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Automated Neurofeedback Brain-training as a Primary ADHD Intervention

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Abstract

Neurofeedback brain-training has a significant presence in the literature for its efficacy in alleviating the symptoms and behavioral manifestations of ADHD, with no enduring negative side-effects. It is considered a behavioral intervention in that it teaches the brain to better manage its own brain-wave activity, leading to reduction of 80-85% of symptoms in the first 30-40 training sessions. Brain-training has shown efficacy in treating autism spectrum disorder, anxiety, depression, learning disabilities, and many more brain-imbalances that prevent children from full academic and social capacity. Barriers to broad-based implementation in both clinical and subclinical settings include cost of equipment, lengthy, in-depth training requirements, and a lack of clear guidance in developing and implementing brain-training protocols specific to each individual's brain-phenotype. Automated Psychophysiological assessment and EEG Biofeedback training systems demonstrate equal efficacy as clinician-guided EEG Systems. We propose that Automated EEG Biofeedback systems have evolved to differentiate and train a multiplicity of brain-phenotypes related to symptoms of ADHD and other childhood developmental disorders. Further, these systems decrease the cost of brain-training significantly, reduce the training requirements for brain-trainers, and significantly increase the effectiveness of all other behavioral and academic school/district level interventions. We propose that automated brain-training can be implemented at a school/district level, by a licensed school social worker, counselor, nurse or other person qualified by their understanding of behavioral training.

Introduction

Attention Deficit/Hyperactivity Disorder (ADHD is a chronic syndrome whose symptoms affect approximately 11% of American school-aged children, and nearly 20% of adolescent boys. The most common symptoms of ADHD include inattention, distractedness, disorganization, impulsiveness and hyperactivity. There has been a substantial increase in the diagnosis of ADHD, 42% between 2003 and 2012 (Visser, Zablotsky, Hlbrook, Danielson, & Bitsko (2015), with many experts believing that ADHD is over-diagnosed. Accurate diagnosis is further challenged by medical symptoms have the capacity to mimic ADHD symptoms. These conditions include vision and hearing challenges, sleep disturbances, substance abuse, mood disorders, learning disorders, sensory-processing disorders, seizure disorders, obsessive-compulsiveness, Asperger's syndrome, fetal alcohol syndrome, and Fragile X syndrome.

Neuro imaging and EEG Brain-mapping research over the past three-decades has produced an Arousal Model of mental health that identifies eleven universal brain-phenotypes involved in nearly all mental health disorders. These brain-phenotypes, subtypes of mental health disorders describe symptom and behavioral manifestations of regional brain overarousal, underarousal, or instability. (Gunkleman & Cripe, 2008; Amen, 2015). The most current Brain-phenotype model for ADHD arises out of Amen's extensive and broad-ranged neuroimaging studies that describe implicated brain-region arousal levels.

Amen's (2015) phenotype model identifies seven brain-phenotypes, with their symptom/behavioral manifestations, and implicated brain-region related to ADHD. The extensive body of neuroimaging studies is revelatory for understanding the underlying neurological imbalances involved in ADHD, for predicting medication efficacy and especially for understanding the importance of neurofeedback as a primary intervention for ADHD.

Our purpose in this article is to provide an overview of the Arousal model that has evolved in neuroscience based on our understanding of brain-phenotypes to provide the context for which automated neurofeedback systems can be applied. Next, we will describe evolvement of automated NFB assessment and interventions, potential side effects, and contraindications. I will review the research support for brain-training in various addiction and mental health populations. Finally, strategies for integrating automated brain-training systems in clinical and subclinical settings is explored.

ADHD/ADD Diagnosis:

Diagnosis of ADHD is typically conducted by licensed physicians, psychiatrists, social workers, and other appropriately trained and licensed mental health providers, using diagnostic indicators provided by the American Psychiatric Association (APA) in the Diagnostic and Statistical Manual, Fifth edition (DSM-5; APA, 2013), or the International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10). Diagnostic features of both systems are restricted to the areas of Inattention, Hyperactivity/Impulsivity, or both. Challenges in arriving at an accurate diagnosis may include the presence of other medical symptoms that mimic ADHD symptoms (McReynolds, Villalpando, & Britt, 2018), which include vision and hearing difficulties, sleep disturbances, mood disorders, learning disabilities, sensory-processing disorders, giftedness, seizure disorders, obsessive-compulsive disorders, Tourette's and Asperger's syndrome, schizophrenia, fetal alcohol syndrome, and Fragile X syndrome (Saul, 2014).

Neuroimaging and EEG research provides many new clues to the underlying etiology of ADHD and the frequently occurring symptoms related to other brain-wave imbalances, including those listed above. In fact, it is only through *seeing* and *hearing* brain activity that a comprehensive Arousal model has developed that provides a framework for both diagnosing and treating the broad range of ADHD symptoms. Brain imagining techniques have developed at a significantly rapid pace over the past 3 decades, leading to a much more comprehensive understanding of the effects of regional brain arousal levels: under-aroused, overaroused, instable, on mental health symptoms. Researchers have now identified Eleven universal brain-phenotypes that describe out-of-balance arousal levels implicated in nearly all mental health disorders. Seven individual brain-phenotypes have been identified related to ADHD specifically (Table 1), with seven phenotypes identified for Anxiety/Depression, six phenotypes for Addiction, and six phenotypes for Eating Disorders. There is considerable overlap between the ADHD phenotypes, and phenotypes related to other mental health disorders. Identifying the individual brain-phenotype involved in ADHD, and other disorders, is a critical first step in diagnosis, and is necessary for predicting medication efficacy (Amen, Hanks, & Prunella, 2008).

Type	**Symptoms**	**Involved br**
1. Classic ADD	Inattentive, distracted, disorganized, impulsive, hyperactive	Low Pre-Frontal Cortex (PFC) and cerebellum
2. Inattentive ADD	Inattentive, distracted, disorganized, *not very* impulsive or hyperactive	Low PFC and cerebellum
3. Over focused ADD	Inattentive plus over focused, worrying, oppositional, holds grudges	Low PFC and increased Anterior Cingular Gyrus (ACG)
4. Temporal Lobe ADD	Temper problems, mood instability, irritability, memory problems, learning disabilities	Abnormal Temporal Lobe (TL)
5. Limbic ADD	Inattentive plus chronic low-level sadness	Low PFC plus high limbic activity
6. Ring of Fire ADD	Inattentive plus hyperactive, impulsive, mood instability, sensitive to noise and touch	Excessive brain activity
7. Anxious ADD	Inattentive plus anxious, tense, nervous, predicts the worst, self-medicates to calm	Low PFC and high basal ganglia

Until recently, assessing brain-phenotypes for ADHD and other mental health disorders required extensive clinical training and experience. Accurate assessment has traditionally relied on quantitative Electroencephalograph (qEEG) evaluation. qEEG systems listen to the various components of brain-wave activity. The most comprehensive qEEG systems analyze data obtained from 19-channels on the scalp where brain-wave signals are known to rise sufficiently to be *heard* by sensors placed on those locations. The signals are amplified, and the data is compared against norms of normal brain activity. The data produces graphics that can identify over 5,100 components of brain activity including arousal levels, connectivity, coherence, and brain-injury. Unfortunately, recording and interpreting the qEEG requires complex interpretations of baseline Electroencephalograph (EEG), participants' presenting symptoms, between-session changes in symptoms, and within session reward criteria. Complex neurofeedback systems, and the necessary skills and knowledge to effectively operate them are typically well beyond operational capacity of most mental health providers, let alone school behavioral interventionists.

A second form of assessing brain-phenotypes, psycho-physiological assessment, demonstrates equal efficacy in reducing ADHD symptoms (Keith, Theodore, Rapgay, Schwartz, & Ross, 2015) and other brain-phenotype imbalances (Scott, 2018). Psycho-physiological assessments more coherently identify both ADHD and other co-occuring mental health symptoms then the DSM-V and ICD-10 include, thereby providing a broader understanding of the underlying brain-arousal levels and their implications for both assessment and treatment. Rather than identifying single features of a specific diagnostic category, psychophysiological assessments provide a more comprehensive perspective on all the mental health issues that may impede learning, social engagement, and academic achievement in school-aged children. Technological development within the neurofeedback field now provides guided semi-automatic psychophysiological assessment and training hardware/software with demonstrated equal efficacy when compared with more complex clinical guided neurofeedback (Keith et al., 2015). Automated assessment and brain-training hardware/software provides practical, safe, and effective brain training tools that can be readily implemented a broad range of sub-clinical school settings.

Treatment for ADHD:

Treatments for ADHD are designed to reduce the behavioral symptoms of ADHD and generally fall under two categories: psychopharmacological, and behavioral. Many children respond well to behavioral interventions coupled with medications (Fabiano et al, 2009), though others do not (Sonuga-Barke, et al, 2013). Behavioral interventions have been associated with several positive outcomes including increased parent empowerment and reducing conduct problems of children diagnosed with ADHD (Daley et al, 2014), though improvements in academic performance and social skills have not been substantiated in reviews of behavioral interventions (McReynolds et al., 2018).

Medication treatment approaches raise multiple concerns regarding both the side effects of typical prescription regimens including possible bone-loss, gastrointestinal problems (Ellis, 2016), sleep problems, decreased appetite (Brazier, 2015), and height suppression (Poulton et al, 2013). Further, medications do not have enduring effects (Swanson et al, 2017). Though medications are being prescribed at younger ages then previously (DSM-5; APA), the use of stimulant medications without matching to brain-phenotype is too simplistic of an approach to treat the complex brain-imbalances underlying an individuals unregulated emotional, behavioral, cognitive, social, and academic difficulties (Dunlop & Newman, 2016). Further, continued benefits from medications require continuous use, with increasing dosages over time to account for tolerance to both pharmacological effect and increases in side effects (Pigott, Bodenhamer-Davis, Davis & Harbin, 2013; Pigott & Cannon, 2014)

Neurofeedback Brain-Training (NFBT) is a form of evidence-based behavioral therapy that uses a computer-human interface to receive, interpret, and provide feedback of brain electrical energy to the trainee. This form of operant conditioning facilitates the brain's neuro-plasticity, its ability to rapidly change and reorganize neural pathways in response to brain-training. NFBT has been broadly recognized as effective in alleviating ADHD symptoms, reaching a "Level 5 Research Outcome, signifying the highest level of clinical research and statistical significance when compared to medication and placebo treatments (Arns et al, 2009, AACAP, 2011).

Arousal models traditionally used in assessing ADHD largely focused on the Beta/Theta ratio, and/or Sensory Motor Rhythm (SMR), primarily in the pre-frontal cortex. Though the *standardized* protocols that have developed have demonstrated efficacy and endurance in neurofeedback studies, inconsistencies in protocol application are the source of methodological criticisms (Pigott & Cannon, 2014).

As previously discussed, methodological evaluation of brain-phenotypes has been largely restricted to clinician administered qEEG analysis, with most training conducted with standardized ADHD protocols.

More recent developments in phenotype models demonstrate regional arousal levels that include the previously identified phenotypes, and add several phenotypes that more distinctly address other implicated brain-regions (Amen, 2015). As previously discussed, assessing the multiplicity of brain-phenotypes is beyond the scope and practice of most clinicians, even many experienced neurofeedback therapists. Designing and implementing treatment protocols that address the multiplicity of symptoms is also beyond the experience scope of all but the most experienced neurofeedback therapists. Further, clinician guided NFBT requires ongoing evaluation of in-session, and between-session changes that typically identify over zealous brain-training. Nearly all previous positive studies demonstrating NFBT's efficacy in alleviating ADD/ADHD symptomology and improving long-lasting EEG patterns have relied on complex neurofeedback systems requiring extensive training and experience, with accumulated understanding of neurophysiology. The complexity of systems, skills, and knowledge required for its clinical and sub-clinical applications has limited more broad spread application of this behavioral training method.

Pioneer neurofeedback researcher and therapist Bill Scott recognized the multiplicity of brain-phenotype symptoms early in NFBT's history. In addition to creating the only 3-dimensional visual feedback instrument, a fractal image of the brain's total EEG, Scott developed NFBT's first, and as far as we know, only automated brain-training system, BrainPaint. The BrainPaint system is a widely used, automated phenotype-based assessment and training human-computer interface. Its design includes a 90-question psycho-physiological assessment with strong correlations to Amen's 7-brain phenotypes for ADD/ADHD. Additionally, the automated assessment includes symptom assessment for each of the phenotypes associated with anxiety, depression, addictions, and eating disorders. Once the trainer completes the automated assessment, the automated system produces recommended training protocol suggestions that have demonstrated efficacy in others with related brain-phenotypes.

Scott's automated NFBT system converges the long history of neurofeedback's demonstrated efficacy in symptom relief in a broad range of mental-health disorders with the emerging understanding of brain-phenotypes. Though BrainPaint has been widely used in research and clinical settings with great efficacy, little literature yet exists on its unique ability to assess and train to specific brain-phenotype arousal levels. Developments in automated NFBT systems provide an advantage in that they directly assist neurofeedback practitioners in assessing and training Arousal levels in those regions identified by the trainee's individual brain phenotype.

Scott's development and continued enhancements to his BrainPaint platform provide the ability to more easily identify individual arousal levels from reported symptoms and behavioral manifestations. The computerized evaluation, incorporated into the BrainPaint software includes the 90-question Symptoms Checklist 90 – Revised that can be completed by the trainer and trainee in approximately 30-minutes. With children, the trainer and trainee's parents complete the evaluation, with the child present. Once the evaluation questions are answered, the system produces brain-training protocol suggestions specific to each individual's phenotype, and brain-training can commence immediately. We propose that a trained school/district level behavioral interventionist can easily implement the BrainPaint evaluation in a sub-clinical setting. This model was tested in the Juneau School district in a 2 year grant aimed at reducing suicides in the school in 2010. The school eliminated suicides for the entire duration of their use of BrainPaint.

BrainPaint's automated production of individualized training protocol sugestions eliminates the skills/knowledge requirements of most NFBT systems. Nearly all childhood brain-phenotypes are trained at two sites along the Sensory Motor Strip with the Brainpaint system, with demonstrated equal efficacy to more complex 19-site NFBT training (Keith et al, 2015). This feature enables much easier technical administration of brain-training, reducing much of the complexity of NFBT to pasting sensors to the trainee's scalp and ears, and coaching them to train their brains.

Scott also had the foresight to include several behavioral and psychiatric evaluation tools within the Brainpaint platform that have great utility in demonstrating, to the client, and in supporting research, positive gains of neurofeedback. These tools are also helpful in determining appropriate training termination points, in that they will identify when a client plateau's in their training. The BrainPaint system includes a Continuous Performance Test (CPT) that reliably assesses attention, focus, and impulse control. BrainPaint's CPT can be used pre-during-and post training. For evaluation and research, we recommend the CPT every 5-10 sessions.

BrainPaint also includes an automated in-session and between-session evaluation, helpful in identifying overzealous or underzealous training protocols, able to make immediate changes to training intensities, on-the-fly. Session-by-session tools to evaluate significant negative effects of neurofeedback which, when appropriate, offer the opportunity to further enhance the training protocol, reducing any identified negative effects. Finally, all clinical and non-clinical trainers will appreciate the semi-automatic production of treatment goals. Scott has developed and included a list of several hundred phenotype related behavioral goals that can be used as is, or adapted on-the-fly for each client. Goal setting assists the neurofeedback process by providing specific behavioral measurements that the client can report improvements/declines in their next session. As progress towards each goal moves towards attainment, trainer and trainee can identify further goals that might be achieved through additional training, or move towards termination of the current cycle of NFBT.

Scott's BrainPaint system is likely one of the more widely used neurofeedback systems, and as previously discussed, is the only automated NFBT system with demonstrated efficacy in both research and clinical settings. Though little research has been conducted in the broader scope of brain-phenotype directed training, Keith et al (2015) demonstrated that this system was equally effective in both assessing and training in a population of addicted individuals with co-occurring ADHD symptoms.

We have used BrainPaint in clinical and non-clinical settings to assess and train over 200 individuals, from nearly all of the eleven known brain-phenotypes. ADHD symptoms are the predominant issues in our child and adolescent clients, while anxiety, depression, and addiction predominate our adult clients. Our clients typically experience the reduction in symptomology in the first few sessions, congruent with Scott's reporting, with 80-85% symptom reduction occurring between sessions 20-40. Congruent with McReynolds et al (2017) reporting, our clients report that symptom reduction continues past termination of NFBT, which leads us to believe that near-complete symptom reduction is possible for nearly all mental health disorders when phenotype based NFBT is administered.

Sub-clinical application of Neurofeedback

Currently, there is no licensing requirement to perform neurofeedback, and is regulated under the scope-of-practice of state-licensing boards. As a behavioral intervention, it can be learned and implemented by a broad scope of current school/district level behavioral interventionists. There is a national certification board that reviews applicant's experience and education. Certification is available at two levels, technician, and therapist, requires 36-hours of CEU's in specific areas of knowledge pertinent to the field, and clinical supervision (BCIA.org). BrainPaint provides a ready-to use and implement system on a leased basis, providing great flexibility for the development and maintenance of a cost-effective behavioral intervention program. Trainers are provided a System and Operations manual that can typically be completed in 10-hours or less, and BrainPaint conducts a weekly support webinar attended by BrainPaint trainers worldwide.

Conclusion

We propose that Automated Neurofeedback Brain-training systems have evolved both towards practical application and demonstrated efficacy and safety to further explore their use as a primary behavioral intervention in sub-clinical settings, specifically school/district level brain-training labs. The BrainPaint automated system reduces training requirements, purchase of complex NFBT assessment and training systems, and provides a ready-to-use NFBT system with wide applicability in clinical and subclinical settings. Its system includes tools that can, and should be used in evaluating a phenotype approach to NFBT, and can be implemented easily, affordably, and safely.

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