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Automated Neurofeedback Brain-training as a Primary Addiction 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 that significantly challenge recovery from addictive disorders, 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 alleviating symptoms of ADHD, depression, PTSD, insomnia and many other neurological conditions that co-occur with addicted populations. Barriers to broad-based implementation 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 addictive disorders as well as many other co-occurring psychophysiological symptoms. These systems decrease the cost of brain-training significantly, reduce the training and experience requirements for brain-trainers, and will increase recovery potential in nearly all addiction treatment models. The aim of this report is to illuminate the broad understandings of automated neurofeedback brain-training as an essential primary intervention in addictions treatment.

Introduction

Addictive disorders are marked by cognitive, behavioral, and physiological impairments with an accompanied dysregulation in brain circuitry that may continue well beyond initial abstinence into the months and years of early recovery. Neuro-dysregulation models are the target of all psychopharmacological research and interventions. Despite increased focus on producing more effective psychopharmacological interventions, treatment of addictive disorders has remained challenging both at the research and clinical level. Traditional treatment models combining bio-psycho-social-spiritual rehabilitation yield poor results, with 65-70% of those completing treatment relapsing within the first 12-months after treatment (McKay, Atterman, Rutherford, Cacciola, &McLellan,1999). One of the most challenging aspects in the addiction recovery field is the presence and treatment of the symptoms of other disorders that co-occur with addictive disorders such as ADHD, Anxiety, Depression, Insomnia, and PTSD.

Neuro-imaging and quantitative Electroencephalograph (qEEG) Brain-mapping research over the past three-decades has produced identifiable patterns of electrical-brain waves, brain-phenotypes, that differentiate those with addictive disorders from normal controls. Analysis of hundred's of thousands of qEEG's and neuro-imaging results have 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 over-arousal, under-arousal, or instability. (Gunklelman & Cripe, 2008; Amen, 2015). The most current Brain-phenotype model for addictions arises out of Amen's extensive and broad-ranged neuroimaging studies that describe implicated brain-region arousal levels. Amen's (2015) phenotype model identifies six brain-phenotypes, with their symptom/behavioral manifestations, and implicated brain-region related to addictive disorders. He also describes six similar phenotypes related to eating disorders. The extensive body of neuroimaging studies is revelatory for understanding the underlying neurological imbalances involved in addictive disorders, for predicting medication efficacy and especially for understanding the importance of neurofeedback as a primary intervention for addictive disorders.

Our purpose in this section 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.

Addiction Diagnosis:

Diagnosis of addictive disorders is typically conducted by licensed physicians, psychiatrists, social workers, and other appropriately trained and licensed mental health providers, typically with a bio-psycho-social-spiritual framework of assessment and treatment. Assessor's are guided by 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 rely on assessment of tolerance, withdrawal, and behavioral manifestations of an unhealthy relationship with the substance of choice. A significant proportion of addiction treatment populations also demonstrate co-occurring symptoms that are better described by other DSM-V diagnoses like ADHD, anxiety, depression, obsessive compulsive disorders, and insomnia, to name a few (McReynolds, Villalpando, & Britt, 2018, Volkow & Li, 2005).

Neuroimaging and qEEG studies provide evidence identifying the underlying etiology of addictive disorders, as well as frequently occurring symptoms related to other mental health disorders, 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 addictive symptoms. Neuro imaging and EEG Brain-mapping research over the past three-decades has produced advances in the 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 over-arousal, under-arousal, or instability. (Gunkleman & Cripe, 2008; Amen, 2015). Amen (2015) identifies six individual brain-phenotypes related to addictive disorders specifically (Table 1). Six corresponding phenotypes have been identified related to eating disorders. Further, seven phenotypes have been identified for ADHD, and seven phenotypes identified for Anxiety/Depression. There is considerable overlap between the addiction phenotypes, and phenotypes related to other mental health disorders. Identifying the individual brain-phenotype involved in addictive and other disorders, is a critical first step in predicting appropriate therapeutic interventions necessary for individualizing addiction recovery at the neurological level (Amen, Hanks, & Prunella, 2008).

Addiction Phenotypes

Type	Symptoms	Brain Region Involved
Compulsive Addicts	Over focused, worrying, trouble letting go of hurts	Increased Anterior Cingulate Gyrus (ACG)
Impulsive Addicts	Inattentive, impulsive, easily distracted	Low Prefrontal Cortex (PFC)
Impulsive/ Compulsive Addicts	Combination of types 1 and 2	High ACG plus low PFC
Sad or Emotional Addicts	Sad or depressed mood, winter blues, carbohydrate cravings, loss of interest, sleeps a lot, low energy, self medicates to improve mood	High limbic activity, low PFC
Anxious Addicts	Anxious, tense, nervous, predicts the worst, self-medicates to calm	High basal ganglia
Temporal Lobe Addicts	Temper problems, mood instability, memory problems, learning disabilities	Abnormal Temporal Lobe activity

Until recently, assessing brain-phenotypes for addictive 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 is obtained from 19-channels on the scalp concurrently, 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 measures 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 (qEEG), 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 as a primary addictions intervention.

A second form of assessing brain-phenotypes, psycho-physiological assessment, demonstrates equal efficacy in improving addiction recovery as well as decreasing ADHD symptoms (Keith, Rapgay, Theodore, Schwartz, & Ross, 2015) and other brain-phenotype imbalances (Ros, Baars, Lanius & Vuilleurnier, 2014; Ros et al, 2016). Psycho-physiological assessments more coherently identify both addictive and other co-occurring 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 addictions recovery. 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 clinical and sub-clinical addiction recovery settings.

Limbic-System Hijacking

In addictions, as well as PTSD, there is an unhealthy relationship between Alpha in our prefrontal cortex, and Theta in the Limbic System. Changes in the ratio of these brain waves are triggered by sensory memory inputs. Sensory memory systems record input throughout our life, some pleasant, some unpleasant. In times of trauma, some of those sensory memories can become linked to the limbic system memory, which is a much more biological memory. In addictions, the limbic system memory remembers how good it felt, how much relief was provided. In the case of PTSD, the limbic system, remembers how bad it felt.

When triggered, the limbic system memory activates the autonomic fight-or-flight response, showing up in brain waves as an escalation of Theta, the rhythm that largely drives the limbic system. Needing more energy to maintain this state of alert, the brain shifts (steals) energy from elsewhere. In the case of both addictions and PTSD, the brain steals energy from the pre-frontal cortex rhythm Alpha. One can imagine, that without sufficient Alpha prefrontally, that portion of the brain doesn't have sufficient energy to do it's job sufficiently. Some of the most important prefrontal left functions are cognition, impulse control, emotional regulation, and decision making. Prefrontal right functions include empathy, compassion, self-care.

This makes a lot of sense physiologically. The thalamus, the brains gatekeeper of sensory information, is very close to the limbic system, and very distant, relatively, to the prefrontal cortex. The limbic system gets the information first, and results in what has been called "limbic system hijacking." When we monitor this brain process with electroencephalograph (EEG) we see Theta taking control of the brain, draining energy from Alpha in the prefrontal cortex. Literally, the part of the brain we need for good recovery does not have the energy it needs to do its job. From the neurofeedback perspective, limbic system hijacking represents dysregulation of the brain-reward circuitry, and provides the basis for development of brain-training protocols specific to correcting this dysregulation, Alpha/Theta training.

Treatment for Addictions:

Substance abuse is an ongoing societal and treatment problem. While significant national resources have been committed to study and treat addictive disorders, there has been little significant improvement in treatment success rates. In the current treatment paradigm, over 70% of individuals relapse back into substance abuse within weeks or months of completion of addiction treatment (Mclellan, Lewis, Brien, & Kleber, 2000). Only 9.1% of those who have reported a lifetime history of a significant substance abuse disorder report having resolved it, either through spontaneous remission, through 12-step attendance, or through formalized substance abuse treatment (Kelly, Bergman, Hoeppner, & Vilsaint; Mclellan et al, 2000).

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 brain imbalances implicit in a broad range of mental health disorders, including addiction recovery. NFBT is safe, with the only reported common side effects of mild headaches and/or slight disorientation. Approximately 75-80% of brain-trainees successfully learn how to train their brain-waves, typically eliminating 80-85% of symptoms related to their brain phenotype (Shepard, 2008, Brainpaint,).

In addition to the arousal dysregulations identified in Amen's (2015) models related to ADHD, depression, and anxiety, addictive disorders exhibit a significant dysregulation between Theta, which drives the limbic system, and Alpha, which drives the pre-frontal cortex. Earliest positive results of neurofeedback in addiction studies focused on training the relationship between alpha and theta and led to wider-spread us of an eyes-closed alpha/theta training (Sokhadze, 2008). Peniston and Kulkosky (1989) conducted the first randomized and controlled study of alcoholics treated with alpha-theta brain training. What we now call the Peniston protocol demonstrated significant improvements in reduction of depression, increase in treatment retention, stabilization of the stress indexing beta-endorphins, more sustained relapse prevention, improvements in psychological adjustment measures (Peniston & Kulkosky, 1989, 1990). Significantly, the experimental group exhibited 80% sobriety rate at the 1-year follow up. These results have been replicated in multiple studies (Sokhadze, 2008).

Bill Scott, an earlier neurofeedback pioneer, furthered development of the Peniston protocol. His early work recognized that training phenotype dysregulations associated with ADHD, depression, and anxiety concurrently with alpha-theta training would enhancing overall training efficacy in addicted populations. Scott's (Scott, Kaiser, Othmer, & Sideroff, 2005) study confirmed his hypothesis, demonstrating a 44% increase in program retention, 67% decrease in against-medical-advice departures, and 77% success rate 18-months post-study. His application of beta/theta and sensory motor training protocols in addition to alpha-theta training are now known as the Scott-Kaiser modification to the Peniston Protocol (Sokhadze et al, 2008). Scott et al's (2005) application of the protocol of the application named after him has been replicated 7-times (DeBeus, Prinzel, Ryder-Cook & Allen, 2001; Burkett, Cummins, Dickson, &Skolnick, 2005; Narimani & Rajabi, 2011; Dehghani-Arani, Rostami, & Nadali, 2013; Keith et al, 2015; Rostami & Dehghani-Arani, 2015; Hashemian, 2015).

More recent developments in phenotype models demonstrate regional arousal levels that include the previously identified addiction 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 overzealous brain-training. Nearly all previous positive studies demonstrating NFBT's efficacy in supporting addiction recovery 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 suggestions 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 under zealous 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 (2018) 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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