible answers. The shapes are randomly assigned and always consist of two of one shape and one of the other. Colors are also randomly assigned to either blue or red. The written instruction, located above the top shape asks participants to either “Match COLOR” or “Match SHAPE.” The correct response is selected by clicking on either the left or right shift key on the computer keyboard that corresponds with the correct answer.

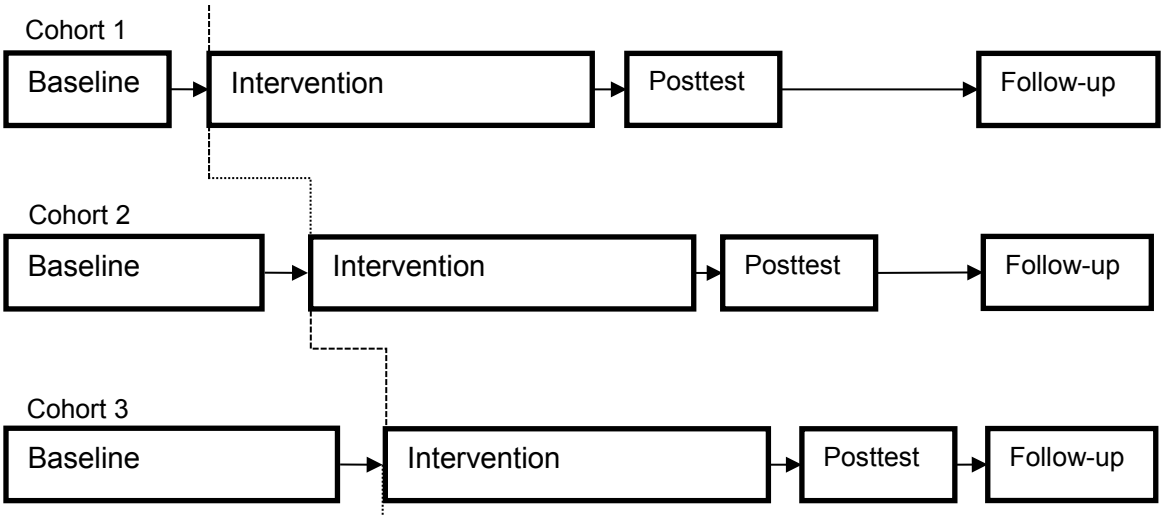



*Figure 8*. Multiple-baseline-across-participants single-case design model.

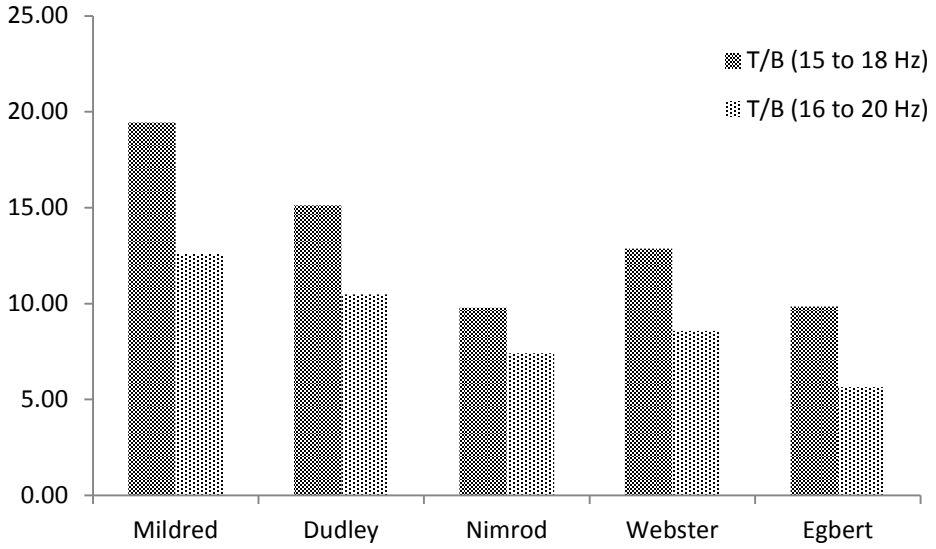



*Figure 9.* Comparison of pre-intervention theta/beta ratios. During the baseline phase, EEG of two overlapping beta bands (15 to 18 Hz. and 16 to 18 Hz) were recorded and compared to determine which frequencies would be enhanced as part of a theta/beta protocol. Beta recorded at 15 to 18 Hz consistently produced the highest theta/beta ratios in all participants.

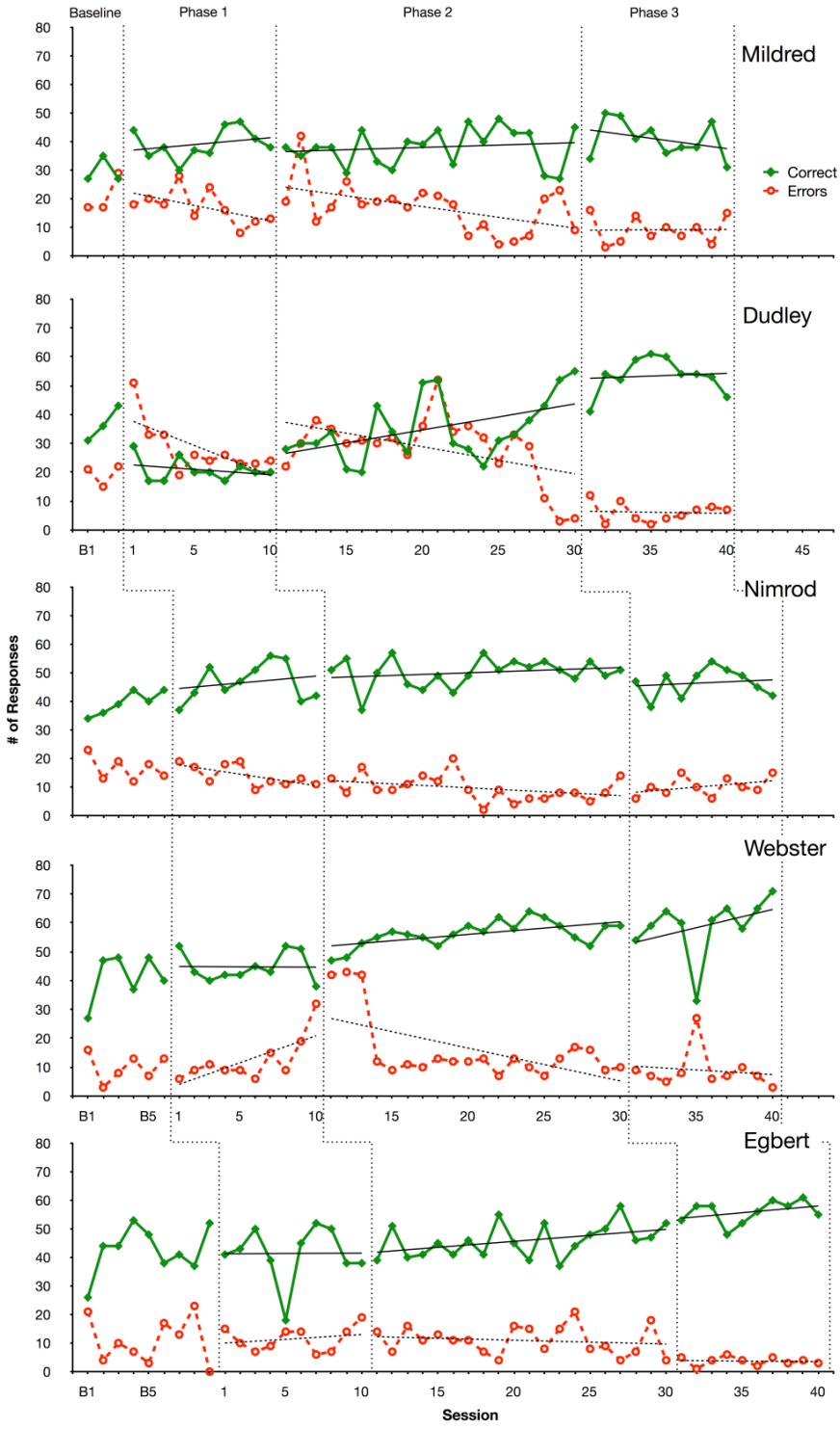



*Figure 10.* CNS-VS SAT correct responses and errors, trends by phase. Trends that were expected to increase are represented by a solid line; trends that were expected to decrease are represented by a dotted line.

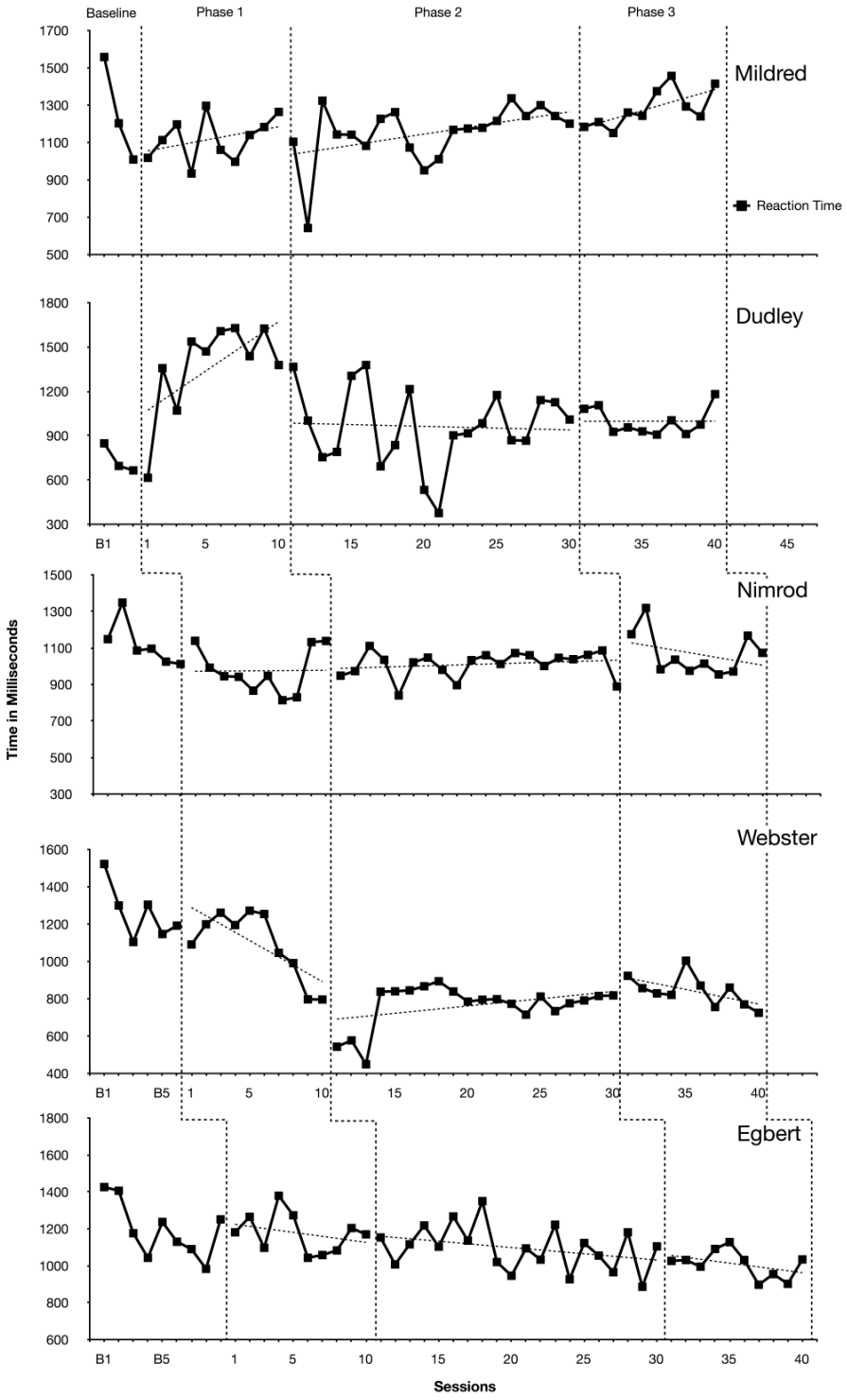



*Figure 11.* CNS-VS SAT mean reaction time, trends by phase. Reaction time is defined as the amount of time between the presentation of the target and correct responses in milliseconds. Trend lines that were expected to decrease are represented by a dotted line.

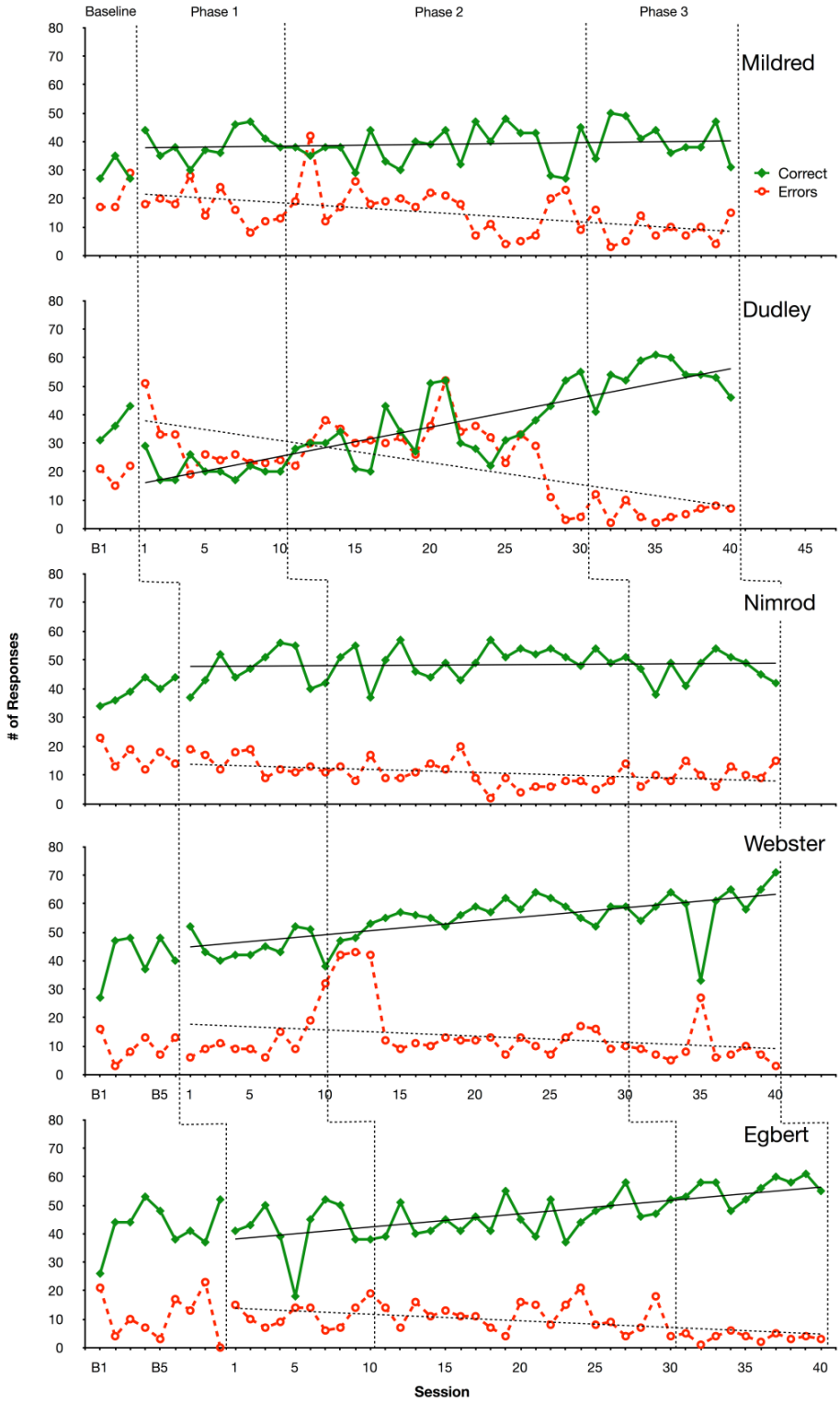



*Figure 12.* CNS-VS SAT correct responses and errors, trends across all phases. Trends that were expected to increase are represented by a solid line; trends that were expected to decrease are represented by a dotted line.

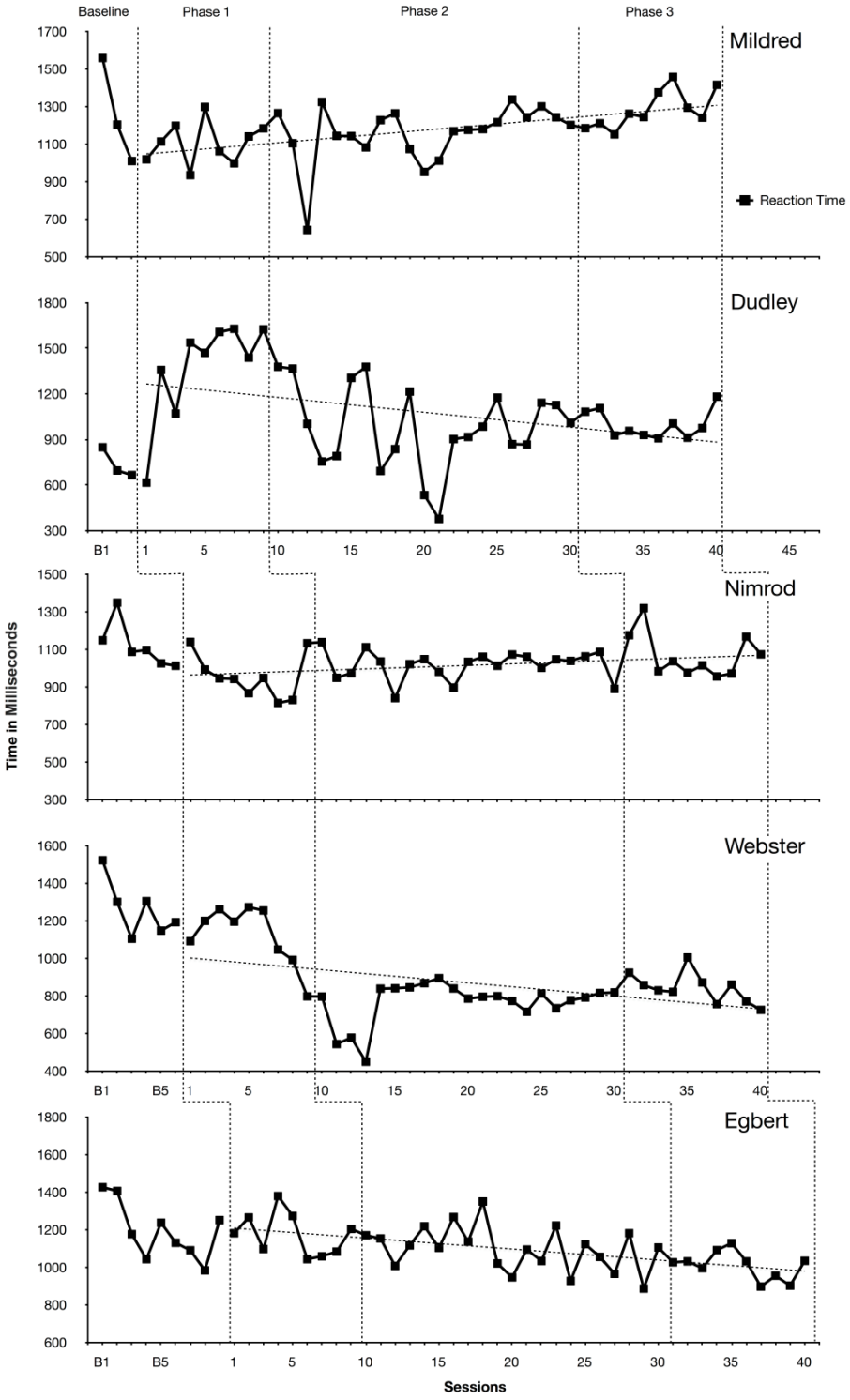



*Figure 13.* CNS-VS SAT mean reaction times, trends across all phases. Reaction time is defined as the amount of time between the presentation of the target and correct responses in milliseconds. Trend lines that were expected to decrease are represented by a dotted line.

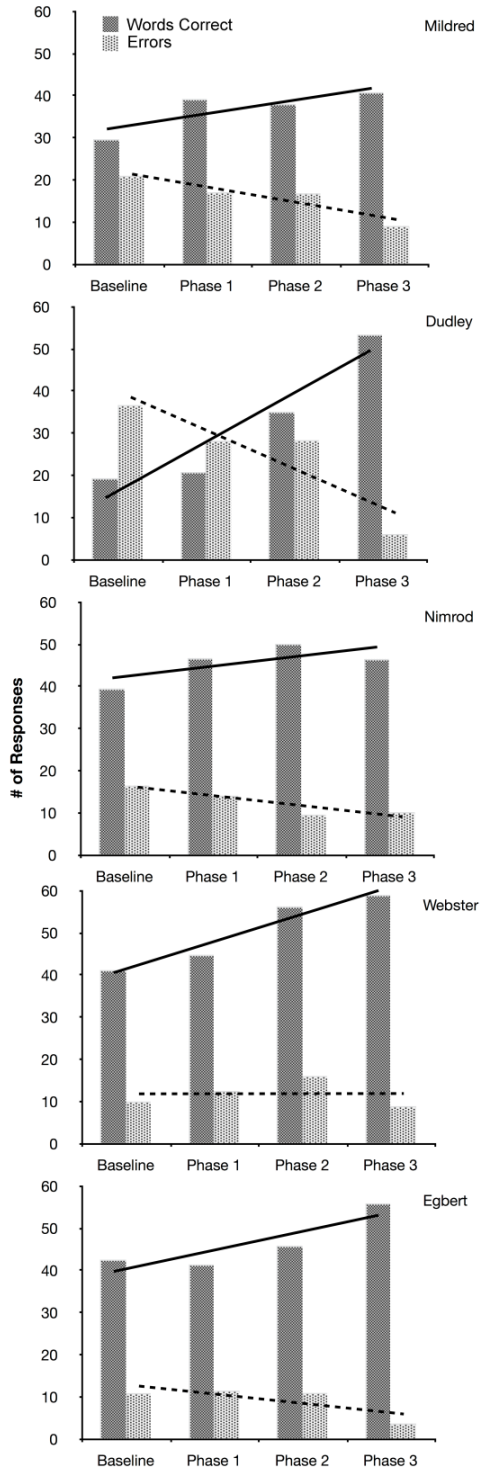



*Figure 14.* CNS-VS SAT levels (means) of raw scores by phase. Trends for the number of correct words were expected to increase and are represented by a solid line; trends for number errors, which were expected to decrease, are represented by a dotted line.

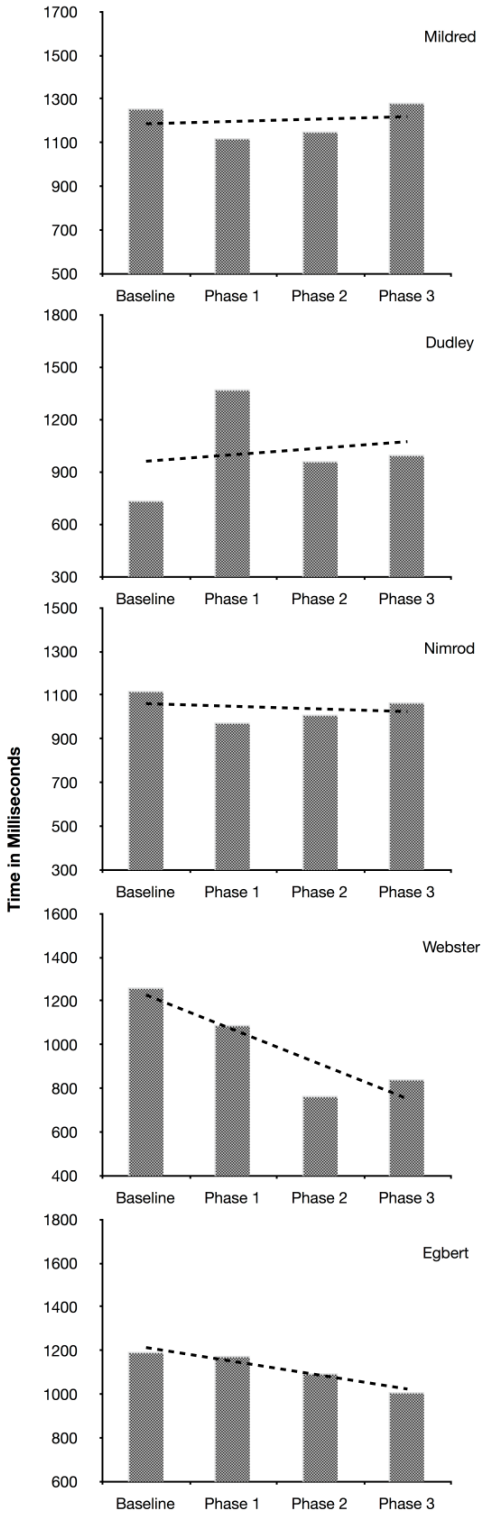



*Figure 15.* CNS-VS SAT levels (means) of reaction times for each phase. Trend lines for reaction times, that were expected to decrease, are represented by a dotted line.

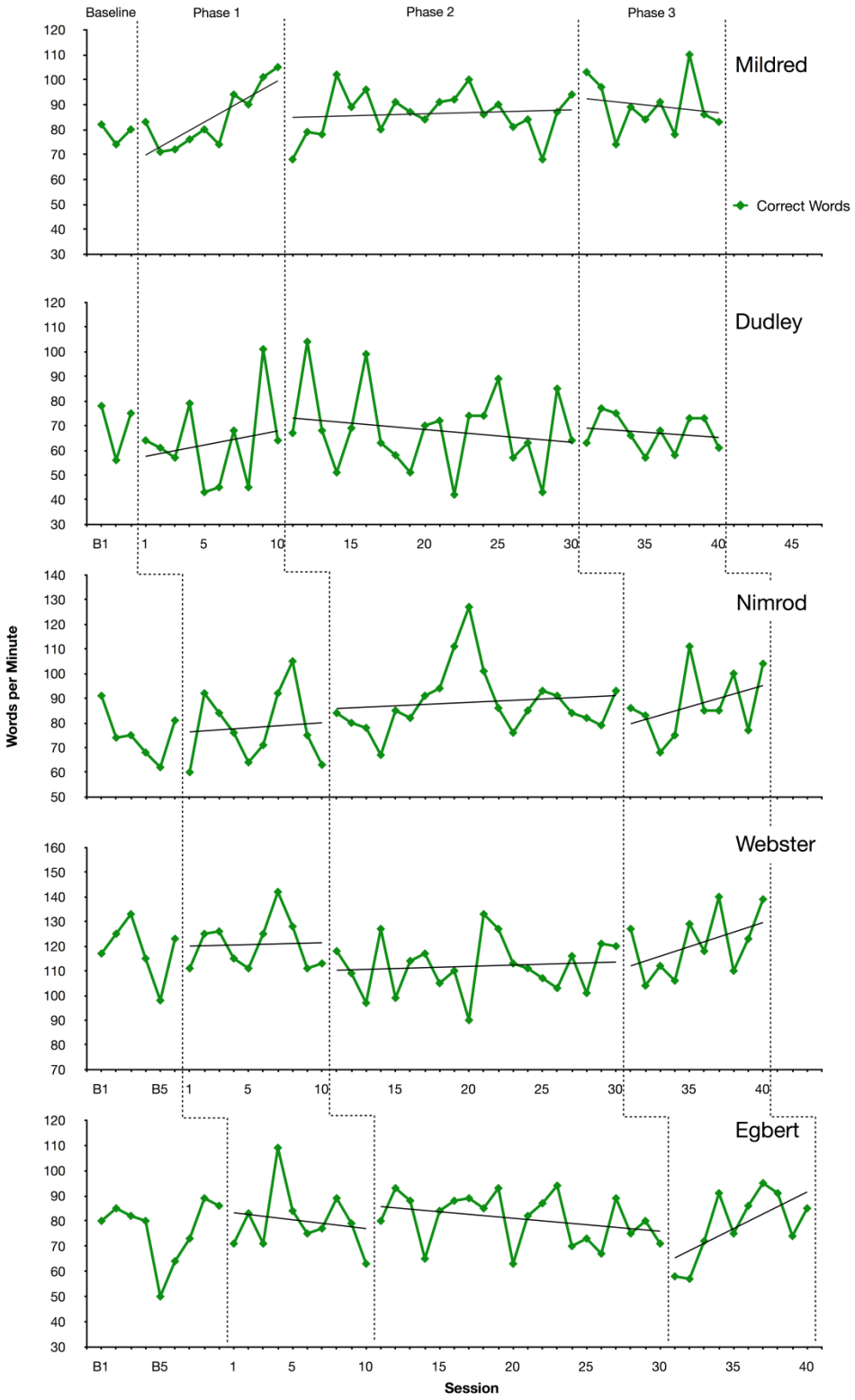



*Figure 16.* DIBELS ORF trends for words correct per minute by phase.

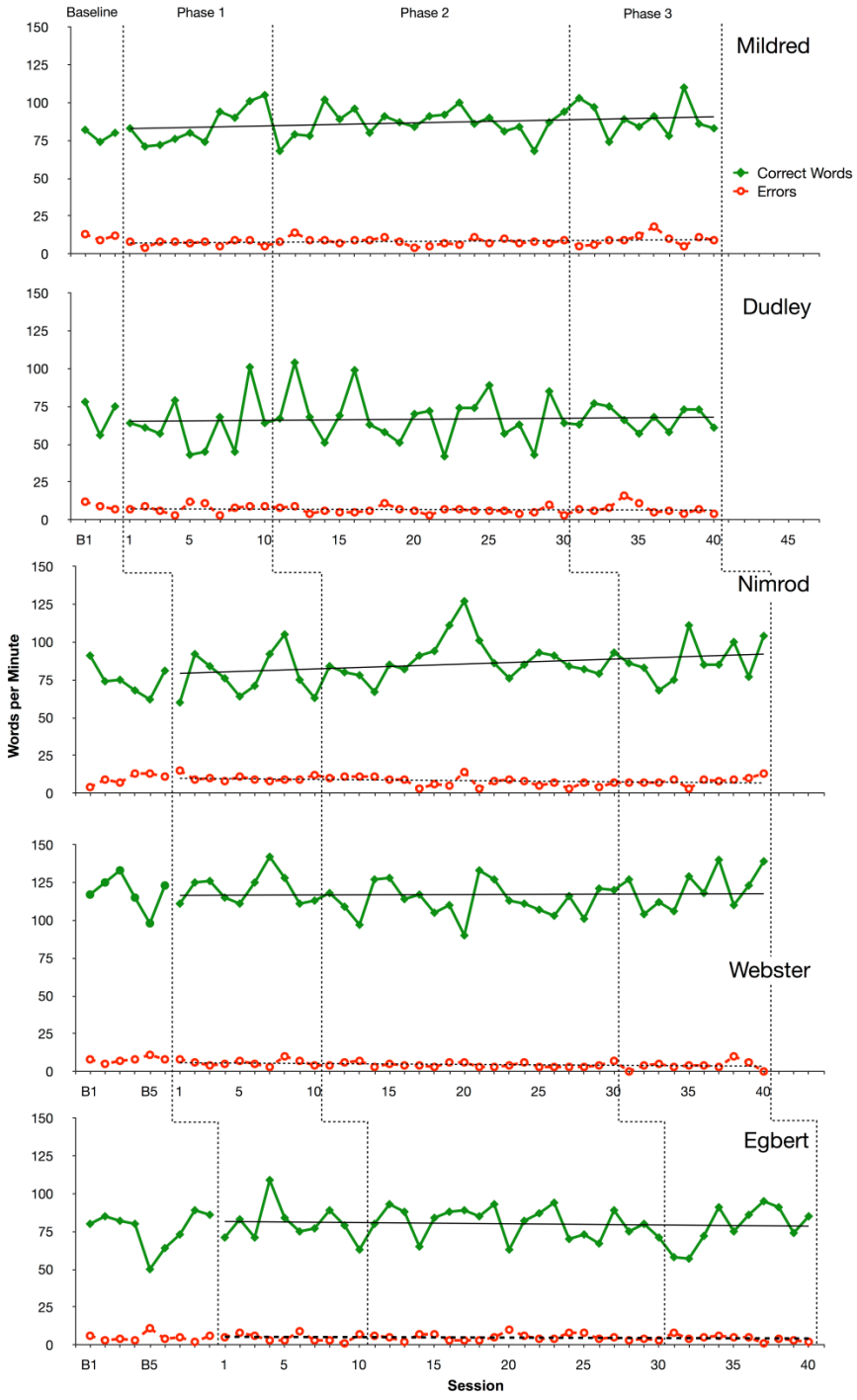



*Figure 17.* DIBELS ORF trends for words correct and errors across all phases. Trends for the number of correct words were expected to increase and are represented by a solid line; trends for number errors, which were expected to decrease, are represented by a dotted line.

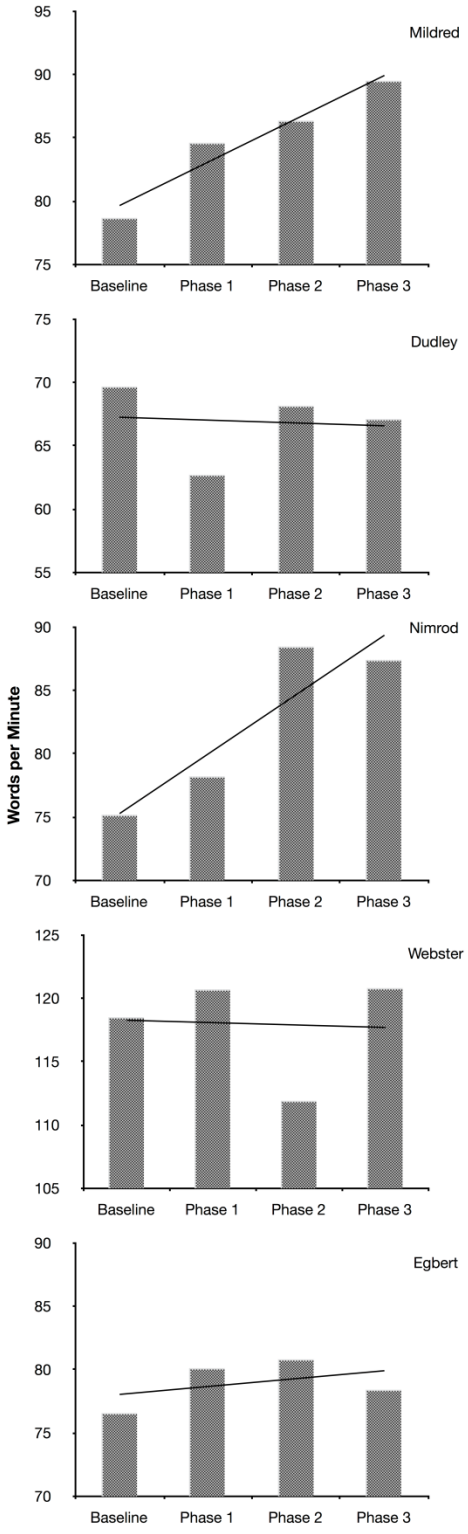



*Figure 18.* DIBELS ORF levels (means) of words read correctly by phase.

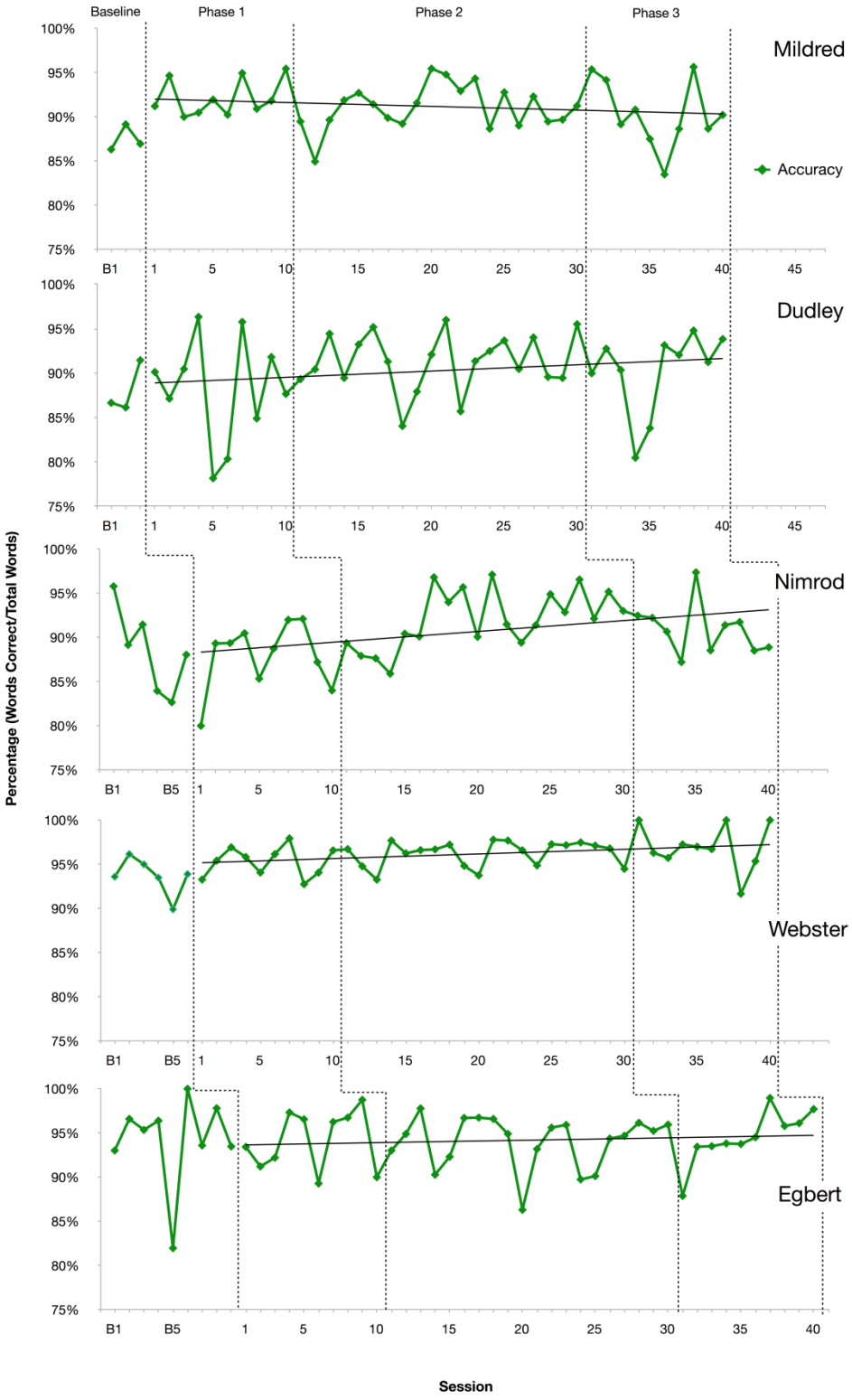



*Figure 19*. DIBELS ORF accuracy trends across phases

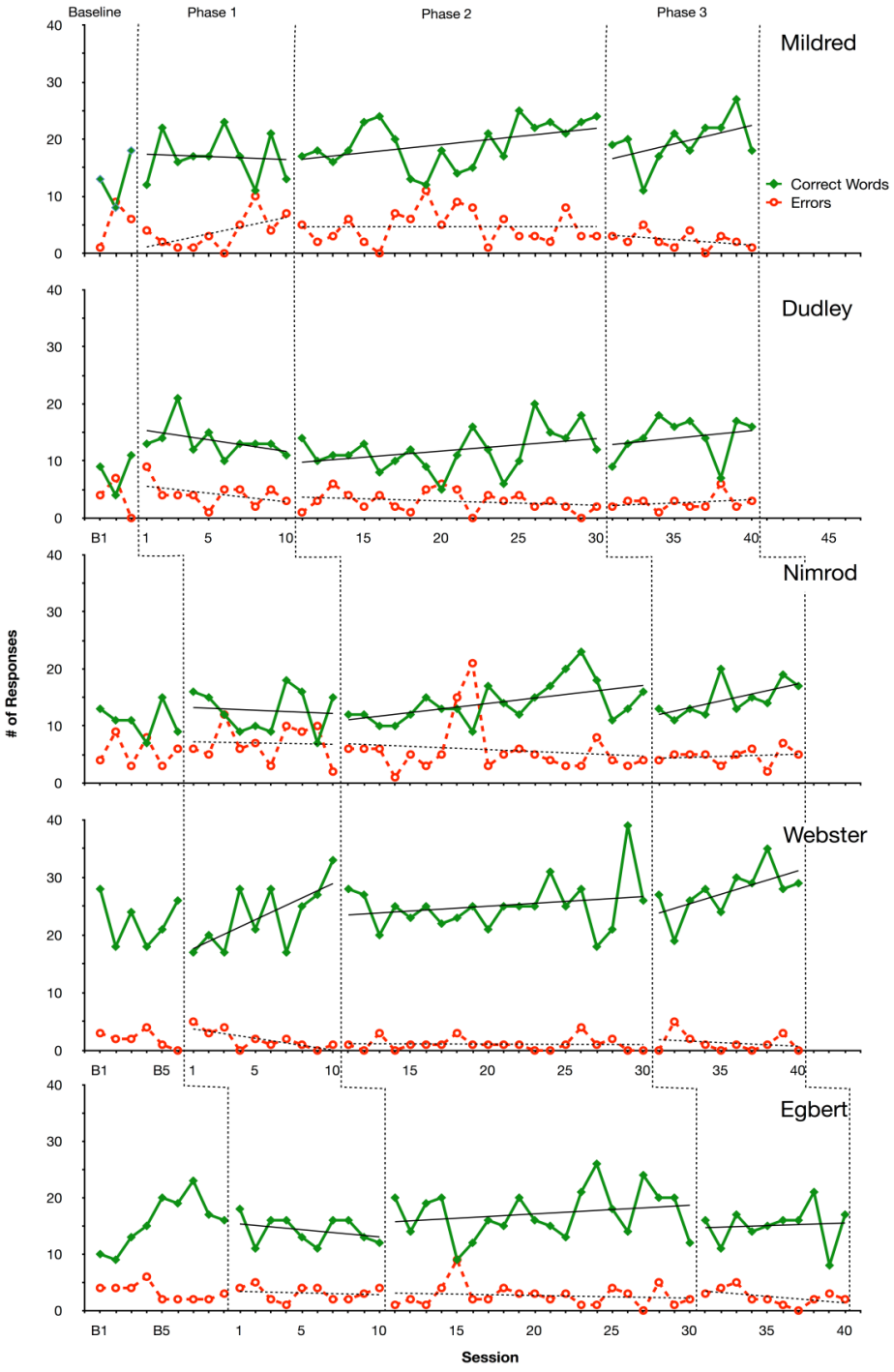



*Figure 20.* Maze words correct and errors, trends by phase. Trends that were expected to increase are represented by a solid line; trends that were expected to decrease are represented by a dotted line.

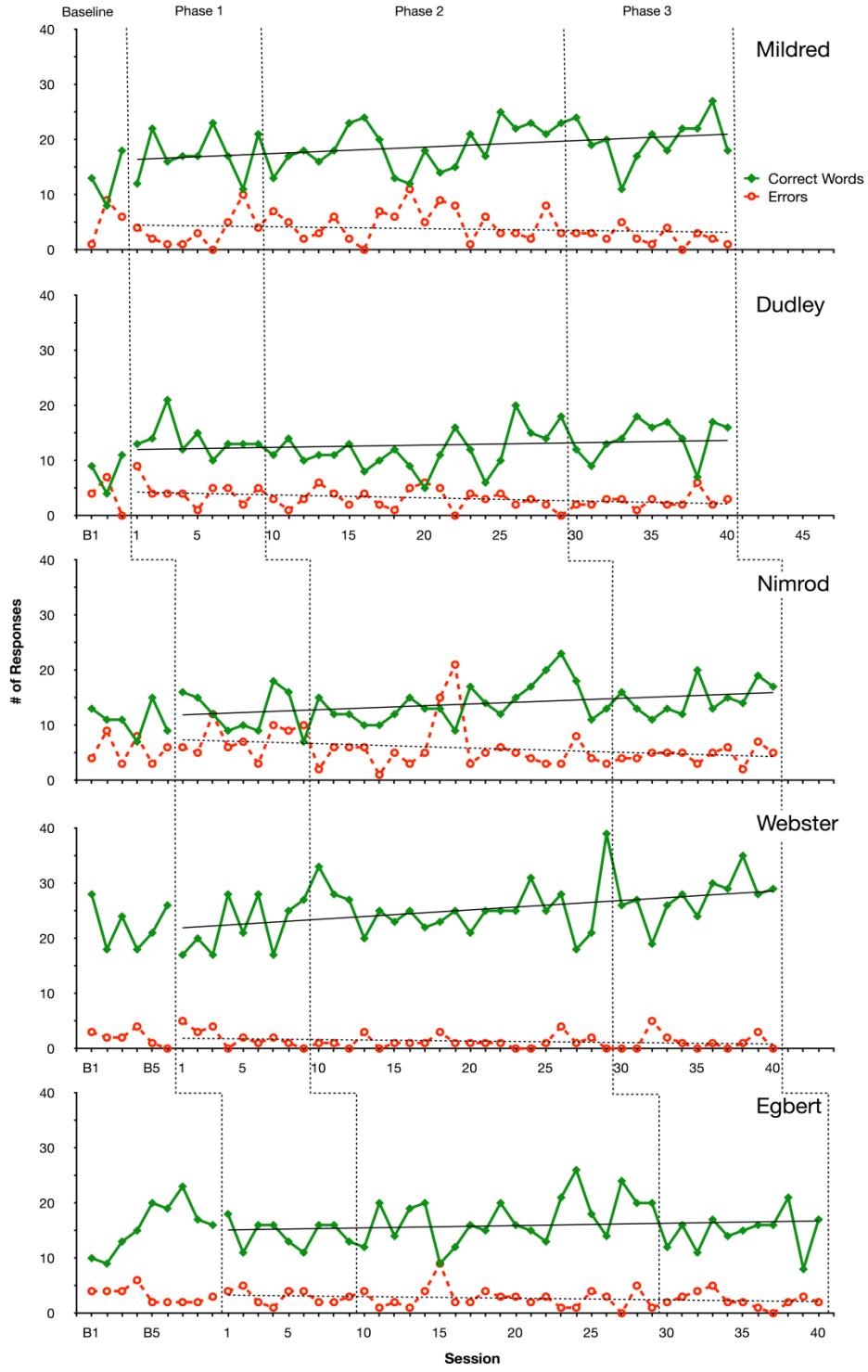



*Figure 21.* Maze words correct and errors, trends across all phases. Trends that were expected to increase are represented by a solid line; trends that were expected to decrease are represented by a dotted line.

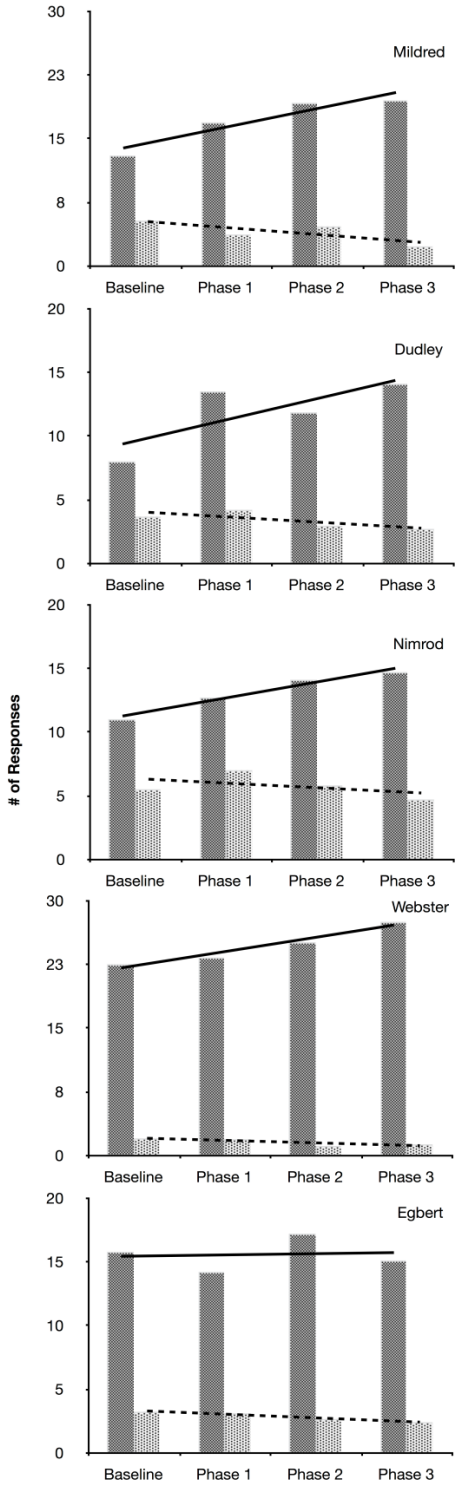
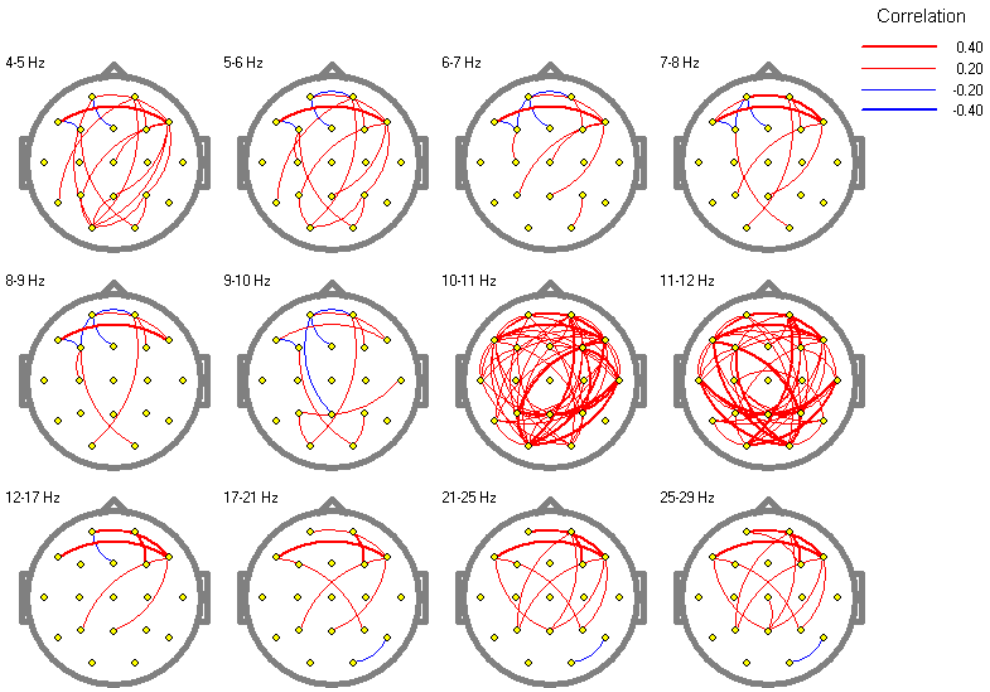



*Figure 22.* Maze raw score words correct and errors, means by phase. Trends that were expected to increase are represented by a solid line; trends that were expected to decrease are represented by a dotted line.

**Pretest Coherence with Eyes Open**




**Posttest Coherence with Eyes Open**

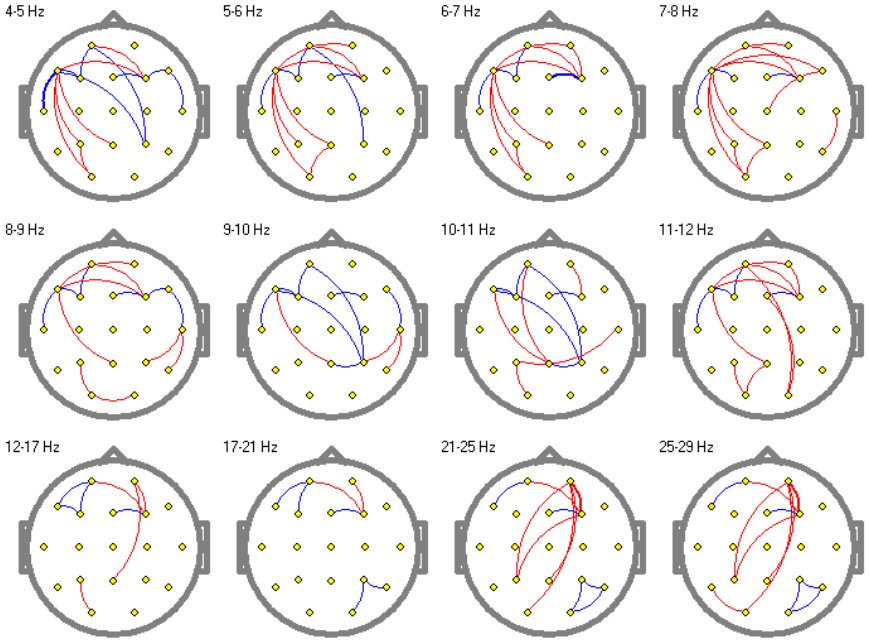
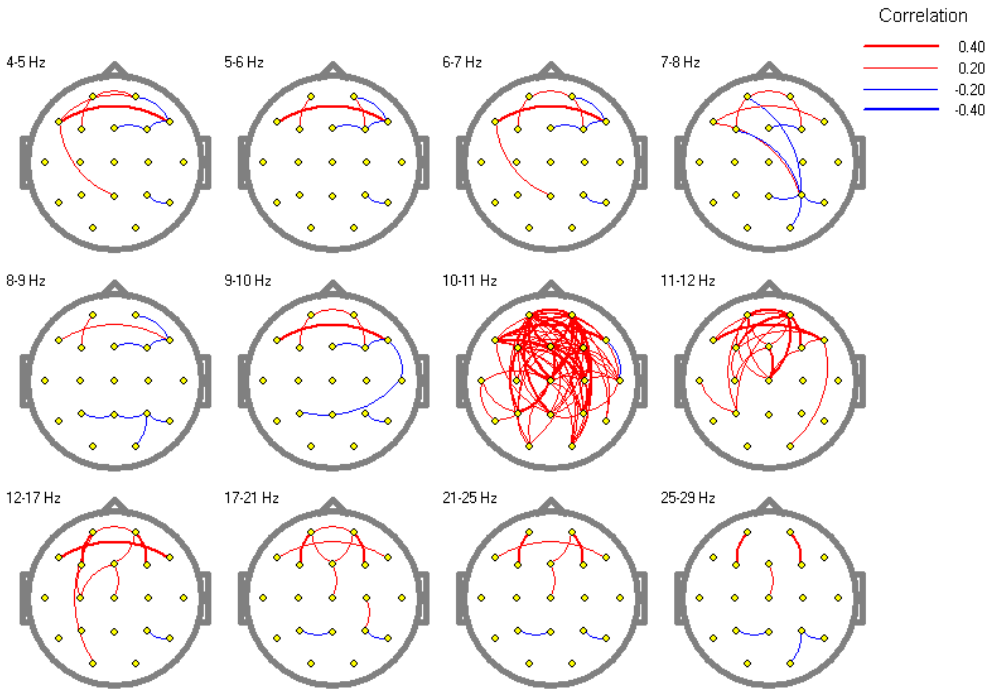



*Figure 23.* Pre- and posttest qEEG coherence diagrams for Dudley. Red = increased (hypercoherence), blue = reduced (hypocoherence). Dots indicate International 10/20 electrode locations.

**Pretest Coherence with Eyes Open**




**Posttest Coherence with Eyes Open**

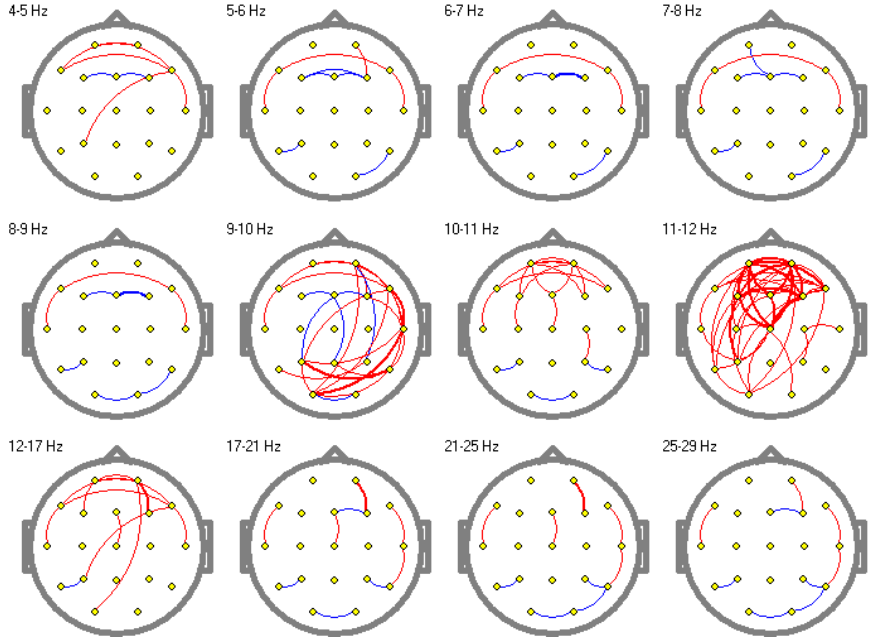



*Figure 24.* Pre- and posttest qEEG coherence diagrams for Nimrod. Red = increased (hypercoherence), blue = reduced (hypocoherence). Dots indicate International 10/20 electrode locations.

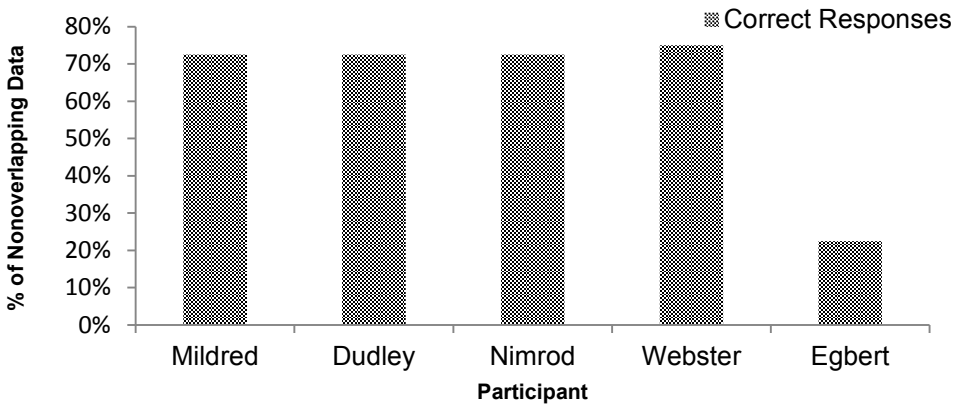



*Figure 25*. CNS-SAT percentage of nonoverlapping data for correct responses

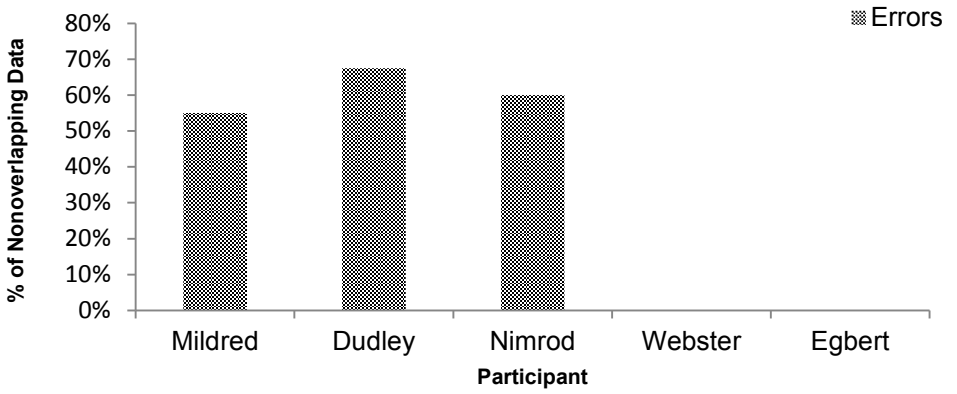



*Figure 26.* CNS-SAT percentage of nonoverlapping data for errors. Webster and Egbert both had 0% nonoverlapping data.

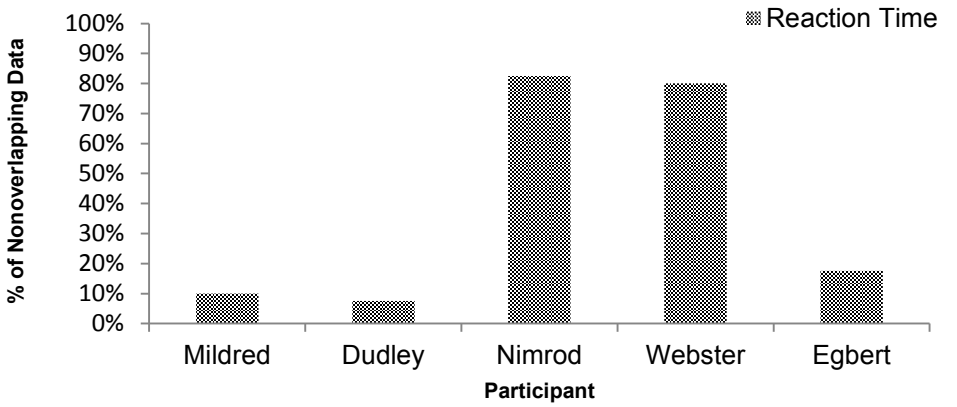



*Figure 27*. CNS-SAT percentage of nonoverlapping data for reaction time

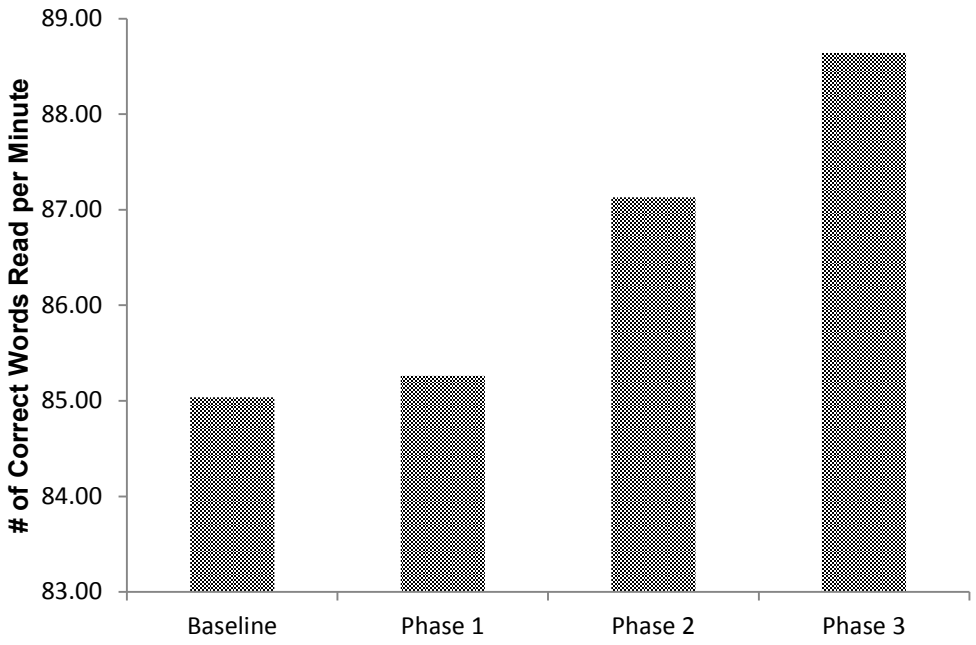



*Figure 28*. DIBELS ORF mean of correct words for all participants across phases

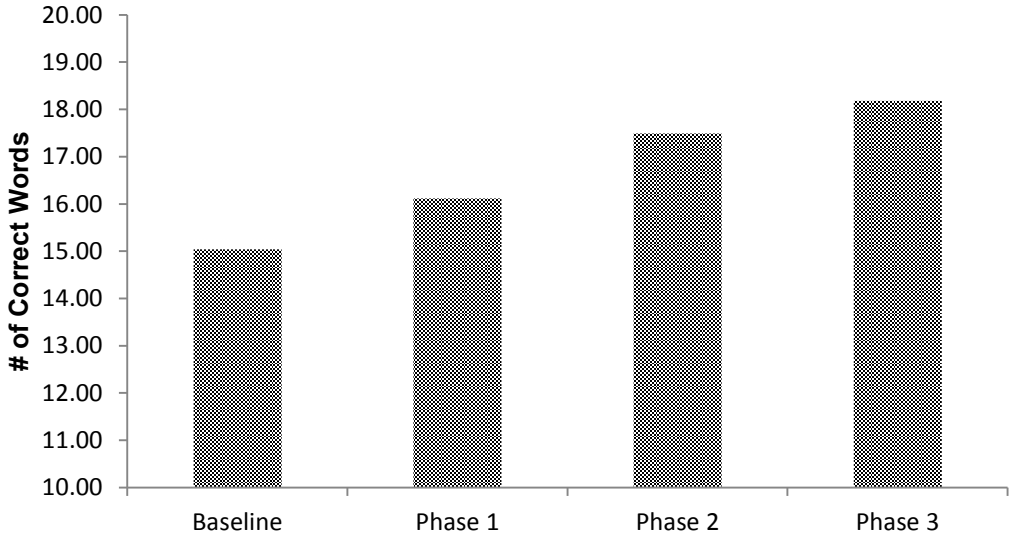



*Figure 29.* Maze mean of correct word choices for all participants across phases

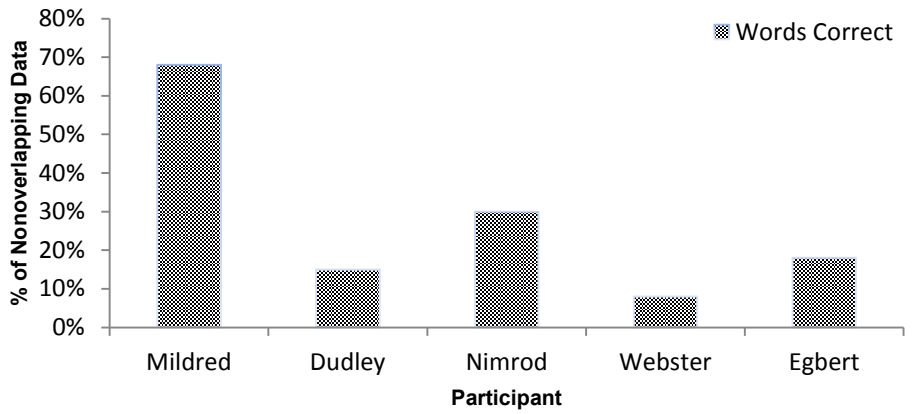



*Figure 30*. DIBELS ORF percentage of nonoverlapping data for words read correctly

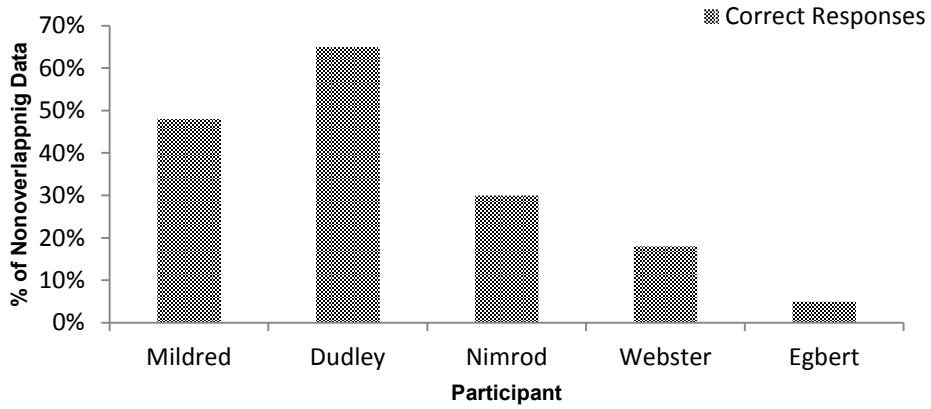



*Figure 31*. Maze percentage of nonoverlapping data for correct word choices

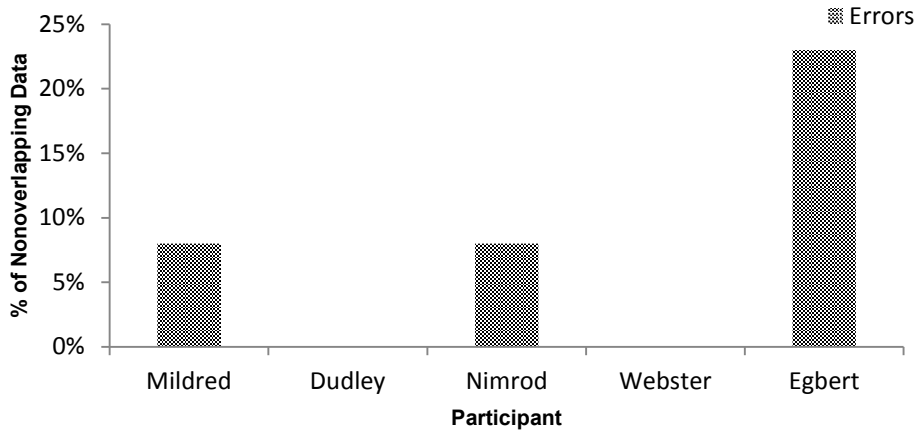



*Figure 32.* Maze percentage of nonoverlapping data for errors. Dudley and Webster both had 0% nonoverlapping data.

**Tables**

Table 1.

*Brainwave Frequencies*

| Name | | Frequency | Associated behaviors |
|---|---|---|---|
| Delta | | 1 to 4 Hz | Deep sleep |
| Theta | | 4 to 8 Hz | Deep relaxation, creativity, distractibility, inattention, and sometimes depression and anxiety. Individuals with ADHD often have elevated levels of theta. |
| Alpha | | 8 to 12 Hz | Relaxed, feelings of calmness and peace. In certain individuals, depression and anxiety may be present. Some individuals with ADHD exhibit elevated levels of alpha. |
| Beta[a] | | 12 to 32 Hz | |
| | SMR | 12 to 15 Hz | Unlike low beta, which may be measured throughout the brain, SMR is located on the top of the head. The production of SMR is associated with a physically relaxed body but an alert mind; it is considered optimal for learning. |
| | Low Beta | 12 to 21 Hz | Alert and focused, individuals with beta that reaches the higher end of this frequency may have sleep disorders, difficulty learning, ADHD, and other difficulties. |
| | High Beta | 21 to 30 Hz | Peak performance and cognitive processing. Individuals with high levels are also subject to worry, depression, anxiety, insomnia, excessive rumination, and other problems. |

[a]Beta is usually divided into subcategories, including those listed above.

Table 2.

*Sunny Shoals Elementary School Demographics for 2011/2012*

| | *n* | Percent of Enrollment |
|---|---|---|
| Total Enrollment | 513 | |
| Ethnicity: | | |
| Asian | 48 | 9.4 |
| Black | 4 | 0.8 |
| Filipino | 11 | 2.1 |
| Hispanic | 103 | 20.1 |
| Native American | 4 | 0.8 |
| Pacific Islander | 1 | 0.2 |
| White | 314 | 31.2 |
| Multiple | 28 | 5.5 |
| Socioeconomically Disadvantaged | 95 | 18.5 |
| English Language Learners | 79 | 15.4 |
| Students with Disabilities | 58 | 11.3 |

*Note*. Data for the 2012/2013 school year were not available.

Table 3.

*Participant Demographics*

| Student | Age | Gender | Grade | Ethnicity | Existing Diagnosis | Family History ADHD | Prescription Medications | Referred for IEP/504 | Eligible for Services | Teacher Referral |
|---|---|---|---|---|---|---|---|---|---|---|
| Mildred | 9.58 | F | 4 | Hispanic | No | Yes | No | No | No | Yes |
| Dudley | 10.63 | M | 4 | Black | Yes | No | No | 504 | Yes | Yes |
| Nimrod | 9.37 | M | 4 | Vietnamese | No | No | No | No | No | Yes |
| Webster | 10.66 | M | 4 | White | No | Yes | No | No | No | Yes |
| Egbert | 9.98 | M | 4 | Hispanic | Yes | No | No | IEP | No | Yes |

*Note*. Age calculated as of March 2013

Table 4.

*Participant Health History as Reported by Parent*

| | Participant | | | | |
|---|---|---|---|---|---|
| | Mildred | Dudley | Nimrod | Webster | Egbert |
| ADHD Diagnosis? | No | **Yes** | No | No | **Yes** |
| If yes, subtype? | | **Inattentive** | | | **Unknown** |
| Family history of ADHD? | **Yes** | No | No | **Yes** | No |
| If yes, subtype? | **Combined** | | | | |
| Prescription medications? | No | No | No | No | No |
| Anxiety | No | No | No | No | No |
| Attention problems | **Yes** | **Yes** | No | **Yes** | **Yes** |
| Behavior problems | **Yes** | No | No | No | **Yes** |
| Depression | No | No | No | No | No |
| Head Injury | No | No | No | No | No |
| Headaches | No | **Yes** | No | No | **Yes** |
| Hyperactivity | **Yes** | No | No | No | No |
| Impulsivity | **Yes** | No | No | No | No |
| Memory problems | **Yes** | No | No | **Yes** | No |
| School/work problems | **Yes** | **Yes** | No | **Yes** | **Yes** |
| Seizures | No | No | No | No | No |
| Sleep problems | No | No | No | No | No |

*Note*. Responses that met criteria for the study or were an area of concern appear in bold.

Table 5.

*Participant Assignment to Cohorts*

| | Student | Age | Gender | Grade |
|---|---|---|---|---|
| Cohort 1 | Mildred | 9.58 | F | 4 |
| | Dudley | 10.63 | M | 4 |
| Cohort 2 | Nimrod | 9.37 | M | 4 |
| | Webster | 10.66 | M | 4 |
| Cohort 3[a] | Egbert | 9.98 | M | 4 |

[a]Cohort 3 originally had two students but one dropped out of the study during the final stage of screening.

Table 6.

*IVA+Plus Pre- and Posttest Standard Scores*

| Subtest | | Participant | | | | | Group | |
|---|---|---|---|---|---|---|---|---|
| | | Mildred | Dudley[a] | Nimrod | Webster | Egbert | Mean | SD |
| FS-RCQ | Pretest | 106 | 19 | 79 | 91 | 68 | 72.60 | 33.13 |
| | Posttest | **109** | **63** | **90** | **97** | **80** | **87.80** | 17.43 |
| | Follow-up[b] | 81 | 38 | 85 | 97 | **88** | 77.80 | 23.02 |
| A-RCQ | Pretest | 108 | 23 | 83 | 89 | 71 | 74.80 | 31.89 |
| | Posttest | **109** | **81** | **95** | **106** | **79** | **94.00** | 13.82 |
| | Follow-up[b] | 95 | 27 | **102** | 100 | **92** | 83.20 | 31.37 |
| V-RCQ | Pretest | 102 | 37 | 80 | 95 | 72 | 77.20 | 25.41 |
| | Posttest | **103** | **53** | **88** | 88 | **87** | **83.80** | 18.46 |
| | Follow-up[b] | 67 | **62** | 68 | **94** | 86 | 75.40 | 13.81 |
| FS-AQ | Pretest | 61 | 59 | 99 | 83 | 54 | 71.20 | 19.11 |
| | Posttest | **77** | 32 | **103** | **95** | **90** | **79.40** | 28.13 |
| | Follow-up[b] | 77 | **42** | 94 | **107** | 73 | 78.60 | 24.58 |
| A-AQ | Pretest | 41 | 79 | 96 | 96 | 74 | 77.20 | 22.53 |
| | Posttest | **65** | 37 | **107** | **99** | **93** | **80.20** | 28.87 |
| | Follow-up[b] | **87** | **45** | 93 | **108** | 75 | **81.60** | 23.66 |
| V-AQ | Pretest | 85 | 46 | 101 | 74 | 49 | 71.00 | 23.53 |
| | Posttest | **91** | 37 | 98 | **92** | **90** | **81.60** | 25.13 |
| | Follow-up[b] | 75 | **48** | 95 | **105** | 75 | **79.60** | 21.93 |
| C-SA | Pretest | 42 | 28 | 91 | 84 | 48 | 58.60 | 27.47 |
| | Posttest | **70** | 7 | **96** | **87** | **82** | **68.40** | 35.59 |
| | Follow-up[b] | **73** | **47** | 94 | **107** | 66 | **77.40** | 23.59 |
| A-SA | Pretest | 10 | 52 | 83 | 105 | 55 | 61.00 | 35.84 |
| | Posttest | **55** | 10 | **92** | 92 | **90** | **67.80** | 35.95 |
| | Follow-up[b] | **83** | **45** | 88 | **110** | 69 | **79.00** | 24.05 |
| V-SA | Pretest | 80 | 21 | 100 | 67 | 52 | 64.00 | 29.81 |
| | Posttest | **88** | **25** | 100 | **84** | **77** | **74.80** | 29.06 |
| | Follow-up[b] | 73 | **61** | **101** | **103** | 71 | **81.80** | 19.01 |
| Supports Diagnosis? | Pretest | Yes | Yes | Yes | Yes | Yes | | |
| | Posttest | Yes | Yes | **No** | **No** | Yes | | |
| | Follow-up[b] | Yes | Yes | **No** | **No** | Yes | | |

*Note*. Posttest results in bold indicate change in the desired direction. FS-RCQ = Full Scale Response Control Quotient (RCQ); A-RQ = Auditory RCQ; V-RCQ = Visual RCQ; FS-AQ = Full Scale Attention Quotient (AQ); A-AQ = Auditory AQ; V-AQ = Visual AQ; C-SA = Combined Sustained Attention; A-SA = Auditory Sustained Attention; V-SA = Visual Sustained Attention
[a]Analysis of Dudley's posttest results must be interpreted with caution. [b]Follow-up was conducted approximately five and a half months after posttest.

Table 7.

*IVA+Plus A-RCQ Quotient (Standard) Scores*

| | Prudence | | Consistency | | Stamina | |
|---|---|---|---|---|---|---|
| | Pre | Post | Pre | Post | Pre | Post |
| Mildred | 100 | **104** | 90 | **103** | 127 | 113 |
| Dudley[a] | 29 | **60** | 43 | 42 | 66 | **157** |
| Nimrod | 66 | **98** | 97 | **105** | 106 | 88 |
| Webster | 84 | **101** | 94 | **107** | 100 | **105** |
| Egbert | 96 | **101** | 83 | 72 | 68 | **82** |
| Mean | 75 | **92.8** | 81.4 | **85.8** | 93.4 | **109** |
| SD | 28.91 | 18.46 | 22.10 | 28.38 | 26.11 | 29.61 |

*Note*. Posttest results in bold indicate change in the desired direction.
[a]Dudley's posttest results must be interpreted with caution.

Table 8.

*IVA+Plus V-RCQ Quotient (Standard) Scores*

| | Prudence | | Consistency | | Stamina | |
|---|---|---|---|---|---|---|
| | Pre | Post | Pre | Post | Pre | Post |
| Mildred | 90 | **94** | 100 | **108** | 114 | 102 |
| Dudley[a] | 66 | 47 | 63 | **79** | 60 | **91** |
| Nimrod | 87 | **102** | 94 | 90 | 80 | **84** |
| Webster | 82 | **90** | 82 | **84** | 114 | 104 |
| Egbert | 77 | **85** | 73 | **104** | 94 | 89 |
| Mean | 80.4 | **83.6** | 82.4 | **93.0** | 92.4 | **94.0** |
| SD | 9.45 | 21.38 | 15.08 | 12.57 | 23.13 | 8.63 |

*Note*. Posttest results in bold indicate change in the desired direction.
[a]Dudley's posttest results must be interpreted with caution.

Table 9.

*IVA+Plus A-AQ Quotient (Standard) Scores*

| | Vigilance | | Focus | | Speed | |
|---|---|---|---|---|---|---|
| | Pre | Post | Pre | Post | Pre | Post |
| Mildred | 0 | **41** | 102 | **113** | 74 | 72 |
| Dudley[a] | 85 | 0 | 50 | 35 | 121 | **136** |
| Nimrod | 82 | **89** | 84 | **103** | 128 | 120 |
| Webster | 99 | 99 | 86 | **105** | 107 | 93 |
| Egbert | 75 | **99** | 67 | **77** | 113 | 109 |
| Mean | 68.2 | 65.6 | 77.8 | **86.6** | 108.6 | 106 |
| SD | 39.11 | 43.84 | 19.88 | 31.86 | 20.91 | 24.65 |

*Note*. Posttest results in bold indicate change in the desired direction.
[a]Dudley's posttest results for vigilance, when considered with his V-AQ score for vigilance, suggest that this participant wasn't motivated to do well during the test administration.

Table 10.

*IVA+Plus V-AQ Quotient (Standard) Scores*

| | Vigilance | | Focus | | Speed | |
|---|---|---|---|---|---|---|
| | Pre | Post | Pre | Post | Pre | Post |
| Mildred | 92 | 41 | 101 | **113** | 75 | 72 |
| Dudley[a] | 10 | 0 | 58 | 37 | 112 | **127** |
| Nimrod | 103 | 103 | 79 | **80** | 119 | 113 |
| Webster | 61 | **106** | 95 | 88 | 87 | **88** |
| Egbert | 1 | **81** | 89 | **92** | 105 | 104 |
| Mean | 53.4 | **66.2** | 84.4 | 82.0 | 99.6 | **100.8** |
| SD | 46.47 | 45.21 | 16.85 | 27.96 | 18.19 | 21.44 |

*Note*. Posttest results in bold indicate change in the desired direction.
[a]Dudley's posttest results for vigilance, when considered with his A-AQ score for vigilance, suggest that this participant wasn't motivated to do well during the test administration.

Table 11.

*WASI-II Results*

| Measure | Participant | | | | | Mean | SD |
|---|---|---|---|---|---|---|---|
| | Mildred | Dudley | Nimrod | Webster | Egbert | | |
| T Scores | | | | | | | |
| Block Design | 48 | 50 | 37 | 45 | 52 | 46.40 | 5.86 |
| Perceptual Reasoning | 46 | 52 | 58 | 67 | 50 | 54.60 | 8.17 |
| Matrix Reasoning | 45 | 42 | 40 | 50 | 53 | 46.00 | 5.43 |
| Similarities | 65 | 59 | 44 | 53 | 55 | 55.20 | 7.76 |
| Derived Scores | | | | | | | |
| Verbal IQ | 109 | 109 | 104 | 116 | 104 | 108.40 | 4.93 |
| Performance IQ | 94 | 93 | 81 | 96 | 104 | 93.60 | 8.26 |
| FSIQ-4 | 102 | 101 | 90 | 107 | 105 | 101.00 | 6.60 |
| FSIQ-2 | 92 | 94 | 98 | 115 | 102 | 100.20 | 9.12 |

*Note*. The WASI-II provides two FSIQ scores, the FSIQ-4 is derived from all four subtests and the FSIQ-2 is derived from only the Vocabulary and Matrix Reasoning subtests.

Table 12.

*WRMT-III Results Standard Scores*

| | Participant | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mildred | Dudley | Nimrod | Webster | Egbert | Sum | Mean | SD |
| Basic Skills (Cluster Score) | 86 | 91 | 94 | 105 | 100 | 476 | 95.2 | 7.46 |
| Word Identification | 93 | 90 | 98 | 110 | 85 | 476 | 95.2 | 9.52 |
| Word Attack | 80 | 94 | 92 | 135 | 115 | 516 | 103.2 | 21.79 |
| Reading Comprehension (Cluster Score) | 89 | 82 | 91 | 124 | 91 | 477 | 95.4 | 16.41 |
| Word Comprehension | 90 | 92 | 99 | 118 | 94 | 493 | 98.6 | 11.35 |
| Passage Comprehension | 89 | 73 | 85 | 126 | 90 | 463 | 92.6 | 19.86 |
| Total Reading (Cluster Score) | 87 | 84 | 93 | 112 | 94 | 470 | 94 | 10.89 |
| Listening Comprehension | 104 | 80 | 74 | 135 | 77 | 470 | 94 | 25.82 |
| Oral Reading Fluency | 93 | 85 | 100 | 96 | 93 | 467 | 93.4 | 5.50 |

*Note*. The Total Reading score is derived from the Basic Skills and Reading Comprehension cluster scores.

Table 17.

*qEEG Pre- and Posttest FFT Theta/Beta Power Ratios*

| | Eyes Closed | |
|---|---|---|
| | Pretest | Posttest |
| Mildred | 5.97 | **5.77** |
| Dudley | 3.88 | 4.29 |
| Nimrod | 1.97 | **1.52** |
| Webster | 4.40 | **3.65** |
| Egbert | 2.00 | **1.92** |

*Note*. Posttest results in bold indicate change in the desired direction. FFT = Fast Fourier Transform. The qEEG report provided information on theta/beta power ratios calculated as $(\text{theta})^2 / (\text{beta})^2$. Theta was defined as (4 to 8 Hz) and beta as (13 to 21 Hz).

Table 18.

*IVA+Plus Pre- and Posttest Standard Scores (Without Dudley's Scores)*

| | | Participant | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Subtest | | Mildred | Nimrod | Webster | Egbert | Sum | Mean | SD |
| FS-RCQ | Pre | 106 | 79 | 91 | 68 | 344 | 86 | 16.31 |
| | Post | **109** | **90** | **97** | **80** | **376** | **94** | 12.19 |
| A-RCQ | Pre | 108 | 83 | 89 | 71 | 351 | 87.75 | 15.44 |
| | Post | **109** | **95** | **106** | **79** | **389** | **97.25** | 13.57 |
| V-RCQ | Pre | 102 | 80 | 95 | 72 | 349 | 87.25 | 13.70 |
| | Post | **103** | **88** | 88 | **87** | **366** | **91.5** | 7.68 |
| FS-AQ | Pre | 61 | 99 | 83 | 54 | 297 | 74.25 | 20.61 |
| | Post | **77** | **103** | **95** | **90** | **365** | **91.25** | 10.90 |
| A-AQ | Pre | 41 | 96 | 96 | 74 | 307 | 76.75 | 25.99 |
| | Post | **65** | **107** | **99** | **93** | **364** | **91** | 18.26 |
| V-AQ | Pre | 85 | 101 | 74 | 49 | 309 | 77.25 | 21.85 |
| | Post | **91** | 98 | **92** | **90** | **371** | **92.75** | 3.59 |
| C-SA | Pre | 42 | 91 | 84 | 48 | 265 | 66.25 | 24.82 |
| | Post | **70** | **96** | **87** | **82** | **335** | **83.75** | 10.84 |
| A-SA | Pre | 10 | 83 | 105 | 55 | 253 | 63.25 | 40.97 |
| | Post | **55** | **92** | 92 | **90** | **329** | **82.25** | 18.19 |
| V-SA | Pre | 80 | 100 | 67 | 52 | 299 | 74.75 | 20.35 |
| | Post | **88** | **100** | **84** | **77** | **349** | **87.25** | 9.64 |
| Supports | Pre | Yes | Yes | Yes | Yes | | | |
| Diagnosis? | Post | Yes | **No** | **No** | Yes | | | |

*Note*. Posttest results in bold indicate change in the desired direction. FS-RCQ = Full Scale Response Control Quotient (RCQ); A-RQ = Auditory RCQ; V-RCQ = Visual RCQ; FS-AQ = Full Scale Attention Quotient (AQ); A-AQ = Auditory AQ; V-AQ = Visual AQ; C-SA = Combined Sustained Attention; A-SA = Auditory Sustained Attention; V-SA = Visual Sustained Attention

# Appendices

## Appendix 1. Institutional Review Board Application and Approval

UNIVERSITY OF CALIFORNIA, RIVERSIDE
Human Research Review Board
Office of Research Integrity

**Date:** January 18, 2013

TO: La Marca, Jeffry
Graduate School of Education

FM: Monica Wicker, HRRB Analyst
Human Research Review Board

**RE: Human Subjects Protocol No. HS-12-135**
**"Neurofeedback as an Intervention to Improve Reading Achievement in Students with Attention Deficit Hyperactivity Disorder, Inattentive Subtype"**

The UCR Human Research Review Board has approved your above referenced protocol on **January 14, 2013**. This approval is valid *through* **January 13, 2014**. Please review your Approval Notice for details regarding this approval.

Three months before your expiration date, you will be sent the "Continuing Review of the Approved Human Subjects Protocol" form, which will allow you to indicate whether you wish to keep the protocol active or not. Please note that the expiration date is the last date that the protocol is approved.

If the Continuing Review Form is not received and approved by **January 13, 2014**, your protocol will expire and all research activities MUST cease. If you feel that stopping the research would invoke safety or ethical issues, please contact the UCR HRRB immediately.

Dr. Augustine Kposowa, Chair, HRRB
Dr. Rollanda O'Connor, Vice Chair, HRRB

Should you have any questions, please do not hesitate to contact us at: IRB@UCR.EDU. Thank you.

Cc: N/A
Jane Gunter
Department Chair, cover & approval notice
ORA File
Faculty Advisor(s): Rollanda O'Connor, rollanda.oconnor@ucr.edu

**HRRB approval is effective from date of this notice and good for one year. Annual reviews are required to keep project active.**

UNIVERSITY OF CALIFORNIA, RIVERSIDE
Human Research Review Board
Office of Research Integrity
**January 14, 2013**

## APPROVAL NOTICE

| | | | |
|---|---|---|---|
| **INVESTIGATOR:** | La Marca, Jeffry | **Administrator:** | N/A |
| **ACADEMIC UNIT:** | Graduate School of Education | | |
| **PROJECT TITLE:** | "Neurofeedback as an Intervention to Improve Reading Achievement in Students with Attention Deficit Hyperactivity Disorder, Inattentive Subtype" | | |
| **H.R.R.B. NUMBER:** | **HS - 12-135** | **PROJECT PERIOD:** | **Fall 2012 to Spring 2013** |
| **APPROVAL DATE:** | January 14, 2013 | **EXPIRATION DATE:** | **January 13, 2014** |
| **FUNDING SOURCE:** | International Society for Neurofeedback & Research ($2,000 grant) Brain Science International (donation qEEG assessments for each participant), UCR Special Education Leadership Fellowship ($300) | | |

**SPECIAL CONDITIONS: The PI MUST submit the following information to the UCR HRRB before proceeding with the study:** None

**THE UCR HRRB HAS REVIEWED THE PROPOSED USE OF HUMAN SUBJECTS IN THE REFERENCED PROTOCOL AND APPROVED IT BASED ON THE FOLLOWING**

1. Level of Review - 45 CFR 46.404 and Full Review
2. Special Population - 45 CFR 45 Subpart D (Children)
3. Risk - Minimal
4. The risks to participants are minimized by using procedures consistent with sound research design that do not unnecessarily expose participants to risk.
5. The risks are reasonable in relation to the anticipated benefits to individual participants and the importance of the knowledge that may reasonably be expected to result.
6. The selection of participants is reasonable and equitable.
7. The PI has had the appropriate human subjects research training.
8. Consent - Signed Consent Approved

Once the special conditions, if any, have been met, the protocol will be approved *through* January 13, 2014.

A "Continuing Review of the Approved Human Subjects Protocol" form will be sent to the PI three months before the expiration date, which will allow the PI to indicate whether to keep the protocol active or not. Please note that the expiration date is the last date that the protocol is approved.

**THE INVESTIGATOR SHALL PROMPLTY REPORT THE FOLLOWING TO THE HRRB:**
**(1) Changes to the protocol (e.g., increase the number of participants, or changing the participant population, recruitment methods, procedures, documents) via an amendment, or**
**(2) Unanticipated problems involving risk to participants or others (please contact the HRRB for instructions).**

DATE APPROVED January 14, 2013

DR. AUGUSTINE KPOSOWA, CHAIR, UCR HRRB
DR. ROLLANDA O'CONNOR, VICE-CHAIR, UCR HRRB
DESIGNATED UCR HRRB MEMBER
DR. MICHAEL PAZZANI (UCR IO), VICE CHANCELLOR, RESEARCH

Last Updated: 12.13.2012

Revised 1/16/13

HS12-135

**UNIVERSITY OF CALIFORNIA RIVERSIDE**

**APPLICATION FOR APPROVAL TO USE HUMAN PARTICIPANTS**

(Application must be typed or Word processed - handwritten forms will not be accepted.)

| | |
|---|---|
| Investigator: Jeffry La Marca | Department: Graduate School of Education |
| Title (e.g., student, professor): Ph.D. Student (ABD) | Department Chair: Dr. Douglas E. Mitchell, GSOE Dean |
| Phone Number(s): [Redacted] | Faculty Advisor (if applicable): Dr. Rollanda O'Connor |
| Email(s): jlama001@ucr.edu | Funding Source: International Society for Neurofeedback & Research ($2,000 grant), Brain Science International (donation of 2 qEEG assessments for each participant), UCR Special Education Leadership Fellowship ($300) |
| Administrator (if applicable): | Email(s): |
| Project Title: Neurofeedback as an Intervention to Improve Reading Achievement in Students with Attention Deficit Hyperactivity Disorder, Inattentive Subtype | |
| Project Period: Fall 2012 to Spring 2013 | |

****NOTE: Signatures are now required on the last page****

**********

## NOTICE OF COMMITTEE ACTION

***HRRB USE ONLY BELOW***

The UCR Human Research Review Board has reviewed the proposed use of human participants in the project identified above and has approved the project with the following determinations:

APPROVED

**Risk:** ☒ Minimal ☐ More Than Minimal

**Category of Review (Indicate 45 CFR 46 Category):**

☐ Exempt ☐ Expedited ☒ Full Committee Review

**Consent:**

☒ Signed Consent Form

☐ Documentation of Consent Not Required; waived per 45 CFR 46.117(c). The following consent procedures have been approved:

☐ Online Consent Statement ☐ Written Consent Statement (PI will provide a hard copy to participants) ☐ Oral Consent Statement

☐ No Consent Needed; waived per 45 CFR 46.116(d)

**Review Period:**

☒ One Year ☐ Six Months ☐ Other

Augustine Kposowa — 14 January 2013

Dr. Augustine Kposowa, Chair / Dr. Rollanda O'Connor, Vice-Chair Human Research Review Board (HRRB) — Date Approved

**FOR EXEMPT RESEARCH ONLY:**

Designated HRRB Staff or Committee Member — Date Approved

Please submit one (1) typewritten copy of this application to the UCR Human Research Review Board (HRRB) in the Office of Research Integrity, University Office Building, Room 211 or 216. You do not need to submit your dissertation or abstract. *Please do not staple any documents.* For information about the Committee review dates or help with preparing the application itself, please contact the UCR HRRB, (951) 827-4811 or (951) 827-6332.

**Cells will enlarge to fit contents.*

1. **PURPOSE:** What are the specific aims of the research project?

While the literature on neurofeedback (NF) spans several decades, this study will be the first to directly study the effect of NF on reading fluency and comprehension although numerous studies have consistently reported improvements in academic performance. Three research questions will be addressed:

1. Will neurofeedback enhance attention as measured by continuous performance tests (CPTs)?
2. Will neurofeedback improve performance on measures of reading fluency?
3. Will neurofeedback improve performance on measures of reading comprehension?

Neurofeedback is a form of biofeedback that helps individuals learn how to volitionally control their brainwaves by interacting with a computer using the principles of behaviorism. Specifically, individuals are operantly conditioned when they are rewarded by visual and/or auditory feedback each time they meet pre-established target goals. Although operant conditioning of brainwaves, through the use of electroencephalography (EEG) that provides real-time information on cortical functioning, has long been recognized for its ability to allow individuals to self-regulate their behavior, no studies have yet been conducted to see if neurofeedback training generalizes to improvements in reading fluency or comprehension. This will be the first study to directly examine what role, if any, NF training can have in improving reading achievement.

2. **PARTICIPANTS:**

a. Will any participants be specifically recruited because they:

☒ Are under the age of 18 *(Please complete Appendix A)*

☐ Are prisoners, probationers, or parolees *(Please complete Appendix B)*

☐ Are pregnant women, fetuses, or neonates *(Please complete Appendix C)*

☐ Are cognitively impaired *(Please complete Appendix D)*

☒ Have any other particular characteristic that may cause them to be considered a vulnerable population? If so, please explain:

Attention Deficit Hyperactivity Disorder, Inattentive Subtype

☐ ***None of the above***

b. Please describe the participant population.

Participants will include nine third and/or fourth grade students, ages 8 and 9, selected from one or more public elementary school(s) located in southern California. Children of this age will have had several years of reading instruction and surpassed the age-of-onset criterion for ADD/ADHD as established by the Diagnostic and Statistical Manual of Mental Disorders DSM-IV-TR Fourth Edition - Text Revision (DSM-IV-TR; APA, 2000). The DSM-IV-TR requires that symptoms of ADD/ADHD must be present prior to the age of seven.

c. Is English their dominant language for *all* the participants? If not, what is their dominant language and how will these participants' language needs be addressed?

Yes.

d. Please provide a justification for the use of your proposed population.

Beginning with the seminal work of Lubar and Shouse (1976) that first documented NF as an intervention for ADD/ADHD, improvements in school performance have been consistently reported (Lubar, 1991; Thompson & Thompson, 1998; Thornton & Carmody, 2005). Given that symptoms of inattention, and not hyperactivity/impulsivity, are most associated with learning difficulties and academic problems (Chhabildas,

Pennington, & Willcutt, 2001) and the literature suggesting that NF is most efficacious for ameliorating symptoms of inattention (Arns, de Ridder, Strehl, Breteler, & Coenen, 2009; Monastra, Monastra, & George, 2002), more well-designed research is warranted. However, less is known about the purely inattentive subtype of ADHD (Dige, Maahr, & Backenroth-Ohsako, 2008; Nigg, 2005). A veritable dearth of studies on the efficacy of NF for academic achievement as an intervention for ADD/ADHD remains. NF has the potential to find considerable utility in academic settings for individuals with ADD/ADHD. In light of the lack of research on efficacious interventions for students with the inattentive subtype and despite consistent findings in the literature that indicate they are most at-risk for problems with academic attainment, this study will examine the efficacy of NF to improve reading achievement for these students.

e. Describe how the participants will be obtained/recruited. Attach any recruitment materials to your application (e.g., flyers, emails, script, etc.).

☐ I will be recruiting participants through the Psychology Department's subject pool. I certify that I have read and am familiar with the procedures and policies approved in the UCR Dept of Psychology Subject Pool protocol (HS 08-045). Here is the text I will be using to recruit participants from the subject pool:

☒ I will be obtaining/recruiting participants in the following manner:

School records will be reviewed by the school counselor (blind to the PI) and potential participants will be referred by classroom teachers, special education personnel, and school administrators based on profiles that are indicative of ADHD, the inattentive subtype as described by the DSM-IV-TR, specifically:

**314.00 Attention-Deficit/Hyperactivity Disorder, Predominantly Inattentive Type**

Six (or more) symptoms of inattention (but fewer than six symptoms of hyperactivity-impulsivity) have persisted for at least six months. Hyperactivity may still be a significant clinical feature in many such cases, whereas other cases are more purely inattentive.

**Characteristics:**

a. Often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities

b. Often has difficulty sustaining attention in tasks or play activities

c. Often does not seem to listen when spoken to directly

d. Often does not follow through on instructions and fails to finish school work, chores, or duties in the workplace

e. Often has difficulty organizing tasks and activities

f. Often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort

g. Often loses things necessary for tasks or activities

h. Is often easily distracted by extraneous stimuli

i. Is often forgetful in daily activities (APA, 2000, p. 92)

Specifically, the school counselor will be asked to identify a pool of potential participants who have already been referred to and/or are receiving services under an existing Individualized Educational Plan (IEP) or 504 Plan (as defined by Section 504 of the Americans with Disabilities Rehabilitation Act of 1973). In the event that a sufficient number of potential participants cannot be identified, an amendment to this application will be filed regarding additional screening procedures that will be used to identify participants who may have not been previously referred.

The school counselor will initiate contact with parents of potential participants by sending home a packet that contains: the initial parent information letter, the initial parent consent form, the initial student assent form, and copies of the Student Health History and the Conners 3AI. Students of the parent(s) who give consent for participation in the study by returning the documents in the packet that require a response will participate in the initial screening process.

Participants will be identified using the screening measures described below in section 4d.

The willingness of parents, teachers, and students to participate, as well as each child's school attendance record, will be considered in the selection process to minimize absences and participant drop-out during the study.

Given that this study will use a multiple-baseline-across-participants single case design (described in greater detail below) that requires a relatively small sample, a history of regular school attendance will help to increase study adherence.

Once a pool of potential participants has been identified and consent has been obtained, additional screening procedures will be used; these are:

1. Attainment of a brief health history of each participant from their parent(s).
2. Completion of the Conners 3 ADHD Index (Conners 3AI) rating scale by parents and teachers. A T-score of ≥ 61 suggests that the participant meets DSM-IV-TR criteria.
3. Assessment on Integrated Visual and Auditory Continuous Performance Test (IVA+Plus) for profiles consistent with ADD. Specifically, test results from the IVA+Plus are analyzed using algorithms described in the IVA+Plus Interpretive Flowchart For ADHD (Sandford, 2005). In the event that results suggest an individual has ADD/ADHD, the flowchart is used to match their characteristics with one of the three subtypes, ADHD not otherwise specified (ADHD-NOS), or suggests that another cognitive disorder may be indicated. Potential participants with scores that are indicative of inattentive subtype will be considered for the study.
4. Demonstration of a full scale IQ (FSIQ) ≥ 80 as estimated by the Wechsler Abbreviated Scale of Intelligence - Second Edition (WASI-II).

Upon completion of the initial screening process, the parents of students who meet eligibility requirements will receive a second information letter and consent form. Potential participants will also be given a second student assent form to sign at this time.

5. Final screening of participants will include administration of a quantitative electroencephalogram (qEEG) to exclude students who may have comorbid conditions, provide a baseline assessment of each individual's EEG, and to inform final intervention protocols.

f. Please indicate the maximum number of participants who will take part in this study. *(Please note: If during the course of the study you anticipate exceeding this number, an amendment will need to be filed to increase the maximum number before the study can continue.)*

Nine will be selected to participate. An estimate of the outer limit of how many students will be screened is 30. However, every effort will be made to screen the smallest number possible, while still identifying nine eligible students.

g. Will participants be compensated for their time? Describe the method, amount, and schedule of participant payment, if applicable. *(Please see Attachment D, "Payment to Research Participants.")*

No.

h. Will participants personally incur any expenses as a result of participation (e.g., fuel), and if so, will they be reimbursed for these expenses? Describe the method, amount, and schedule of participant payment, if applicable. *(Please see Attachment D, "Payment to Research Participants.")*

Participants will not incur any expenses.

i. Additional Information Necessary for HRRB Review:

Would it be possible for the PI to screen a large sample of students and select those who fall in the clinical range without specifying to teachers or parents that the students were selected for inattentive symptoms?

This is not possible and unnecessary as children without ADHD will not express persistent symptoms of inattention and the additional time required for screening would be excessive. Although the total number of students in grades 3 and 4 at the school is unknown, if there are 200 students in these grades (100 students per grade), the time required to administer just the IVA+Plus (20 minutes per student), is approximately 67 hours. Considerable additional time would be required to administer and score the Conners 3AI, the WASI-II, and the WRMT-III. The cost of providing full screening (including qEEG assessments) for all students is

prohibitive.

The prevalence of ADHD (all subtypes) is currently estimated at 9 percent (12.3% of boys and 5.5% of girls; Akinbami, Liu, Pastor, & Reuben, 2011) with the number of children meeting criteria for the inattentive subtype estimated at 6.12 percent. It is estimated that more than half of all individuals with ADD/ADHD are not receiving treatment (Attachment 8). Given this information, the estimated number of children from a pool of 200 students with the inattentive subtype would be 12. Screening 200 students would take well over one month of non-stop testing during school hours to complete in order to identify roughly six potential participants.

Does the PI intend to meet with each parent face to face?

As per the parent information letters and consent forms, parents may contact the PI at any time. The PI will meet with parents, on an individual basis, should they request a conference.

3. **STUDY LOCATION:** Where will the study take place? (Check all that apply.)

☐ On the UCR campus. Please provide room number(s) and/or a description of the location.

☐ Online *(Please complete Appendix F)*

☒ On at least one external site (not on the UCR Campus). **Please provide the contact information for this site(s):**

Redacted

In the event that an insufficient number of eligible participants can be identified at [redacted] then additional participants will need to be recruited from another school within the [redacted]. Should this be occur, UCR's IRB will be notified and additional letters of support will be obtained from each site.

Indicate if:

☐ The site is OUTSIDE of the United States. If so, please review our FAQs (*http://or.ucr.edu/ori/faq.aspx#85*) and/or SOPs (*http://or.ucr.edu/WebDocs/RI/Forms/IRB/ucr_irb_sops.pdf*) about transnational research.

☐ The external site has its own IRB. If so, has its IRB approved the research?

☐ The external site does not have its own IRB. Has permission to conduct research at that site been sought and/or obtained?

☒ The external site plans to rely upon UCR's IRB

☐ On many sites (multi-site); this study is a **collaborative study being conducted with other PIs at other institutions**. Describe the communication of information among those sites relevant to the protection of participants.

Additional Information Necessary for HRRB Review:

**PROCEDURES:** Describe how participants will be involved in the study by answering the following questions and providing any additional information as necessary.

a. Who will assist the investigator?

The PI will be solely responsible for all pre-screening, intervention, and post-intervention phases. However, a highly trained technician, provided by Brain Science International (BSI), will conduct pre- and post-intervention qEEG assessments. The technician will have experience attaching electrodes at 21 sites on the scalp. Electrode placement for qEEG assessments requires that the technician has training to ensure accurate attachment of electrodes at precise locations on the scalp and that each connection is made to ensure that optimal impedance levels are obtained for accurate measurement of EEG. qEEG analyses will be conducted by additional personnel (primarily Ph.D. or M.D. level individuals with expertise in EEG and neurological assessments). All individuals from BSI will be blinded to participants' real identities with the exception that the qEEG technician will be exposed to each participant's given name (but not surname) during the qEEG assessments.

As funding for this research is being provided by a grant from the International Society for Neurofeedback & Research (ISNR), their research foundation has requested that an expert in neurofeedback be available as a consultant. Dr. Michael Linden, a clinical psychologist, will serve in this role. Dr. Linden, however, will have no contact with the participants. He will, however, be given access to data collected during the study but with all personal identifiers removed. Similarly, Dr. Joseph Sanford is a clinical psychologist from BrainTrain (located near Richmond, Virginia). As the developer of both the IVA+Plus and SmartMind Pro, the neurofeedback software application being used, he will be available for consultation on technical matters pertaining to the software. Dr. Sandford will have no contact with the participants, although he may be given access to data with all personal identifiers removed.

b. How often will the participants be involved?

Once a pool of potential participants has been identified, this study will use a multiple-baseline-across-participants single case design that contains several phases. These are: 1) Initial screening, 2) Final screening and pretest, 3) Baseline, 4) Intervention, 5) Posttests, and 6) Follow-up assessments. All potential participants will take part in Phase 1, potential participants who appear to be good candidates for the intervention will take part in Phase 2, and only students who have met inclusionary criteria will take part in the remaining phases. The total estimated amount of time that will be required for each phase is described in the following table:

| Phase | Estimated time required of each participant | Estimated time for all participants to complete phase |
|---|---|---|
| 1. Initial Screening | 60 minutes | 2 week window for Phase 1 screenings |
| 2. Final Screening and Pretest | 2 hours | 1 week window for Phase 2 screenings |
| 3. Baseline | 10 minutes per session.<br>This phase is the one that varies across participants. The first group to start will have only a few days of baseline; the last group to start will have a few weeks of baseline. | This length of this phase will vary per participant and the number of sessions required will be determined during the study.<br>Baseline continues for some students while others begin the treatment. This is how the experimental design controls for maturation effects (growth over time that could occur without the treatment). |
| 4. Intervention | 45 to 60 minutes for 40 sessions | 8 weeks per participant. The total time required for all participants to complete this phase will be determined during the study. |
| 5. Posttests | 2 hours, 10 minutes | 3 days |
| 6. Follow-up | 1 hour, 15 minutes | 2 days |

Attachment 6 contains a table of each assessment, task, or activity that will occur during each phase, along with a summary of estimated times each of these will require.

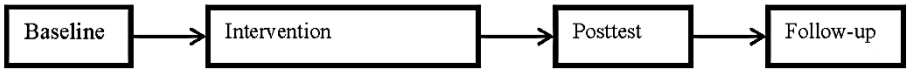
summary of estimated times each of these will require.

**c. How long will participants be involved?**

Participants will be involved in approximately 2 hours, 15 minutes of screening, 50 minutes to an unknown number of minutes of baseline testing (see below for explanation), 40 sessions (approximately 45 to 60 minutes each) of the intervention, and approximately 3 hours, 25 minutes of posttest and follow-up assessment.

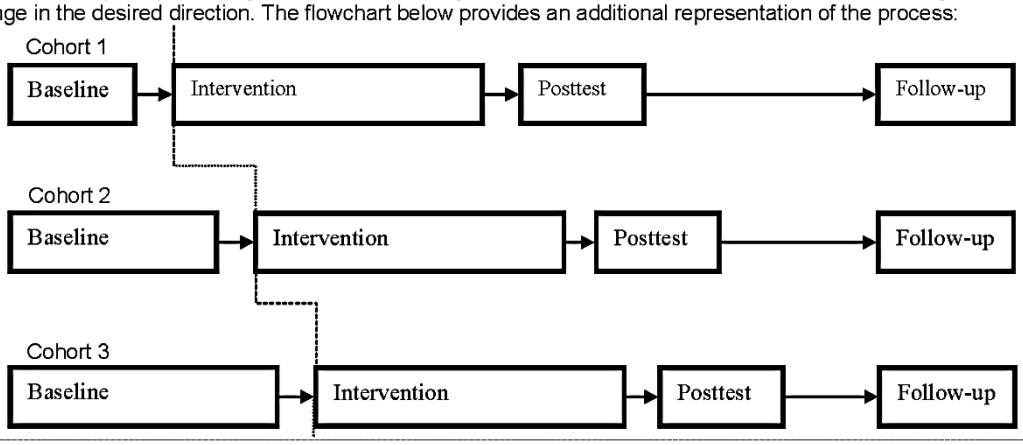
As part of multiple-baseline-across-participants single case designs, all participants in a study begin at a baseline phase in which target behaviors are observed. In studies such as this one, participants are randomly assigned to cohorts in order to aid in efficient data collection and analysis. Participants in this study will be randomly assigned to one of three cohorts of equal sizes. Each cohort will progress through subsequent phases in this study, beginning the intervention phase at different times although each will follow the same sequence.

The path that each cohort will follow in this study includes the Baseline Phase, the Intervention Phase, the Posttest Phase, and the Follow-up Phase. This path is described as follows:




During the baseline phase, Cohort 1 participants will be assessed using three probes: 1) ORF – oral reading fluency, 2) MAZE - reading accuracy, and 3) SAT – attention. When these probes indicate that the behaviors being measured are stable (e.g., 3 to 5 sessions in which significant fluctuations in scores are not observed), participants will proceed to the Intervention Phase (40 sessions of NF training, followed by continued assessments using the baseline probes). Upon completion of the Intervention Phase, Cohort 1 will be assessed using posttest measures. Four to six weeks later, Cohort 1 will be administered follow-up assessments.

As noted previously, each cohort will begin the Baseline Phase at the same time; they will proceed to the Intervention Phase only after certain conditions have been met. Specifically, Cohort 1 will proceed when their baseline scores are stable. Cohort 2, however, will not proceed to the Intervention Phase until changes in the scores of Cohort 1 begin to change in the hypothesized direction (e.g., reading speed, reading accuracy, and/or attention will improve), Similarly, Cohort 3 will not begin the Intervention Phase until Cohort 2 scores begin to change in the desired direction. The flowchart below provides an additional representation of the process:




**d. What data will be recorded and how? Please indicate what machines, equipment, and/or instruments will be used, if any.**

Screening measures:

1. Student Health History – completed by each child's parent at home.
2. Conners 3 ADHD Index (Conners 3AI) - Ten-item rating scales will be completed by each participant's parent(s) at home and a teacher. These require approximately five minutes to complete.
3. Integrated Visual and Auditory Continuous Performance Test (IVA+Plus) requires approximately 20 minutes to administer. The IVA+Plus will also be used as a pre- and post-intervention measure of attention.

Pre- and posttest measures:

1. qEEG assessment will serve as a final screening tool to ensure participants will be good candidates for the intervention, provide pre- and post-intervention measures of EEG (brain wave) activity, and be used to guide and individualize NF protocols for each participant.
2. Woodcock Reading Mastery Test, Third Edition (WRMT-III) will provide pre- and post-intervention measures of reading skills.

Intervention software application:

1. SmartMind Pro is a password-protected NF training software application that maintains records of each participant's EEG.
2. A hardware EEG amplifier, created for BrainTrain (also the publisher of SmartMind Pro), will be used to collect EEG data throughout the training process. The amplifier does not maintain any data; it only transfers data to the software application through the use of adhesive electrodes that are placed on each participant's scalp during training.

Progress monitoring measures (to be used during baseline and following each NF session):

1. AIMSweb Reading Curriculum-Based Measurement (R-CBM), including a test of oral reading fluency (1 minute), and test of reading accuracy (90 seconds).
2. Central Nervous System Vital Signs (CNSVS) Shifting Attention Test (SAT) will provide a 90 second measure of attention.

e. Please describe the procedures.

Screening and Pretests:

1. The participant's health history and Conners 3AI rating scale will be completed by parents and/or a teacher.
2. The WASI-II, WRMT-III, and AIMSweb are standardized measures with results recorded manually by the PI.
3. The IVA+Plus and the CNSVS are computerized tests with results recorded and maintained within their respective password-protected applications.

Final Screening Procedure:

Participants who appear to be good candidates for the study will receive qEEG assessments that will be conducted by a technician provided by Brain Science International. The full identity of each participant will be concealed from the technician and only pseudonyms and a case number ID will be used on the protocols for the assessment. The technician will be exposed to each participant's given name. Assessments will be conducted at the participants' school and results transmitted to Brain Science International via secured Internet connection to their HIPAA compliant server. Analysis will be conducted by Brain Science International medical personal and transmitted back to the PI in the same manner.

The qEEG procedure includes the placement of 21 electrodes on the scalp as designated by the International 10-20 system. Due to the need to ensure good impedance and for maintaining good contact during the recording of EEG, electrodes will be attached using a water-soluble gel. Each electrode site, as well as the ears (which will be used for ground and reference placement), will be prepared with NuPrep, a mild abrasive gel to remove any oil from the skin. During the recording, participants will have their EEG recorded while remaining still with their eyes closed, eyes open, and while engaged in simple tasks such as reading and doing simply math problems. Each assessment, including setup and cleanup, requires about an hour to complete.

Intervention:

4. EEG data will be gathered and NF training will be accomplished through the use of the BrainTrain EEG amplifier and SmartMind Pro. This will be done by placing adhesive EEG electrodes (sensors) on the participant's scalp. One "active" electrode will record EEG at one position on the scalp and two other adhesive electrodes will be used as a ground and a reference, respectively. The active electrode will be placed on the top of the scalp (referred to as Cz using the International 10/20 system for EEG electrode placement; a ground and a reference electrode will be placed on each mastoid process (only one electrode on each side of the head). The position of the active electrode may be placed elsewhere and this will be determined on an individual basis should the qEEG assessment indicate that this position would be more beneficial for the needs of each participant.

The NF training sessions will consist of playing games that appear on a computer monitor. No joysticks or other controls are needed as the individual's brainwaves drive the games; success on each activity is entirely dependent upon the participant's ability to volitionally meet specific pre-determined EEG patterns as identified by the qEEG assessment and the SmartMind Pro software application. Students selected for this study will have met selection criteria that requires elevated theta/beta ratios, a characteristic that is correlated with the ADD, inattentive subtype. Elevated levels of theta are associated with several physiological states including deep relaxation, creativity, distractibility, inattention, and sometimes depression and anxiety. Individuals with ADD/ADHD often have elevated levels of theta. Optimal amplitude of low beta is associated with a state of focused alertness that is correlated with learning.

Participants selected for this study will exhibit statistically significant elevations in the amplitude of theta (4 to 8 Hz) measured in microvolts (μV or one millionth of a volt) when compared to typically developing others. Similarly, they will exhibit significantly lower amplitudes of low beta (12 to 21 Hz). Selection criteria requires that participants have elevated theta/beta rations ≥ 4.0 and EEG profiles consistent with ADD/ADHD. NF training protocols will be individualized for each participant to inhibit theta and enhance beta.

Each session will contain 30 minutes of NF training in which participants will be rewarded by visual and auditory feedback when they met or exceed target amplitudes for theta and beta during the games. An example of one of these games is provided in Appendix B. Immediately following each NF session, participants will be administer the three progress monitoring measures (R-CBM ORF and MAZE, and the CNSVS SAT).

Posttests:

Upon completion of 40 sessions of NF, participants will receive another qEEG assessment conducted by a technician from Brain Science International. In addition, each will be re-assessed on the Conners 3AI, the IVA+Plus, and the WRMT. Approximately four to six weeks after all participants have completed the intervention, they will receive a follow-up evaluation on the Conners 3AI, the IVA+Plus, and the WRMT-III.

Data from all measures will be gathered and maintained on a password-protected computer with participants only identified by a pseudonymous name and case ID; relevant information collected from each student will be maintained on a password-protected spreadsheet.

f. If participants will see a study title that is different from the one in this application, please provide that study title.

g. Additional Information Necessary for HRRB Review:

Would it be possible for the PI to include a non-clinical control group, which would reduce the labeling risks and also enhance the strength of the study's scientific contribution by permitting the PI to conclude that NF training led to an increase in reading performance beyond that associated with traditional education in typically developing youth (and, ideally, in other youth with the ADHD inattentive profile who do not receive the training)?

This study uses a multiple-baseline-across-participants single-case design (SCD) model, in which participants provide their own (within-subject) control. This model uses an experimental design that is fundamentally different than randomized controlled studies. SCDs do not use randomized controlled groups.

SCDs have been of considerable utility in the development of evidence-based practices in special education (Horner et al., 2005; Kennedy, 2005; Kratochwill et al., 2010), applied and clinical psychology (Chambless & Hollon, 1998; Gustafson, Nassar, & Waddell, 2011), and within the field of neurofeedback (Kratochwill et al., 2010). SCD is used to establish causal relations between independent and dependent variables. In other words, by examining whether experimental control of an independent variable produces a consistent effect on a dependent variable, SCD can determine if there is a functional relation between the two (Kennedy, 2005). Unlike correlational studies that use randomized control-group designs requiring a large number of participants, SCD research needs just a few participants (i.e., one to twelve), with each serving as his or her own control. Individual performance of each participant is examined prior to, during, and after the intervention (Horner et al., 2005). Although disagreements exist regarding the minimum number of participants required within a SCD to lend support that an intervention is efficacious, Chambless and Hollon (1998) suggest that three or more are required, along with replication of the study from another independent research site, to suggest that the treatment is "possibly efficacious."

Horner et al. (2005) noted that SCD has a long-established history that has been particularly useful in research that has studied the principles of behaviorism and conditioning. Indeed, one of the earliest studies that demonstrated EEG could be conditioned used a SCD. Knott and Henry (1941) found that classical (not operant)

conditioning of the alpha-blocking response was possible. The first neurofeedback study that examined operant conditioning of EEG to alleviate symptoms of ADD/ADHD also used a SCD. Specifically, the Lubar and Shouse (1976) seminal study reported that operant conditioning of EEG to enhance SMR, in a single participant, reduced symptoms of hyperactivity and improved scores on behavioral assessments in an elementary school classroom.

5. **DECEPTION:** Will deception be necessary? *(For more information, please see **Section 15.4: Deception** in the UCR HRRB SOPs):*

☒ No

☐ Yes. *Please complete Appendix E.*

6. **SCIENTIFIC MERIT:** How does your research design (i.e., procedures) help accomplish the specific aim(s) of the research project?

Screening procedures consist of all the standard currently used assessments for identifying individuals with ADD (i.e., health histories, rating scales, and CPT evaluation). The use of qEEG assessment constitutes the current-state-of-the-art approach for confirming the presence of attention deficits. Although there are no "gold standards" for identifying individuals with ADD, qEEGs are now filling this void.

Participant selection procedures are designed to narrowly define the sample to include only participants who will most benefit from the intervention (e.g., only individuals with symptoms of inattention will be included). Most studies on ADD/ADHD do not adequately make this distinction despite consistent research findings that the majority of individuals with ADHD do not express symptoms of hyperactivity and impulsivity. In addition, research confirms that symptoms of inattention are strongly correlated with academic under-achievement, whereas hyperactivity and impulsivity are not.

Screening and intervention procedures are designed to ensure that participants are good candidates for NF. This will be accomplished through the use of qEEGs to ensure that participants have EEG profiles that are receptive to NF. In addition, the qEEG assessment will be used to individualize NF protocols. Post-intervention qEEG assessments will provide evidence of the efficacy of the intervention. In addition, research indicates that 40 sessions of NF is optimal for observing changes result from operant conditioning of EEG, as well as for being sufficient for measurable behavioral changes to occur.

The pre- and posttest measures used in this study will provide psychometrically sound and accepted practices for evaluating outcomes. In addition, the progress monitoring measures and procedures being used have demonstrated utility for monitoring changes in the behaviors being studied (e.g., attention and reading achievement).

It is anticipated that participants will demonstrate improved performance on the measure of attention (IVA+Plus) and that the posttest qEEG will display measurable changes in cognitive functioning in which EEG has been normalized through NF. It is hoped that participants will display improved performance on the measure of reading achievement (WRMT-III). Furthermore, it is hoped that the robustness of the intervention will be demonstrated at follow-up.

7. **RISKS:**

a. Determine what risks, if any, there might be to participants. Consider such risks as physical, psychological, social, financial, legal or political risks, and assess the likelihood of the seriousness of any of these risks. ***("No risk" is not an acceptable answer.** Please use "There are no foreseeable risks" as the lowest common denominator.)*

There are no foreseeable risks with regard to NF training. NF has been in use for many decades; it is not regulated by the FDA, and there are no known reported side-effects or adverse reactions listed in the scientific literature (Sterman, 2000). Additional risks may include:

1) A student and/or parent may feel singled out for being invited to participate,

2) Students miss a substantial amount of class time,

3) During of the study some participants may get tired,

4) [redacted]

5) Slight potential for a reaction to the adhesive used for the electrodes.

b. Describe procedures that will be used to minimize potential risks to participants.

The following address each of the potential risks described in 7a:

1) Screening procedures are designed to first find students who have been previously identified with ADHD, inattentive subtype. Specifically, as noted above in item 2e, potential participants will be referred by the school counselor, classroom teachers, special education personnel, and school administrators based on profiles that are indicative of ADHD. For example, students with exiting Individualized Educational Plans (IEP), 504 Plans (as defined by Section 504 of the Americans with Disabilities Rehabilitation Act of 1973), or who have already received a medical diagnosis of ADHD, inattentive subtype, will be automatically considered as potential participants. These students, therefore, have already been identified as having special needs.

   At present, the number of students who may be eligible for participation based upon the above criteria (e.g., an IEP, a 504 Plan, or an existing diagnosis), is unknown. Additional students, who may have difficulties with attention, may also be identified by the school personnel described above and may be screened as potential participants. Although schools cannot make a medical diagnosis of ADD/ADHD, they are obligated under the Individuals with Disabilities Education Improvement Act (IDEIA; reauthorized in 2004) to identify students with special needs. IDEIA is a Federal entitlement law that "guarantee[s] a free, appropriate public education (FAPE) to each child with a disability in every state and locality across the country" (U.S. Department of Education, 2000). In addition to FAPE, school districts are also obligated to proactively seek out and identify students with disabilities and refer them for services as early as possible; this responsibility is referred to as "child find."

   Providing a FAPE obligates schools to provide services to children with attention problems, even when a medical diagnosis of ADHD has not been made. Furthermore, the central role that schools are required to play has long been recognized. This role was emphasized when the National Institutes of Health (NIH) was required by Congress (PL 99-158; "Health Research Extension Act of 1985, 42 U.S.C. § 281 [2006],") to "establish an Interagency Committee on Learning Disabilities [ICLD] to review and assess Federal research priorities, activities, and findings regarding learning disabilities (including central nervous system dysfunction in children)." The report noted that management of ADD/ADHD is generally relegated to two domains: "(a) nonpharmacologic (educational and cognitive-behavioral, and other psychological and psychiatric approaches); and (b) pharmacologic therapies." Although the ICLD predominantly comprised representatives from medical agencies within the Federal government (and also included representatives from the United States Department of Education [USDE] and a few other governmental entities), their report emphasized the primacy of education with regard to interventions. Specifically, it stated that, "*Educational management represents an important priority and often forms the cornerstone of all other therapies, nonpharmacologic or pharmacologic*" (emphasis added; Interagency Committee on Learning Disabilities, 1987, p. 201).

   It is known that many individuals with ADHD, inattentive subtype are often not diagnosed until middle school or high school when problems arise with maintaining focus, completing homework, or remembering material they have read. Indeed, many individuals with the inattentive subtype are not identified until adulthood, despite the presence of symptoms that may have previously been attributable to laziness or lack of motivation (National Resource Center on ADHD, 2004). Therefore, the concern for a student and/or parent feeling singled out for being invited to participate is tempered by the following:

   - Schools are obligated to seek out students with attention problems, even when a medical diagnosis is not available. The screening procedures used by this study represent the state-of-the-art methods for identifying these children. All of these screening procedures are currently used in schools for identifying children with attention deficits with the exception of the qEEG assessment. Although qEEGs are not medical procedures per se, due to cost and complexity of interpretation, they are usually conducted and analyzed by individuals with training in the medical professions. Only students who appear to be good potential candidates will receive qEEGs.
   - It is anticipated that many of the participants will already have an existing medical diagnosis of ADD/ADHD or they will be receiving interventions for ADD/ADHD at the school.
   - Schools are required to provide services, under IDEIA, to children with attention problems, despite the lack of a medical diagnosis.

To address the HRRB Committee's concerns that children or parents may have about been singled out for participation, they will be:

- Provided with information on the benefits of this study
- Given full opportunity to decline participation

2) Participants may miss a substantial amount of class time. To minimize this, arrangements will be made with teachers in advance of the screening process so that assessments will take place at times that will be least disruptive to regular classroom activities. Each of the final participants selected will be scheduled to receive the intervention will be scheduled at the same time each day. Initial screening procedures require minimal amounts of time:

   - Student health histories and completion of the Conners 3AI will not take place during instructional time. It is estimated that the history will take approximately ten minutes to complete and the Conners 3AI will require about five minutes.
   - The IVA+Plus requires approximately 20 minutes of student time. The instrument is considered to be a very efficient screening tool for ADD/ADHD.
   - The WASI-II requires approximately 30 minutes to administer.

   Only students who, based on the results of the screening processes just discussed, who have parents who consent to their child's participation, and appear to be good candidates for the study will receive qEEGs. This assessment requires approximately one hour to complete.

   The final set of students who are selected as participants will then be administered the WRMT-III, which takes approximately 40 minutes to administer.

   Once the study begins, each student will receive 40 sessions of neurofeedback with the total amount of time spent in each session estimated to be 45 to 60 minutes. Each session will consist of 30 minutes directly engaged in neurofeedback training, and 4 additional minutes of progress monitoring. The rest of the session will be spent on setting up the equipment (e.g., attaching electrodes, ensuring that good impedance levels are obtained for the NF training, and providing necessary instructions to the participant).

   To ensure that minimal interference with classroom work occurs and assist the classroom teacher in planning, teachers and parents of each student will be consulted in establishing the schedule. Participants will be scheduled for NF at the same time each day. This will also assist in maintaining experimental fidelity as EEG is known to fluctuate throughout the day. By scheduling each participant's session at the same time each day, there is less likelihood that their EEG will be influenced by naturally occurring circadian rhythms.

   As the design of the study requires that each participant complete 40 sessions of neurofeedback, sessions will not occur during alterations to the regular school schedule (e.g., minimum-days, parent-teacher conference weeks, holidays, school assemblies, testing, etc.). In addition, sessions will be rescheduled following student absences.

3) In order to address student fatigue, NF activities will include a variety of different games. During training, the PI will remain with each participant to encourage, monitor, and support their progress. Participants will be monitored for fatigue throughout the study. In the event that a participant becomes distressed or displays excessive fatigue, the PI will ask, "Are you tired?" If the participant indicates in the affirmative, the PI will state, "That's okay. We can stop today and continue tomorrow." As per the student assent form, participants will have been assured that they can drop out of the study at any time; however, as they will be playing computer games, it is anticipated that most will like the experience.

4) [redacted]

c. Additional Information Necessary for HRRB Review:

One risk/expense for teachers is that they will have an additional burden of creating take-home material or holding make-up exams for the participants. Please discuss how to minimize this expense for teachers.

The PI is a credentialed teacher. Should the need arise; the PI will proctor make-up exams. The PI will also assist the classroom teacher in the creation of additional take-home materials if these are needed.

Should the study be carried out after school hours?

Carrying out this study after school hours is not feasible due to parents becoming responsible for transportation. In addition to the added expense that would be incurred by parents for transportation, after school studies are prone to sporadic attendance. The risks associated with conducting this study during class time is balanced by the potential benefits of the intervention.

8. **RISK-BENEFIT RATIO:** (This question **MUST** be answered) Activities involving human participants can be approved only if expected benefits outweigh potential risks.

a. Describe possible benefits to each individual participant.

Beginning with the first study to report on the successful use of neurofeedback as an intervention for ADD/ADHD (Lubar & Shouse, 1976), improvements in school performance have been consistently reported. Based upon existing research, it is anticipated that most participants will show measurable improvements in sustained attention following 40 sessions of NF. Accounts of improvement in reading achievement have been noted by several studies; it is hoped that the anticipated improvements in attention will generalize to reading fluency and comprehension.

b. Describe possible benefits to a class of participants, society in general, or the advancement of science.

On October 1, 2012, PracticeWise, a proprietary research organization that prepares the biannual report on "Evidenced-based Psychological Interventions for Children and Adolescents" for the American Academy of Pediatrics announced that NF has just been elevated to their highest rating of efficacy: Level 1 - Best Support. Unlike other interventions for attention deficits, particularly those that use of psychostimulants or require medical professionals to implement and monitor, NF can be used by highly-trained educators. NF is safe, has no side effects, and uses well-established theories of behaviorism to produce positive changes in cognitive functioning.

Although the research on NF extends over many decades, most studies have been conducted in the fields of clinical psychology and neurology due, in part, to the technological challenges that have made research in educational settings difficult to pursue. Those technical challenges, however, have now been overcome as equipment and software are relatively inexpensive and simple to use. In addition, the ability to use these tools is within the reach of highly trained special educators and school psychologists. Although research on the use of EEG biofeedback to improve academic achievement has not yet been directly studied in school settings, the ability for NF training to improve sustained attention, particularly in individuals with the inattentive subtype of ADHD, has been consistently documented. (40 sessions is considered standard for using NF as an intervention for attention deficits.)

This study will be the first to directly examine what role, if any, NF training may have to improve reading achievement. Should findings indicate that improvements occur, considerable opportunities for follow-up studies will become available.

c. State your reasons for believing that the benefits of your proposed activity outweigh potential risks.

No risks are anticipated.

d. Additional Information Necessary for HRRB Review:

The following addresses the HRRB Committee's concerns pertaining to labeling effects, false-positive identifications, negative expectancy, the reliability of screening protocols, and the risk-benefit ratio:

The veracity of ADD/ADHD as a genuine disorder is recognized by essentially every professional medical, psychological, and scientific organization. Its legitimacy is supported by tens of thousands of studies spanning many decades (Attachment 8). Indeed, attention deficits are the most widely studied and treated of all psychiatric disorders (American Academy of Pediatrics, 2011; Goldman, Genel, Bezman, & Slanetz, 1998; Hart, Lahey, Loeber, Applegate, & Frick, 1995; Volkow et al., 2011).

Despite the overwhelming scientific evidence that confirms the existence of attention deficits, the popular press has long characterized ADD/ADHD as a "myth, fraud, or benign condition [that] may cause thousands of sufferers not to seek treatment for their disorder. It also leaves the public with a general sense that this disorder is not valid or real or consists of a rather trivial affliction" (Barkley, 2002, p. 89). Furthermore, these fallacious beliefs have resulted in such frequent misconceptions by the public, that an international consortium of more than 80 of the most widely published and cited researchers on ADD/ADHD issued an International Consensus Statement on ADHD (Attachment 8). Seven members of the consortium (all of whom signed the document) are researchers from five different University of California campuses (Berkeley, Davis, Irvine, Los Angeles, and San Francisco). Russel Barkley (2002b, p. 1389) notes that the consensus statement was created "to correct the rampant misinformation frequently appearing in the world media concerning a childhood mental disorder, its nature, causes, and management, especially via medication." Although this document is unusual in that it was written in response to correct widespread misconceptions by a naïve public, an enormous body of scientific literature exists on the severe and life-altering impact that attention-deficits have upon those with these disorders, especially when many of these individuals, particularly those with the inattentive subtype, are often not diagnosed until much later in life after comorbid conditions develop.

While issues pertaining to the HRRB Committee's concern that this study's participants may be at risk for labeling effects and the contention that "extensive evidence shows that selecting and labeling children in educational settings initiates a cascade of teacher- and administrative-expectation effects with the potential for profound negative effects on the child," a review of the scientific literature on ADD/ADHD reveals that not a single study has ever been published on the impact of labeling individuals with ADHD, inattentive subtype. The literature does contain numerous studies on the effect of labeling children with the hyperactive/impulsive and combined subtypes (Ohan, 2011); however, these studies address the overt disruptive behavioral issues that characterize those subtypes. Individuals with the inattentive subtype do not manifest these behaviors. With approximately 200 students in grades 3 and 4 at the proposed school site for this study, it is possible that a sufficient number of students for participation will be known by the school counselor, in which case no additional labeling would occur with these measures.

The failure to identify individuals with ADD/ADHD has a deleterious effect upon the lives of those with the disorder. The International Consensus Statement on ADHD (Attachment 8) states,

> ADHD can cause devastating problems. Follow-up studies of clinical samples suggest that sufferers are far more likely than normal people to drop out of school (32–40%), to rarely complete college (5–10%), to have few or no friends (50–70%), to underperform at work (70–80%), to engage in antisocial activities (40–50%), and to use tobacco or illicit drugs more than normal. Moreover, children growing up with ADHD are more likely to experience teen pregnancy (40%) and sexually transmitted diseases (16%), to speed excessively and have multiple car accidents, to experience depression (20-30%) and personality disorders (18–25%) as adults, and in hundreds of other ways mismanage and endanger their lives.

Numerous studies have identified that individuals with the inattentive subtype are at great risk for academic underperformance and failure (Sexton, Gelhorn, Bell, and Classi, 2012). Reading and math disorders, along with other learning disabilities, appear to be more prevalent in individuals with the inattentive subtype than found in those with the predominately hyperactive-impulsive type (Barkley et al., 1992; Bauermeister, Alegría, Bird, & Rubio-Stipec, 1992; Weiler, Bernstein, Bellinger, & Waber, 2000; Willcutt & Pennington, 2000).

In regard to the Committee's concerns that "this study will prompt the screening and selection of students who have not been identified previously" and will therefore increase the "potential for false-positive identifications and potentially damaging labeling effects," research is quite clear that exactly the opposite is an issue (e.g., that identification processes are often beset with false-negatives with many children being labeled "lazy" and "unmotivated" instead (National Resource Center on ADHD, 2004). Hallahan and Kauffman (1994, p. 505) argue that "by not labeling the student and so not providing special services, we run the risk of stigma and discrimination."

The need to identify participants who meet diagnostic criteria for ADHD, inattentive subtype in this study is paramount. This is clearly evident in the comprehensive screening procedures that will be used. While behavior ratings scales, such as the Conners 3AI, have been a staple in the identification process for many years, they remain subjective measures, although their use can be informative during the early stages of the screening process. In recognition of this, the Conners 3AI has been designed to under identify individuals with ADD/ADHD and the publishers acknowledge the importance of using with other screening measures. Continuous performance tests (CPT), on the other hand, are objective measures and are widely used in identifying individuals with ADD/ADHD. The CPT that will be used in this study, the IVA+Plus, has a sensitivity of 92% and a specificity of 90%. Similar to the Conners 3AI, the publisher also recommends that it be used in

conjunction with other screening tools.

qEEG assessments are currently becoming the gold standard for identifying individuals with ADD/ADHD as they are not only objective, but provide a detailed analysis of the neurophysiological processes of the brain. Research has long demonstrated that individuals with ADD/ADHD exhibit cortical slowing (high amplitude slow brainwave activity). Individuals with ADD/ADHD are characterized with relatively very high amplitude theta (4 to 8 Hz) while they are awake when compared with typically developing peers. High amplitude theta, however, is associated with the neurophysiological state of light sleep. Unless a typically developing individual is trained to increase this frequency, they will not express the same high amplitudes that characterize individuals with ADD/ADHD. Furthermore, most people who intentionally attempt to enhance theta will simply fall asleep. Therefore, qEEG assessments are considered to be the most reliable and efficient measure for identifying individuals with ADD/ADHD.

The utility of qEEG assessments, however, is not just valuable for screening but, as in the case of this study, will provide highly reliable objective information on the efficacy of neurofeedback protocols. As Brain Science International has donated both pre- and posttest qEEG assessments, it will be possible to determine whether and how each participant's EEG has changed. The qEEG assessments will, therefore, also serve as an empirical measure to document changes in EEG that cannot be explained by a placebo effect.

9. **PRIVACY:** **Privacy refers to how much a person (participant) has control over the extent, timing, and circumstances of sharing oneself (physically, behaviorally, or intellectually) with others.* Describe the provisions to protect the privacy interests of participants by answering the following questions and providing any additional information as necessary.

a. Where and when will the participant provide information?

All information obtained from each participant will occur at his/her public school. Data will be collected on a daily basis for the duration of the study.

b. Who is receiving this information (e.g., research assistants, PI)?

The PI will have full access to the information. Access to qEEG data will be provided to Brain Science International; however, BSI will be blinded to the real identity of the participants.

c. Additional Information Necessary for HRRB Review:

10. **CONFIDENTIALITY:** **Confidentiality refers to the methods used to ensure that information obtained by researchers about their participants is not improperly divulged.* Describe procedures to be used to maintain confidentiality by answering the following questions and providing any additional information as necessary.

a. Are you collecting identifying information (e.g., names, addresses, phone numbers, birthdates, social security numbers, licenses, audio/video recordings)? If yes, please describe.

Names and birthdates will be recorded and maintained in a password-protected spreadsheet by the PI for the duration of the study to ensure recording for proper analysis. Upon completion and final analysis of the study, all real names will be purged from the spreadsheet, and participants will only be identifiable by the pseudonyms assigned during the research.

b. Who will have access to any identifying information and for what reason?

Only the PI will have access to identifying information.

c. Where will the data be stored?

Data will be stored in a password-protected spreadsheet that will, in turn, be stored on a password protected computer. This computer will be located in the PI's home office. To ensure participant confidentiality, identifiable information will be removed from all physical documents (e.g., Health History, Conners 3AI) upon receipt and replaced with pseudonyms. These documents will be kept in a safe, located in the PI's home, and will be destroyed upon completion of the study. During the study, only one password protected spreadsheet will be maintained on a

password protected computer that connects each identity to a randomly assigned pseudonym.

d. Will the data be destroyed? If so, when?

Upon completion and final analysis of the study, all personally identifying information will be purged from the spreadsheet, leaving data pertaining to each participant only identifiable by pseudonyms. Data that contains non-identifiable information will not be destroyed.

e. If findings are published or made public, how will the participants' identities be masked?

It is anticipated that findings will be published. As a condition of the grant to fund this study by the International Society for Neurofeedback & Research, a publishable manuscript is to be submitted to the Journal of Neurotherapy. Participants and the school will only be identified by pseudonyms. If the school wishes to be identified as the host site in a publication acknowledgement, then written consent from the superintendent of the school district will be required.

Although nine students will be selected as participants, they will not be personally identifiable. Unlike individuals with ADHD, hyperactive/impulsive subtype who exhibit overt disruptive behaviors, individuals with the inattentive subtype have a hidden disability: it is often impossible for others (including many educators) to recognize their symptoms without additional training. In addition, the National Center for Health Statistics (2011) estimates that the prevalence of ADD/ADHD is currently 9.0% of all children (12.3% of boys and 5.5% of girls). Of all children with ADD/ADHD, it is estimated that 51 % have the inattentive subtype. Given the large number of students at the school who may met DSM-IV-TR criteria for a medical diagnosis of ADHD, inattentive subtype (a hidden disability), not including students with impaired attention but don't meet criteria, it is extremely unlikely that individual participants will be identifiable.

f. Additional Information Necessary for HRRB Review:

Please specify a referral process (e.g., referring to school psychologist, referral to community resources) for parents who may inquire about additional services and/or be alarmed to learn that their child may have attention issues.

Parents who express any concerns will be provided with an information sheet (Attachment 7) from the Greater Orange County Chapter #455 for Children and Adults with Attention-Deficit/Hyperactivity Disorders (CHADD). As noted on that information sheet,

> CHADD was founded in 1987 in response to the frustration and sense of isolation experienced by parents and their children with AD/HD. At that time, one could turn to very few places for support or information and it was thought that AD/HD was a childhood condition. Many people seriously misunderstood AD/HD. Many clinicians and educators knew little about the disability, and individuals with AD/HD were often mistakenly labeled "behavior problems," "unmotivated," "not intelligent."

As a non-profit organization, they serve to provide the public with access to community resources where support can be obtained. In addition, the Greater Orange County Chapter is affiliated with the Child Development Center at University of California, Irvine (http://www.cdc.uci.edu/chadd.shtml).

In addition, parents inquiring about services will also be referred to the school counselor, as well as provided with a brochure (Attachment 7) from the Child Development Center (CDC) at the University of California, Irvine (UCI). The CDC at UCI provides comprehensive clinical and educational services for individuals with attention deficits.

11. **CONSENT:** Describe consent process by answering the following questions and providing any additional information as necessary. Please also **provide a Consent Statement,** even if this consent is to be presented to the participants verbally. For guidance on completing a consent document, please use the Consent Writer Program.

a. Who will conduct the consent process?

The PI will conduct the consent process.

b. Where will consent be obtained?

Consent will be obtained at the participants' school.

c. Do you plan to collect signed consent forms?

☒ Yes. A copy of the consent document is attached. *(For more information about the consent document requirements, please go to http://or.ucr.edu/ori/faq.aspx#47)*

☐ No. Appendix I is attached.

d. With what language will the consent document be administered?

English

e. Will anyone other than the participant provide consent (e.g., parents, legally authorized representatives, etc.)?

Yes. Parents.

f. How long will the waiting period between informing the prospective participant and obtaining consent last? If the PI will lose contact with the potential participant during this waiting period, how will participants be recontacted? *(Please consider **Section 9: Confidentiality** when answering this question.)*

Every effort will be made to obtain consent as soon as possible after the initial contact has been made. It is not anticipated that there will be a waiting period.

g. What steps are being taken to minimize the possibility of coercion or undue influence?

Parents and participants have been assured in the consent/assent forms that participation is completely voluntary and that they may cease participation in the study at any time.

h. Additional Information Necessary for HRRB Review:

12. **DEBRIEFING:** This is only necessary if deception is involved, or if it is required by another entity (e.g., department subject pools).

☐ ***Please check here if participants will need to be debriefed, and attach a summary of any explanation of the purposes of this study that will be given to the participants after their participation.***

13. **ADDITIONAL REVIEW:** Has this research obtained, or will this research require review and/or approval by other UCR research compliance committees (i.e., IACUC, IBC, SCRO, etc.), other entities at UCR not under the control of the PI, or other non-UCR entities? If so, please indicate the committee or entity and provide verification of an approval from those units/entities if approval has already been obtained.

No

14. **RESEARCH INVOLVING CONFLICTS OF INTEREST** (UCR SOP Sections 7.5.10 and 13.9): Conflict of interest occurs when project personnel, their spouses, dependent children, or domestic partners have a personal financial interest in the outcome of the research. For example, sometimes a research sponsor also serves as a director, officer, partner, or consultant for the research; or the researcher may own stock options, receive personal income, or receive loans or personal gifts from the research sponsor. *If it is determined that you may have a conflict of interest, you may be asked to complete Appendix H.*

Please answer the following questions. ***Note that "No one" and "Not applicable" are acceptable answers.*

a. Who on the research team has or may have the conflict?

No one.

b. Who is the Sponsor(s) with whom the PI or research team member(s) has/have (or may have) a personal financial relationship?

Funding, in the form of a grant from the International Society for Neurofeedback & Research has been received in the amount of $2,000.

Brain Science International (BSI) has donated the pre- and post- qEEG assessments for each participant. In addition, BSI will be flying in a technician to conduct both the pre- and post-intervention assessments.

c. What is the amount of this personal financial relationship (amount of equity, annual compensation, etc.)?

No financial relationship.

d. Additional Information Necessary for HRRB Review:

15. **PROJECT ROSTER:** Please provide the names of all the **individuals, *INCLUDING THE PI(S),* who will work on this project**; ***LIST PI NAME FIRST.*** This page will not be made available to the public. Give a valid email address (UCR or your own) so that we can document training for regulatory agencies. Include all investigators, student employees, post-doctoral researchers, staff research associates, post-graduate researchers and technicians who will actually work experimentally. If you need more space, please attach additional names on a separate page.

Federal regulations require that all UCR personnel participating in human participants' research complete the UCR Human Subjects Tutorial ***within the last five years*** before initiating research activities. The tutorial can be found at: http://or.ucr.edu/appTutorial/TutorialClient/Introduction.asp and the person MUST register, complete the tutorial, print out the certification page and send it to the Office of Research Integrity.

If a research assistant or collaborator has completed a similar tutorial elsewhere, please submit a copy of that institution's certification. This certification will only be valid at UCR for five years, after which the UCR Human Subjects tutorial will need to be completed and its certification submitted to the Office of Research Integrity.

Completing the Human Subjects Tutorial at UCR or another institution is required and protocols cannot be approved without completion of it.

**The principal investigator is responsible for keeping this roster current. You must amend the protocol when staff are added or subtracted from this project. Submit protocol amendments electronically to Monica Wicker (mwro@ucr.edu), Office of Research Integrity.**

| **Last Name** *(*LIST PI NAME(S) FIRST*)* | **First Name** | **Date Tutorial Completed** | **Email Address** |
|---|---|---|---|
| La Marca | Jeff | 11/5/2012 | Redacted |
| One or two technicians from Brain Science International have not yet been identified. Prior to working with participants, they will either 1) complete the UCR online tutorial or 2) provide a certificate that is comparable to the one available from UCR. The completed certificate(s) will filed with the UCR HRRB prior to contact with participants. | | | |

 Application No. _____

16. **ATTACHMENTS:** List all supplementary material to be considered a part of this protocol and paper-clip them to this application. Following are the kinds of attachments that are necessary to complete many applications. Please check all that apply, and/or add to this list as necessary.

- ☒ Informed consent statement (See Section 9: Informed Consent of the UCR SOPs or the Consent Writer Program).
- ☒ Parent information letter to be used when minors are involved. Please note that parents must be informed and their permission obtained.
- ☒ Child assent (if necessary).
- ☒ Sample instruments including cover letters of introduction or sample dialogue.
- ☒ Authorization or letters of access from cooperating institutions, such as public schools, restricted housing, or businesses.
- ☐ Approval from another institution (another UC campus, a hospital, a school) assisting in the study when that institution is required to carry out an independent review of the use of human participants.
- ☒ Other(s): Attachment 6: Table of Estimated Times for Assessments and Tasks
  Attachment 7: Information Sheet, Greater Orange County Chapter #455 for Children and Adults with Attention-Deficit/Hyperactivity Disorders (CHADD)
  Attachment 8: International Consensus Statement on ADHD

 Application No. _____

**Assurances**

***PI TO COMPLETE ONLY:***

I, the *Principal Investigator*, certify that:

- ☒ The study has been designed to protect the human participants.
- ☒ I understand that I am responsible for the scientific conduct of the research and for providing all reports and information to the HRRB as required.
- ☒ All members of the research team are appropriately credentialed to perform the work undertaken in the protocol.
- ☒ I and my research team are not in violation of UCR's Conflict of Interest Policy while participating in the research.
- ☒ I will conduct the study identified above in the manner described on the attached narrative. If I decide to make any changes in the procedure, or if a participant is injured, or if any problems occur which involve risk or the possibility of risk to participants or others, I will immediately report such occurrences or contemplated changes to the UCR Human Research Review Board, Office of Research Integrity, University Office Building, Rooms 211 or 216, (951) 827-4811 or (951) 827-6332.

11/6/2012

Principal Investigator (PI) Signature Date

*****

***CHAIR / DIRECTOR / DEAN TO COMPLETE ONLY (cannot be the same as PI):***

I, the *Chair/Director/Dean*, certify that:

- ☐ The protocol application is scientifically sound and has scholarly merit.
- ☐ The investigator(s) are competent to conduct the research and protect the research participants.
- ☐ The investigator(s) have the resources needed to protect the research participants and to adequately pursue and complete the project.

Chair/ Director/Dean Signature Date

*****

**IF THE INVESTIGATOR IS A STUDENT (*FACULTY ADVISOR TO COMPLETE ONLY*):**

I, the *Faculty Advisor/Chair/Director/Dean* of the student researcher, certify that:

- ☐ I have read and approved this protocol.
- ☐ I believe this is "research" as defined by DHHS (i.e., a systematic investigation designed to develop or contribute to generalizable knowledge).
- ☐ The student is competent to conduct the activity as described herein.

Faculty Advisor Signature Date

Protocol #_____

**HRRB Appendix A**
**Research Involving Children as Participants**

***45 CFR 46, Subpart D; UCR SOP Section 10.1***
*Children are "persons who have not attained the legal age for consent to treatments or procedures involved in the research" [45 CFR 46.402(a)]. Therefore, they are covered by additional and specific protections under 45 CFR 46 and other federal and state laws. This supplement helps the HRRB to assess the risks and assure that research procedures comply with these special regulations.*

**1. Children as Participants**

a. What is the age range of the children in this research? (Please check all that apply.)

- ☐ Neonates (new born). If all participants are neonates, complete only HRRB Appendix C."]
- ☐ Older than newborn to age 2
- ☒ Ages 3-11
- ☐ Age 12 to under age 18

b. Where will the children be recruited and participate? (Please check all that apply.)

- ☐ Home
- ☒ School
- ☐ University lab/office
- ☐ Other. Please specify:

**2. What are the risks and benefits to the children?**

Check the category below that best represents the degree of risk and benefit to which the children in this study will be exposed. **Note: more than one category may be indicated, such as when a protocol involves both a study group and a control group;** in these cases, please specify.

*Minimal risk is defined as "the probability and magnitude of harm or discomfort anticipated in the research are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests" [45 CFR 46.102(i)].

☒ **Category 1:** The proposed research poses risks no greater than that ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests (i.e., minimal risk*) [45 CFR 46. 404].

☐ **Category 2:** The proposed research poses a greater than minimal risk* with the potential for direct benefit to participants [45 CFR 46.405]. Please explain how the benefit to risk assessment at least as favorable as that presented by alternative approaches?

☐ **Category 3:** The proposed research poses a greater than minimal risk* with no potential for direct benefit to individuals, but likely to yield generalizable knowledge about the participants' conditions [45 CFR 46. 406]. Please answer the following questions:

How is the risk of the protocol a minor increase over minimal risk*?

How does the procedure present experiences to participants that are reasonably commensurate with those

inherent in their actual or expected situations?

How is the knowledge to be gained of vital importance for the understanding or amelioration of the condition?]

☐ **Category 4:** The proposed research does not meet the criteria in the above categories but presents an opportunity to understand, prevent, or alleviate serious problems affecting the health or welfare of children [45 CFR 46.407]. Please provide justification for why this research should be approved:

**3. Parental Permission**

In general permission from both parents is required for research involving children unless one parent is deceased, unknown, incompetent, or not reasonably available, or when only one parent has legal responsibility for the care and custody of the child. For Categories 1& 2, however, the IRB may find that the permission of one parent is sufficient. [45 CFR 46.408(b)]

a. What permission will be obtained from the parents?

- ☐ Permission will be obtained from both parents unless one parent is deceased, unknown, incompetent, or not reasonably available, or when only one parent has legal responsibility for the care and custody of the child.
- ☒ Permission from only one parent is being requested even if the other parent is alive, known, competent, reasonably available, and shares legal responsibility for the care and custody of the child.
- ☐ A waiver of parental permission is being requested [46.408(c)] because parental or guardian permission is not a reasonable requirement to protect the participants for the following reasons:
  - ☐ The child is neglected or abused by their parents or guardians
  - ☐ Other. Please specify:

b. Is the research is being conducted in a group setting (e.g., a classroom)?

- ☒ No
- ☐ Yes. Please explain what provisions have been made for children whose parents have not given permission for them to participate:

**4. Assent from Children**

*Adequate provisions must be made for soliciting the assent of children when in the judgment of the IRB the children are capable of providing assent. Assent means a child's affirmative agreement to participate in research.* [45 CFR 46.402(b)]

a. Please indicate whether the children you will study are generally capable of providing assent; evaluate age, maturity, and psychological state of the children involved.

- ☒ All are capable. Please complete the rest of the form.
- ☐ Some are capable. Please explain why some children are capable and some are not capable (for example, having a wide range of ages, maturity, or psychological states), and complete the rest of the form.

☐ None are capable. Please answer the following questions:

☐ The children are not capable of providing assent due to their age, maturity, or psychological state.

☐ The capability of the children is so limited that they cannot be reasonably consulted.

☐ Other reason. Please explain:

Child assent can be waived if the PI assures the following (please check to confirm assurance):

☐ The intervention of procedure involved in the research holds out a prospect of direct benefit that is important to the health or well-being of the child and is available only in the context of research.

☐ I cannot provide this assurance. (Please contact the Office of Research Integrity at (951) 827-4811 or 6332, or IRB@ucr.edu)]

b. Describe how assent is will be obtained, including what information will be provided to the participants. Will there be special considerations for young children and/or the children's psychological state?

The study will be explained verbally to each child. Each child will receive a letter (attached) informing them about the study. In addition, each child will be informed of and given the opportunity to ask any questions about the research.

c. Describe how assent will be documented. Please attach copies of all assent forms, if any.

Each child will be given an assent form to sign (attached).

**5. Children who are Wards of the State, or any Other Agency, Institution, or Entity [45 CFR 46.409]**

*Wards are minors whose legal guardians have been appointed by the court. Federal regulations for wards are slightly different than for all other children in that the federal regulations require that the institution's IRB appoint an advocate for each child who is a ward, in addition to any other individual acting on behalf of the child as guardian or in loco parentis. As a result, the UCR HRRB needs to know the following information:*

a. Is the research related to the child's status as a ward?

☒ No

☐ Yes. Please explain:

b. Is the research conducted in a setting in which the majority of children involved as subjects are *not* wards?

☐ No

☒ Yes. Please explain:

The research will be conducted in a public school.

## Appendix 2. Parent Letter for Initial Screening

January 14, 2013

Regarding: Potential participation in a research study

Dear Parent:

My name is Jeff La Marca and I am a Ph.D. student at the University of California, Riverside. I am interested in studying the use of biofeedback to help students attend to school tasks and perhaps improve their reading skills. Biofeedback uses computers to help people listen to their bodies. Biofeedback equipment often provides information on brainwaves, heart function, breathing, muscle activity, and skin temperature. The computer then provides "feedback" to the user. This enables individuals to change their behaviors, over time, so that they can perform better on different tasks. Your child has been nominated as a possible participant in this research. Identifying students to participate will be based on a screening process that is designed to identify students who will have the best chance to benefit from biofeedback training.

Should you wish your child to participate, you will be asked to complete a brief health history and a rating scale about your child. In addition, your child will receive several assessments to see if he/she has a good chance to benefit from the program. These tests take about 60 minutes and will be done during school hours at your child's school.

Biofeedback has been studied for many years and there could be benefits for your child. Some studies indicate that both school performance and grades improve. I want to explore whether students will read faster and better after training. Some studies suggest that the effects of biofeedback can be very long lasting. More information will be sent to you if your child is screened and found eligible for the research study.

There will be no cost to you and participation is free. Participation in the screening and in the research is voluntary. The choice for your child to participate in screening is up to you, and you or your child can also decide to stop participating at any time. If your child does participate, all information obtained will be part of the data collected for the study. This information will not be connected to your child's name in any way. Your child's identity will be kept anonymous and completely confidential.

If you have any questions regarding this research, please contact me at [redacted]. If you have any question about your rights or your child's rights as a participant in a research study, please contact the University of California, Office of Research Integrity by phone (951-827-4811), by email (irb@ucr.edu), or at University Office Building #200, Riverside, CA 92521.

Most Sincerely,

UC RIVERSIDE Institutional Review Board
4/4/13
Approved
4/3/14
Expires
HS 1213
IRB #

Jeff La Marca, Ph.D. Student
Graduate School of Education
University of California, Riverside

## Appendix 3. Parent Consent Form for Initial Screening

UNIVERSITY OF CALIFORNIA, RIVERSIDE
Parent Consent Form
(Regarding: Potential participation in a research study)

Your child is being asked to be screened for potential participation in a research study because he or she may benefit from biofeedback. The purpose of this study is to examine the effect of biofeedback on attention and reading achievement. Participation in this research study is completely voluntary. Please read the information below and ask questions about anything that you do not understand before deciding if you want your child to be screened. The researcher listed below will be available to answer your questions.

**INVESTIGATORS AND SPONSORS**

***Lead Researcher:***

- Jeff La Marca, Ph.D. Candidate (ABD) - Graduate School of Education

***Study Location:***

- Redacted during school hours

***Study Sponsor(s):***

- Brain Science International
- International Society for Neurofeedback & Research (funding for this study is being provided by a research grant)

**PARTICIPATION REQUIREMENTS:**

With your permission, your child will be assessed to see if he or she is a good match with the requirements of this research. Participants will be selected based on the results of screening measures that will measure cognitive functioning, health history, and reading achievement. This testing will occur during the school day and take one hour to complete. Final selection will be based upon the results from these assessments, and if your child is found eligible, you will receive a new consent form with another opportunity to decide whether you want your child to participate, along with more information about the study.

**PROCEDURES**

***Total Time Involved:***

Screening will take about one hour. If you agree to this screening process, I will schedule a convenient time with your child's teacher.

**RISKS**

There are no known risks, harmful effects, or discomforts associated with the screening assessments beyond those encountered in daily life. Participation in this study requires that students will miss class time.

**BENEFITS**

The screening will not provide any benefits to your child. If your child is found eligible, it is possible that participation in the study could improve attention to school tasks.

**COMPENSATION/COST/REIMBURSEMENT**

Participation in this study is completely free. No reimbursement or compensation is offered.

**WITHDRAWAL OR TERMINATION FROM STUDY**

You and your child are free to withdraw from this screening at any time. Your decision to participate or not will not affect any services to which your child is entitled that are provided by the school district.

**CONFIDENTIALITY**

***Data Storage***

Information collected in this research, including paper-based records and computer-based data, will be maintained by the Lead Researcher. Children's names will be removed so that each participant is identified by a number known only to the Lead Researcher. Electronic data will be stored on a password protected computer.

***Data Access and Privacy***

Only the Lead Researcher and the study sponsors (the International Society for Neurofeedback & Research and Brian Science International) will have access to your data, and only the Lead Researcher will know the identity of your child.

***Data Privacy***

Data from students who are not selected will be destroyed. The research data for students who participate later in the research study will be maintained indefinitely; however, these records will not be identified with names or other personal information and only unidentifiable data will be kept indefinitely.

**IF I HAVE QUESTIONS**

If you have any comments or questions regarding the conduct of this research or your rights as a research subject, please contact the University of California, Office of Research Integrity by phone (951-827-4811), by email (irb@ucr.edu), or at University Office Bldg. #200, Riverside, CA 92521.

- Jeff La Marca, Ph.D. Candidate (ABD), Graduate School of Education
  **Phone:** Redacted, **E-mail:** Redacted
- Dr. Rollanda O'Connor, Professor and Faculty Advisor, Graduate School of Education
  **Phone:** Redacted, **E-mail:** Redacted

**VOLUNTARY PARTICIPATION STATEMENT**

I understand that participation in this study is voluntary. My child may refuse to answer any question and we may discontinue his/her involvement at any time without penalty or loss of benefits to which s/he might otherwise be entitled. My decision will not affect our future relationship with UC Riverside. My signature below indicates that I have read the information in this consent form and have had a chance to ask any questions I have about the study. I agree to allow my child to participate in the study.

_____ _____

Parent/Legally authorized representative Date

_____ _____

Signature of Investigator Date

## Appendix 4. Student Assent Form for Initial Screening

UNIVERSITY OF CALIFORNIA, RIVERSIDE
Student Assent Form – Initial Screening

Dear Student:

You are being asked to be in a research study. This is like a science project. You are being asked to join because this study may help us know how to help you and other children learn better.

In a real science project, there are many rules. These rules help us to learn as much as we can. Because of these rules, not all students who start the study will get to finish. This is because the study may not work for you.

This study will happen at your school. Mr. La Marca will be the person who will work with you. He will ask you many questions. You will be asked to work on a computer for about 15 minutes. You will spend about one hour with Mr. La Marca.

Some students will be asked to come back later and do more things. If you are selected, Mr. La Marca will contact your parents and also ask if you want to continue with the study. The decision to continue will be left up to you and your parents. Nothing in this study will harm or hurt you.

By signing this form, you are saying that you want to join this study. It is your choice to join. If you agree, your name will not be used and the information from the things you do will not be linked to your name. You can decide to stop any time during the study if you want to.

| Student's Name | Signature | Date |
|---|---|---|

## Appendix 5. Parent Letter for Second Screening

January 14, 2013

Regarding: Potential participation in a research study

Dear Parent:

Based upon initial screening assessments, your child is being considered as a possible participant in the research on the use of biofeedback to help students attend to school tasks and perhaps improve their reading skills. Biofeedback uses computers to help people listen to their bodies. Biofeedback equipment often provides information on brainwaves, heart function, breathing, muscle activity, and skin temperature. The computer then provides "feedback" to the user. This enables individuals to change their behaviors, over time, so that they can perform better on different tasks. The decision for determining eligibility to participate will be based on an additional screening process that is designed to identify students who will have the best chance to benefit from biofeedback training. The final decision to participate will be made by you and your child.

Should you wish your child to participate; your student will receive a specialized test to determine if biofeedback may be useful. This test is called a qEEG and is used to evaluate brainwave patterns. This is done by attaching many adhesive sensors on the head. This is completely painless. These sensors detect brainwaves just as a thermometer detects body temperature. You child will also be given a reading test and an introductory experience with the biofeedback program. These tests take about two hours and will be done during school hours at your child's school. All children selected to participate in this study will be tested again at the end, and then once more four to six weeks later.

Children selected for the study will play games on a computer; there are no controls because students will learn to control the computer with only his or her brain. This is done by attaching three adhesive sensors on the head. Again, this is completely painless. These sensors send information to the computer and your child will use this information to control what happens during the games. Your child will receive 40 sessions of neurofeedback (a type of biofeedback that uses brainwaves) in which he/she will spend 30 minutes interacting with a computer. In addition, several assessments for reading and attention, lasting approximately 5 minutes, will be conducted after each session. The total time in each session is approximately 45 to 60 minutes. Please contact me (see below) with any concerns or preferences regarding the specific class time that your child will miss.

Neurofeedback has been studied for many years and there could be benefits for your child. PracticeWise, a research organization for the American Academy of Pediatrics has just announced that biofeedback has reached their highest rating (Level 1 – Best Support) for helping children to attend better. Research has shown that this training often improves attention. Some studies indicate that both school performance and grades improve. I want to explore whether

students will read faster and better after 40 sessions of neurofeedback training. Some studies suggest that the effects of neurofeedback can be very long lasting.

It is important for you to know that neurofeedback is completely safe and has been studied for a long time. There are no known side-effects. There will be no cost to you and participation is free. Participation in this study is voluntary. The choice for your child to participate is up to you, and you or your child can also decide to stop participating at any time. If your child does participate, all information obtained will be part of the data collected for the study. This information will not be connected to your child's name in any way. Your child's identity will be kept anonymous and completely confidential.

If you have any questions regarding this research, please contact me at [redacted]. If you have any question about your rights or your child's rights as a participant in a research study, please contact the University of California, Office of Research Integrity by phone (951-827-4811), by email (irb@ucr.edu), or at University Office Building #200, Riverside, CA 92521.

Most Sincerely,

Jeff La Marca, Ph.D. Student
Graduate School of Education
University of California, Riverside

## Appendix 6. Parent Consent Form for Second Screening

UNIVERSITY OF CALIFORNIA, RIVERSIDE
Parent Consent Form
(Regarding: Potential participation in a research study)

Your child is being asked to participate in a research study because he or she may benefit from neurofeedback, a type of biofeedback that uses brainwaves. The purpose of this study is to examine the effect of neurofeedback on attention and reading achievement. Participation in this research study is completely voluntary. Please read the information below and ask questions about anything that you do not understand before deciding if you want your child to participate. The researcher listed below will be available to answer your questions.

**INVESTIGATORS AND SPONSORS**
***Lead Researcher:***

- Jeff La Marca, Ph.D. Candidate (ABD) - Graduate School of Education


***Study Location:***

- [redacted]

***Study Sponsor(s):***

- Brain Science International
- International Society for Neurofeedback & Research (funding for this study is provided by a research grant)

**PARTICIPATION REQUIREMENTS:**

With your permission, your child will be further assessed to see if he or she is a good match with the requirements of this research. Participants will be selected based on the results of screening measures that will measure attention, cognitive functioning, health history, and reading achievement. This testing will occur during the school day and take about two hours to complete. Your child will receive a brainwave evaluation called a quantitative electroencephalogram (qEEG), which involves placing 21 sensors on his or her head and takes about 45 to 60 minutes to complete. Final selection will be based upon the results from these assessments, along with your permission.

**PROCEDURES**

***Total Time Involved:***

Students selected to participate will be involved in this study for about three to four months. In the first one to three weeks, students will have an introduction to neurofeedback. Most of these sessions will last about 10 minutes. Next, students will receive 40 sessions of neurofeedback spread across about 3 months. During neurofeedback, your child will be connected to a computer using sensors attached to his or her head that will detect brainwaves. Your child will learn to

control his or her brainwaves to play video computer games. Each session will take about 45 to 60 minutes daily during school hours. In the last week, the researcher will repeat the same assessments used to select the students, including another qEEG. Four to six weeks after all children have completed their training sessions, the researcher will repeat the measures one more time, except that no qEEG will be done.

**RISKS**

There are no known risks, harmful effects or discomforts associated with the assessments, qEEG, or neurofeedback training beyond those encountered in daily life. There is, however, a very small chance that the sensors and/or adhesives used may irritate the skin. If this occurs, the sensors will be removed and you will be notified.

Participation in this study will require that students miss class time. The neurofeedback sessions will be coordinated with your child's teacher to minimize class disruption.


**BENEFITS**

By participating in this study your child might receive the following benefits:

- Participants might show improvements in sustained attention following 40 sessions of neurofeedback.
- It is possible that your child may have improved reading skills as a result of this study.
- Some research reports that neurofeedback may produce long-term improvements in attention, behavior, grades, and academic achievement. These improvements, however, have not always been found.

**COMPENSATION/COST/REIMBURSEMENT**

Participation in this study is completely free. No reimbursement or compensation is offered.

**WITHDRAWAL OR TERMINATION FROM STUDY**

You and your child are free to withdraw from this study at any time. Your decision to participate or not will not affect any services to which your child is entitled that are provided by the school district.

**CONFIDENTIALITY**
***Data Storage***

Information collected in this research, including paper-based records and computer-based data, will be maintained by the Lead Researcher. Children's names will be removed so that each participant is identified by a number known only to the Lead Researcher. Electronic data will be stored on a password protected computer.

*Data Access and Privacy*

Only the Lead Researcher and the study sponsors (the International Society for Neurofeedback & Research and Brain Science International) will have access to your data, and only the Lead Researcher will know the identity of your child.

*Data Privacy*

Data from students who are not selected will be destroyed. The research data for students who participate in the research study will be maintained indefinitely; however, these records will not be identified with names or other personal information. Only unidentifiable data will be kept indefinitely.

**IF I HAVE QUESTIONS**

If you have any comments or questions regarding the conduct of this research or your rights as a research subject, please contact the University of California, Office of Research Integrity by phone (951-827-4811), by email (irb@ucr.edu), or at University Office Bldg. #200, Riverside, CA 92521.

Contact:

- Jeff La Marca, Ph.D. Candidate (ABD), Graduate School of Education
  **Phone:** [redacted], **E-mail:** [redacted]
- Dr. Rollanda O'Connor, Professor and Faculty Advisor, Graduate School of Education
  **Phone:** [redacted], **E-mail:** [redacted]

**VOLUNTARY PARTICIPATION STATEMENT**

I understand that participation in this study is voluntary. My child may refuse to answer any question and we may discontinue his/her involvement at any time without penalty or loss of benefits to which s/he might otherwise be entitled. My decision will not affect our future relationship with UC Riverside. My signature below indicates that I have read the information in this consent form and have had a chance to ask any questions I have about the study. I agree to allow my child to participate in the study.

_____ _____

Parent/Legally authorized representative Date

_____ _____

Signature of Investigator Date

## Appendix 7. Student Assent Form for Second Screening

UNIVERSITY OF CALIFORNIA, RIVERSIDE
Student Assent Form

Dear Student:

You are being asked to be in a research study. This is like a science project. You are being asked to join because this study may help us know how to help you and other children learn better.

In a real science project, there are many rules. These rules help us to learn as much as we can. Because of these rules, not all students who start the study will get to finish. This is because this study may not work for you.

This study will happen at your school. For some students, the study will last about three or four months. Mr. La Marca will be the person who will work with you. You may also meet with someone else two times. Mr. La Marca will be there. That person will put many sticky sensors on your head and that will help us see what your brain is doing and take pictures of it. The sticky sensors may pull out a couple of hairs when they are removed. There is a very small chance that the sensors or the sticky stuff attached to them may irritate your skin. If this happens, we will stop and remove them. Your parents will also be told. When the pictures are ready, Mr. La Marca will show them to you.

If you are selected for this study and decide you want to do it, you will learn how to use your brain to play video games. This will be done by placing sticky sensors on your head. You will learn to control the computer with your brain. You will meet with Mr. La Marca on 40 different days to play these games. He will ask you a lot of questions, too.

When you have finished all 40 days, you will meet with someone else again and have more sticky sensors placed on your head. This will make more pictures and will help to see if your brain has made any changes. Mr. La Marca will also show these pictures to you.

You will also take some tests at the beginning of the study and again at the end. . In the beginning, you may become a little frustrated as you first learn to control the computer because you will not feel anything. I will help you learn. Nothing in this study will harm or hurt you.

By signing this form, you are saying that you want to join this study. It is your choice to join. If you agree, your name will not be used and the information from the things you do will not be linked to your name. You can decide to stop any time during the study if you want to.

Student's Name Signature Date

## Appendix 8. Student Health History Questionnaire

# STUDENT HEALTH HISTORY QUESTIONNAIRE

All answers to questions contained in this questionnaire are strictly confidential. Although you may elect to not answer any of the questions, this information is necessary in order for your child to participate in this study.

| | | | |
|---|---|---|---|
| **Student's name** *(Last, First, M I ):* ☐ **M** ☐ **F** | | **Age:** | **DOB:** |
| **Address:** | | | |
| **City:** | **State:** | | **Zip:** |
| **Parent(s) or legal guardian(s) of student:** | | | |
| **Father's name** *(Last, First, M I ):* | | ☐ Single ☐ Partnered ☐ Married ☐ Separated ☐ Divorced ☐ Widowed | |
| **Address***(If different than student's)*: | | | |
| **City:** | **State:** | | **Zip:** |
| **Phone (Home):** | **Phone (Cell):** | **E-mail:** | |
| **Mother's name** *(Last, First, M I ):* | | ☐ Single ☐ Partnered ☐ Married ☐ Separated ☐ Divorced ☐ Widowed | |
| **Address** *(If different than student's)*: | | | |
| **Phone (Home):** | **Phone (Cell):** | **E-mail:** | |

**STUDENT HEALTH HISTORY**

| | | | | |
|---|---|---|---|---|
| **Has your child ever been diagnosed with Attention Deficit Hyperactivity Disorder?** ☐ Yes ☐No | | | | |
| **If yes, what type?** | ☐ Hyperactive/Impulsive | ☐ Inattentive | ☐ Combined | ☐ Don't know |
| **Has a member of your child's family (parents, grandparents, brother, sister, aunt, or uncle) ever been diagnosed with Attention Deficit Hyperactivity Disorder?** ☐ Yes ☐No | | | | |
| **If yes, what type?** | ☐ Hyperactive/Impulsive | ☐ Inattentive | ☐ Combined | ☐ Don't know |
| **Is your child:** | ☐ Right-handed | ☐ Left-handed | | |

**List any other medical problems that your child's doctors have diagnosed**

**List your child's prescribed drugs and over-the-counter medications**

| **Name of medication** | **Reason taken** | **Dose** | **How often and when taken** |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

**Developmental history**

| **Prenatal and birth:** | | | **Describe** |
|---|---|---|---|
| Prenatal stress or injury | ☐ Yes | ☐ No | |
| Prenatal drug/alcohol exposure | ☐ Yes | ☐ No | |
| Birth trauma | ☐ Yes | ☐ No | |
| Anoxia (oxygen deprivation at birth) | ☐ Yes | ☐ No | |
| Premature delivery | ☐ Yes | ☐ No | |

| Physical Trauma | | | |
|---|---|---|---|
| | | | **Describe** |
| Head injury (including minor falls, etc.) | ☐ Yes | ☐ No | |
| Coma (loss of consciousness) | ☐ Yes | ☐ No | |
| High Fever | ☐ Yes | ☐ No | |
| Central Nervous System Infection | ☐ Yes | ☐ No | |
| Drug overdose or poisoning | ☐ Yes | ☐ No | |
| Anoxia (oxygen deprivation) | ☐ Yes | ☐ No | |

**STUDENT AND FAMILY HEALTH HISTORY**

| Please indicate if your child and/or a family member related to your child (parents, grandparents, brother, sister, aunt, or uncle) currently experiences, or has experienced in the past, any of the following: | | | | | | |
|---|---|---|---|---|---|---|
| | **Your student** | **Other family member(s)** | | **Your student** | **Other family member(s)** | |
| Anxiety | ☐ Yes ☐ No | ☐ Yes ☐ No | Hyperactivity | ☐ Yes ☐ No | ☐ Yes ☐ No | |
| Attention problems | ☐ Yes ☐ No | ☐ Yes ☐ No | Impulsivity | ☐ Yes ☐ No | ☐ Yes ☐ No | |
| Behavior problems | ☐ Yes ☐ No | ☐ Yes ☐ No | Memory problems | ☐ Yes ☐ No | ☐ Yes ☐ No | |
| Depression | ☐ Yes ☐ No | ☐ Yes ☐ No | School/work problems | ☐ Yes ☐ No | ☐ Yes ☐ No | |
| Head Injury | ☐ Yes ☐ No | | Seizures | ☐ Yes ☐ No | ☐ Yes ☐ No | |
| Headaches | ☐ Yes ☐ No | ☐ Yes ☐ No | Sleep problems | ☐ Yes ☐ No | ☐ Yes ☐ No | |

Thank you for completing this questionnaire.

**If your child is selected to participate in this study, it is important that you notify me in the event that your child begins any new medications, or dosages are changed while he or she is participating.** This information is important as changes in medication can affect the study outcomes. In the event that you have difficulties completing this form or have any questions, please contact me (Jeff La Marca) by phone: Redacted or by e-mail: Redacted.

## Acknowledgement of Parent(s) or Legal Guardian(s):

This form was completed by:

| | | |
|---|---|---|
| Father/Legally authorized representative | Signature | Date |
| Mother/Legally authorized representative | Signature | Date |