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Aim and Scope

NeuroRegulation is a peer-reviewed journal providing an integrated, multidisciplinary perspective on clinically relevant research, treatment, and public policy for neurofeedback, neuroregulation, and neurotherapy. The journal reviews important findings in clinical neurotherapy, biofeedback, and electroencephalography for use in assessing baselines and outcomes of various procedures. The journal draws from expertise inside and outside of the International Society for Neurofeedback and Research to deliver material which integrates the diverse aspects of the field. Instructions for submissions and Author Guidelines can be found on the journal website (http://www.neuroregulation.org).

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***Address correspondence to**: Rex L. Cannon, PhD, BCN, Neurogifted, 10151 Enterprise Center Blvd, Ste 207, Boynton Beach, FL 33437, USA. Email: rcannonphd@gmail.com

Welcome to *NeuroRegulation*, Volume 3, Number 4. We wish to thank all students, researchers and clinicians who submitted and presented at this year's annual conference in Orlando. It was a pleasure to hear the presentations, and we encourage presenters to take the next step and write up their studies and submit their data to *NeuroRegulation*.

In the current issue authors utilize a variety of novel techniques and report interesting findings. Erik Peper, Shannon Lee, Richard Harvey, and I-Mei Lin present concepts associated with academic performance and methods for improvement. Mark Johnson, Eugenia Bodenhamer-Davis, and Michael Gates present a case series detailing neuromodulation techniques improving symptoms of tinnitus. Additionally, the 2016 ISNR annual conference abstracts are presented in this issue. I had the opportunity to talk with each of the student poster presenters. It was a pleasure to engage these individuals, and I thank them for the opportunity to learn about their projects.

NeuroRegulation thanks these authors for their valuable contributions to the scientific literature for neurofeedback and quantitative EEG. We strive for high quality and interesting empirical topics. We encourage the members of ISNR and other biofeedback and neuroscience disciplines to consider publishing with us. It is important to stress that publication of case reports is always useful in furthering the advancement of an intervention for both clinical and normative functioning. Thus, we encourage all individuals practicing neurofeedback to submit case studies! We thank you for reading *NeuroRegulation*!

Rex L. Cannon, PhD, BCN
Editor-in-Chief
Email: rcannonphd@gmail.com

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Breathing and Math Performance: Implications for Performance and Neurotherapy

Erik Peper[1], Shannon Lee[1], Richard Harvey[1], and I-Mei Lin[2]

[1] Institute for Holistic Health Studies/Department of Health Education, San Francisco State University, San Francisco, California, USA
[2] Department of Psychology, College of Humanities and Social Sciences, Kaohsiung Medical University, Taiwan

Abstract

This report of findings describes students' self-reported difficulty and anxiety during test taking and the effect of deliberate gasping or diaphragmatic breathing on the ability to solve math problems. During the evaluation of an experiential classroom activity, 103 university students filled out a short questionnaire about performance anxiety and blanking out when taking exams. Then, they were asked to solve math problems while either gasping or slow diaphragmatic breathing. Students reported a high frequency of blanking out (mean = 5.3), difficulty during exams (mean = 6.7), and difficulty with math (mean = 6.2) on a scale from 1 (never) to 10 (always). The students reported significantly more difficulty in solving math problems when gasping than during slow breathing ($p < .01$) and significantly more anxiety during gasping ($p < .01$) than during slow breathing ($p < .01$) when solving math problems. Most students were completely surprised how their breathing patterns affected their ability to perform a simple math test. Numerous students have reported that when they implemented this slow breathing approach at the moment they felt anxiety, their anxiety slightly decreased and they would perform better on exams. Included are comments to improve study habits, memory consolidation, and how to incorporate somatic feedback of breathing patterns into learning and training within other settings such as during neurotherapy.

Keywords: gasping; math performance; anxiety; diaphragmatic breathing; learning

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***Address correspondence to**: Erik Peper, PhD, Institute for Holistic Health Studies/Department of Health Education, San Francisco State University, 1600 Holloway Avenue, San Francisco, CA 94132, USA. Email: epeper@sfsu.edu

Edited by:
Rex L. Cannon, PhD, Neurogifted, Boynton Beach, Florida, USA

Reviewed by:
Wesley D. Center, PhD, Liberty University, Lynchburg, Virginia, USA
Nancy L. Wigton, PhD, Grand Canyon University, Phoenix, Arizona, USA

Introduction

Students at all levels of education experience test anxiety (Cale, Fowler, & Rempfer, 2012; Tatum, Lundervold, & Ament, 2006). Test anxiety is a type of performance anxiety that is "the negative affect, worry, physiological arousal, and behavioral responses that accompany concern about failure or lack of competence on an exam or similar evaluative situation" (Matthews, Zeidner, & Roberts, 2006, p. 175). Students often report blanking out on retrieving memorized information when taking an exam for which they have studied (Arnsten, Mazure, & Sinha, 2012). And, fear and poor study habits often contribute to forgetting or inability to retrieve the material (Cassady & Johnson, 2002; Fitkov-Norris & Yeghiazarian, 2013).

Study habits can contribute to performance difficulty and observations of study behaviors suggests most students listen to music, respond to text messages, or monitor social network sites such as Facebook, Twitter, Instagram, or Pinterest while studying (David, Kim, Brickman, Ran, & Curtis, 2015; Swingle, 2016). Other students study materials for one class and then immediately shift to materials from another class. While at home they study while sitting or lying on their bed and continue to check their cell phones (Sellgren, 2016).

At other times, students have internalized the cultural or familial beliefs that math is difficult and they do not have the aptitude for this material (e.g., your mother was also poor in math material; Cherif, Movahedzadeh, Adams, & Dunning, 2013). These beliefs and dysfunctional study habits limit learning (Neal, Wood, & Drolet, 2013). Yet, these beliefs can be transformed. For example, when students are asked to write about a past experience where they successfully coped with a challenge, they reported an increase in self-efficacy (Nelson & Knight, 2010). And, high academic self-efficacy is correlated with lower levels of test anxiety and higher academic performance (Barrows, Dunn, & Lloyd, 2013; Nelson & Knight, 2010; Nie, Lau, & Liau, 2011).

Fear or performance anxiety may cause blanking out on an exam or class presentation (Hodges, 2015; Spielberger, Anton, & Bedell, 2015). At that moment of the demanded performance, the brain may be flooded with thoughts such as “I can’t do it,” or “I will fail,” or “I used to know this, but…,” or “What will people think?” The body responds with a defense reaction as if they were being threatened for survival. The emotional reactivity and anxiety overwhelms cognition, resulting in an automatic ‘freeze’ response of breath-holding or very shallow breathing. At that moment, the person blanks out (Hagenaars, Oitzl, & Roelofs, 2014; Lin, Ji, Peper, & Chang, 2014; Sink et al., 2013; von der Embse, Barterian, & Segool, 2013).

In a previous report involving a class of 95 college students, 90% reported feeling stressed out during an exam that included inability to recall (59%), experiencing a blackout (58%), performing worse under stress than in practice (58%), and difficulty processing information (42%). Students who experience feeling stressed out compared to those who did not also reported higher anxiety scores and psychosomatic symptoms (Lin et al., 2014). People who reported feeling stressed out on a daily basis tend to breathe more thoracically and shallowly (e.g., shorter exhalation), have increased sympathetic activation, decreased parasympathetic activation, and decreased total heart rate variability (HRV; Lin et al., 2014; Valoriani et al., 2014).

When students engage in chest (thoracic) breathing during exams they also report feelings of tension and anxiety (Timmons, 1994) which may increase test anxiety. At times, students may appear dazed or stunned, like a ‘deer in the headlights’ and freeze when looking at exam questions or when attempting to respond to instructors’ questions. In our evaluations of classroom activities, when we coach students to breathe slowly and diaphragmatically, they may counteract the freezing response and perform better, often retrieving what they previously had studied. Although many physiological markers such as increased heart rate and skin conductance do not directly correlate with math anxiety (Dew, Galassi, & Galassi, 1984), higher HRV has been correlated with lower anxiety scores and with better performance (shorter times) in completing anagram tests (Holroyd, Westbrook, & Badhorn, 1978). Increases in HRV has been associated with slower breathing and sympathetic-parasympathetic balance (Lehrer & Gevirtz, 2014; Shaffer, McCraty, & Zerr, 2014; Xhyheri, Manfrini, Mazzolini, Pizzi, & Bugiardini, 2012). This evaluation of classroom activities involves reports of students’ difficulty and anxiety during test taking and the effect of deliberate gasping to simulate a freezing response or diaphragmatic breathing to simulate a calming response when solving a math problem.

Method

Subjects

The report evaluated a classroom activity related to breathing. Whereas the information in this report was anonymous the class room roster included 103 university students; average age 24 years (*SD* = 7.1 years). As an evaluation of a classroom activity, this report of findings was exempted from Institutional Review Board oversight.

Procedure

While sitting in a classroom, students filled out a short questionnaire rating their level of experiencing performance difficulty, anxiety, and blanking out when taking exams. Then they were taught and practiced the following two different breathing patterns (gasping or slow breathing) when they heard the onset of a question.

Gasping when hearing onset of the question.
The moment you hear the beginning of the question, gasp as if shocked or surprised. React just as quickly and automatically as if seeing a car racing towards you. At that moment, you do not think, you don’t spend time identifying the car or look at who is driving. You reflexively and automatically jump back to the curb.

Let’s practice. Remember the moment you hear the onset of my voice asking the question, “What day was it yesterday?” gasp as if startled or afraid.

During the first few practices, many students waited until they have heard the whole phrase before they gasp. The teacher then explains:

If you reacted like that waiting till the end to gasp, it would be similar to seeing a car approaching you *and just staying in place instead of jumping out of the way.*

The practice was repeated until the gasping, freezing response becomes more automatic.

Slow breathing when hearing the onset of the question.
The moment you hear the beginning of the question which you are to answer, breathe slowly inward and then exhale slowly. During the first few practices, many students waited till they have heard the whole phrase until they breathe slowly. Again, start breathing the moment you hear the onset of the question.

The practice is repeated until it became more automatic. After students have practiced and role rehearsed the two different breathing patterns, the students sitting in the left side of the classroom were asked to gasp while the students sitting in the right side of the class room were asked to take a slow diaphragmatic breath when they heard the onset of the math question such as “Subtract 7 from 93.” Then they were asked to breathe in the opposite pattern, and a similar math question was asked.

When finished, they rated the difficulty in solving the math problem from 1 (easy) to 10 (impossible) as well as their levels of anxiety while performing the math problem from 1 (none) to 10 (severe). In addition, the breathing patterns of a few representative students were recorded to observe their breathing pattern when they performed the task.

Results

When taking exams, the students reported blanking out (mean = 5.3; *SD* = 2.2), difficulty during exams (mean = 6.7; *SD* = 2.5), and difficulty with math (mean = 6.2; *SD* = 2.5) on a scale from 1 (never) to 10 (always) as shown in Figure 1.

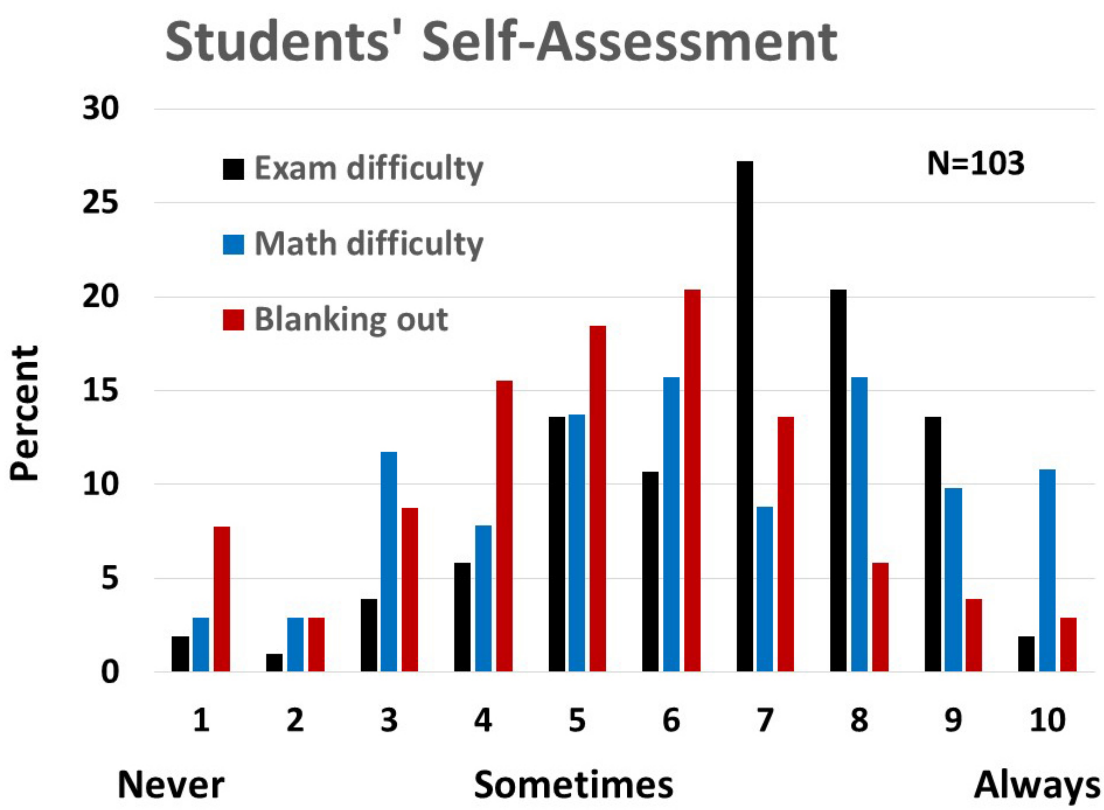

Figure 1. Self-reported difficulty in taking exams, math and blanking out.

The students reported more difficulty in solving math problems ($p < .01$) when gasping (mean = 6.2) than during slow breathing (mean = 4.9) and an increase in self-assessed anxiety ($p < .01$) during gasping (mean = 5.2) than during slow breathing (mean = 4.0) when solving the math problem as shown in Figure 2.

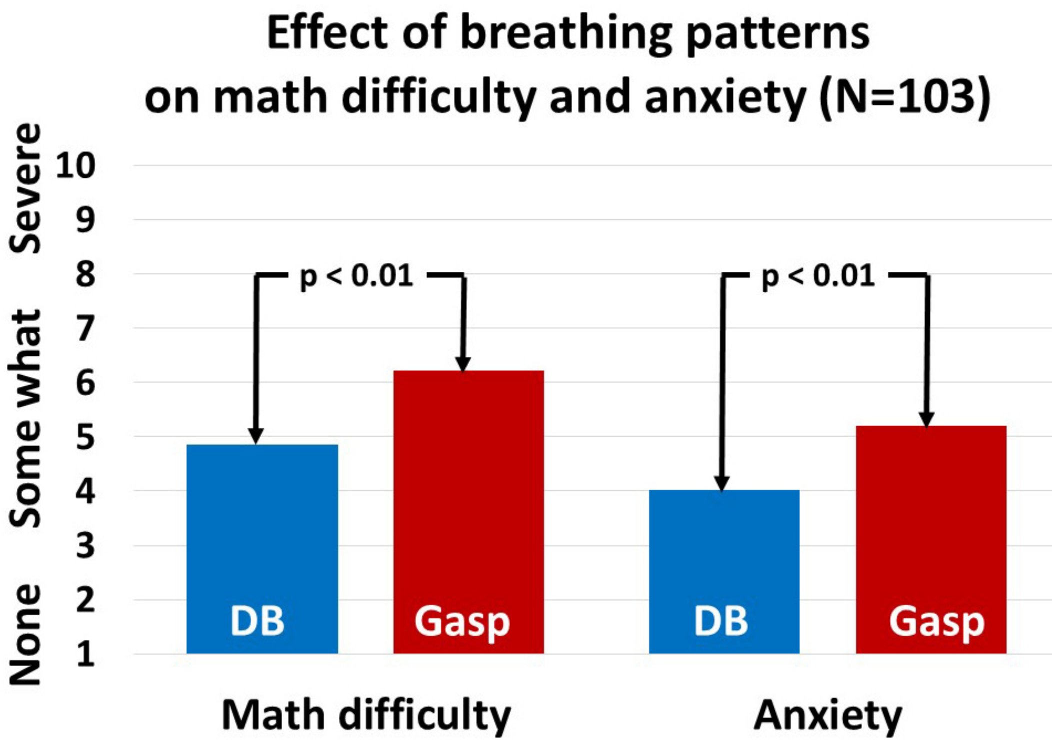

Figure 2. The effect of breathing style on math performance. Diaphragmatic breathing significantly increased math performance and decreased anxiety.

The correlation analysis showed that a history of blanking out was correlated with test anxiety ($r = 0.4$) and math difficulty was high correlated with anxiety during gasping or slow diaphragmatic breathing ($r = 0.60$).

During class, a few students volunteered for physiological recordings of their breathing patterns. A representative physiological recording of gasping and slow diaphragmatic breathing at the onset of hearing the math problem is shown in Figures 3 and 4.

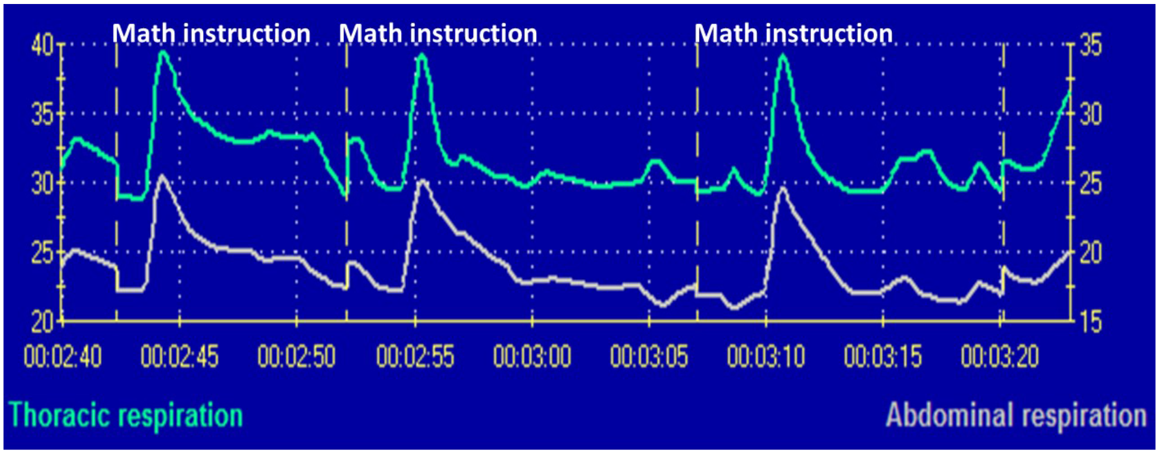

Figure 3. Representative thoracic and abdominal respiration trace as the participant gasps when hearing the onset of the math problem.

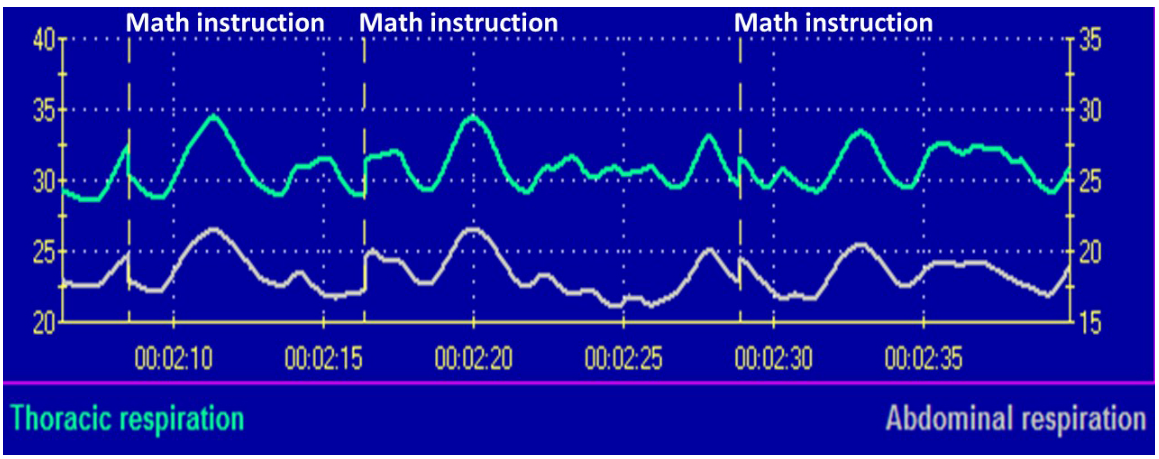

Figure 4. Representative thoracic and abdominal respiration trace as the participant breaths slower when hearing the onset of the math problem.

Discussion

Many students were totally surprised how their breathing patterns affected their ability to perform a simple math test. Some reported that they completely "blanked out" and could not perform the simple math calculation. Simulating a gasping condition as compared to slow diaphragmatic breathing condition is a useful experiential exercise to demonstrate that breathing patterns can significantly affect performance and anxiety. As one 20-year-old college student said, *"When I gasped, my mind went blank and I could not do the subtraction. When I breathed slowly, I had no problem doing the subtractions. I never realized that breathing had such a big effect upon my performance."*

The physiological recordings from class volunteers showed that some students did not totally master slow diaphragmatic breathing. Nevertheless, by inhibiting gasping and breathing more diaphragmatically, they improved their performance. The change in performance is most likely due to the change in breathing patterns and not to different focus of attention, since in both conditions the students had to attend to their breathing pattern. Most likely, a gasping pattern of breathing triggered the defense reaction which activated the sympathetic-adrenal system which in turn triggered the fight/flight response and reduced cognitive functioning (Porges, 2009).

Guiding students through this classroom exercise not only showed how a gasping breathing pattern made them perform worse but also increased anxiety. More importantly, the students learned an intervention to counter the automatic effects of gasping and anxiety by substituting slow diaphragmatic breathing for gasping. Anecdotally, students have reported that when they implemented this slow breathing approach at the moment they felt anxiety, their anxiety slightly decreased and they performed better on exams. Thus, when you are stressed and blank out during exams, taking a slow diaphragmatic breath may improve performance.

To improve performance on exams, it is also useful to condition a slow breathing with learning the material. For example, students can implement a ritual of taking three slow breaths when they begin to study and whenever they focus on new material. Then, when they take the exam and do not remember, or are anxious, they perform the same ritual of slow breathing to allow easier retrieval from memory. Obviously, this ritualistic breath-conditioning approach is only useful if the students have studied the course materials effectively (suggestions for how to study effectively, see Peper, 2016). By taking charge of study habits and practicing slower breathing during studying and test taking, students reported that they experienced significant improvements in learning, remembering, accessing, and processing information.

Potential Application During Neurofeedback Therapy

Breathing patterns can significantly affect cognitive functioning and should be accounted for in neurofeedback therapy. Researchers have reported that neurofeedback improved cognitive functioning among children and have found large effect sizes for inattention and impulsivity and medium effect sizes for hyperactivity (Arns, Heinrich, & Strehl, 2014); however, neurofeedback usually requires 30 to 40 sessions or more to achieve success (Arns, Heinrich, & Strehl, 2014). It is possible that respiratory dysfunction such as breath-holding, slight gasping, or hyperventilation (the patterns associated with a fear/freeze reaction) contributes to lowering cognitive performance because gasping or hyperventilation is associated with an increase in theta electroencephalography (EEG) and a decrease in cortical blood flow (Fried, 1986; Konishi, 1987). Given that breathing affects the EEG, we recommend first to normalize and improve respiratory patterns, then observe whether breathing practice improves behavior and performance before beginning 30 to 40 sessions of neurofeedack training.

Training in Breath Awareness

The general breathing training consists of observing the dysfunctional breathing pattern, having the participant exaggerate the dysfunctional pattern (e.g., gasping) to experience if “freezing” evokes the symptom. Then, teach the “healthy breathing” response pattern that does not evoke the symptom. After mastering the healthy breathing response, it is recommended to teach the participant to become aware of the dysfunctional breathing pattern, interrupt the dysfunctional pattern, and substitute the functional pattern. The purpose is to facilitate self-control and mastery which increases hope and shifts illness beliefs. The mechanism is similar to that of cognitive therapy for treatment of depression where the participant learns to identify dysfunction thought patterns. It also provides a “biological” model of how their symptoms are generated (e.g., the triggering of the alarm reaction shift blood flow) and how to take control. We use the following sequence to teach breath awareness.

Observe the pattern. The therapist observes the physiological recordings and somatic patterns of the participant when he/she performs a task (e.g., math subtraction).

Identify the dysfunctional pattern. The dysfunctional anticipatory patterns and response patterns are identified such as a 1 or 2 μV increase in trapezius surface electromyography tension, subtle gasping, or breath holding, looking away, or slouching, or collapsing in defeat.

Exaggerate the dysfunctional pattern. The participant practices and performs the extreme exaggeration of the dysfunctional pattern. After mastery, have the participant perform the exaggerated pattern at the same time he/she performs the task (e.g., subtraction). In most cases, their cognitive performance decreases or their symptoms increase. If the symptom is aggravated, point out that this covert dysfunctional body pattern contributes to increasing the symptom. Thus, if they can become aware of this pattern, anticipate when it would occur, and substitute a healthy pattern, then they may be able to reduce their dysfunction.

Teach a functional pattern. Awareness of the dysfunctional pattern often increases anxiety and symptoms. Thus, the participant also needs to be taught an alternative health-promoting pattern. Have them practice the health-promoting pattern such as effortless breathing. Then ask them to perform the task while performing the health-promoting pattern. In many cases, they observe that they can do the task significantly better or their symptoms are reduced. Repeat the same process with their exaggerated dysfunctional pattern.

Teach how to implement the new pattern into daily activities at home and at work. If they experience a difference in performance or symptoms, teach them to become aware during the day of situations that would trigger the dysfunctional pattern and substitute the functional pattern. Each time they catch themselves that their body has responded in this dysfunctional pattern, they interrupt the pattern and substitute the newly learned functional pattern.

Conclusion

Teaching awareness of covert dysfunctional patterns (e.g., gasping breath) and substituting functional patterns (e.g., slow effortless breathing) may be the basis for a useful clinical intervention to reduce anxiety symptoms and improve health. It is similar to how Whatmore and Kohli (1968) taught patients to reduce their dysponesis (misdirected muscle efforts) and demonstrated significant improvement across numerous disorders ranging from depression or hypertension to chronic pain. Similarly, Stroebel (1983) developed the quieting reflex and demonstrated significant improvement for primary Raynaud's disease, classic migraines, and common migraines after a 2-year follow-up (Ford, 1983). While Dahl, Brorson, and Melin (1992) showed significant reduction in seizures at the 8-year follow-up in children with refractory epileptic seizures.

This report of findings from an evaluation of a classroom activity has some limitations. For example, even though the data was analyzed in a systematic fashion, the findings may not be considered research because the report may not be generalizable beyond the evaluation of a classroom activity. The report is intended to serve as a description of activities that may be further investigated in various research settings where other tools such as random assignment to groups would be employed to extend knowledge beyond a cross-sectional snapshot of a classroom activity.

When participants learn functional health-promoting skills and apply this into their daily lives, their health and performance improves. Thus, when students take charge of their study habits and practice slower breathing during studying and test taking as compared to gasping or breath holding, they may experience improvements in learning, remembering, accessing, and processing information. We recommend that these slow breathing skills are taught to improve health and productivity.

Author Note

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Neuromodulation Methods to Suppress Tinnitus in Somatosensory Subtypes: A Case Series

Mark L. Johnson, Eugenia Bodenhamer-Davis, and Michael S. Gates

University of North Texas, Denton, Texas, USA

Abstract

Background: Some initial evidence suggests that neurofeedback and electrical stimulation therapy modalities may suppress tinnitus in some individuals. This study retroactively examined a case series of adults treated for tinnitus using varied neuromodulatory interventions, to explain relationships between etiological factors for tinnitus and differential responses to these interventions. **Methods:** Eight tinnitus client records were used to examine the efficacy of several different neuromodulation modalities used to treat tinnitus, which included neurofeedback, cranial electrotherapy stimulation (CES), and microcurrent electrical therapy (MET). Pre- and posttreatment measures (BAI, BDI, BHS, PSQI, THI, and TSS) were then compared for changes related to treatment outcomes. **Results:** Paired-sample *t*-tests showed the Tinnitus Severity Scale (TSS) and the Tinnitus Handicap Inventory (THI) to be significantly different following treatment, with tinnitus severity subsiding and sleep quality improving. Discriminant function analysis using the TSS, THI, and PSQI (Pittsburgh Sleep Quality Index) difference scores correctly classified all (100%) participants in either the somatosensory or nonsomatosensory groups. **Conclusions:** Results of this small pilot study suggest that MET can improve tinnitus symptoms for individuals with a somatosensory form of the disorder in which tinnitus percept is unilateral or greater in degree on one side, fluctuates in intensity, and appears to involve musculoskeletal or central nervous system overarousal pathogenesis.

Keywords: tinnitus; microcurrent; Alpha-Stim

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***Address correspondence to**: Mark Johnson, 627 Capitola Ave #C, Capitola, CA 95010, USA. Email:markjohnson2@my.unt.edu

Edited by:
Rex L. Cannon, PhD, Neurogifted, Boynton Beach, Florida, USA

Reviewed by:
Rex L. Cannon, PhD, Neurogifted, Boynton Beach, Florida, USA
Randall Lyle, PhD, Mount Mercy University, Cedar Rapids, Iowa, USA

Introduction/Background

Tinnitus is a not a disease, but rather a vexing symptom in which a phantom sound is heard with no accompanying external source. Since tinnitus is a symptom that can be produced by numerous disorders and may have different causes and different pathophysiologies, searching for a single treatment for all forms of tinnitus could be futile (Møller, 1997). It has been suggested that the tinnitus percept may emerge from multiple, changing, overlapping subnetworks that can be affected by neuromodulatory activity (De Ridder et al., 2004). Thus, it has proven beneficial to identify individual functional subtypes of tinnitus that may respond to one or possibly a combination of treatments found to have some therapeutic efficacy.

Van de Heyning et al. (2007) described two major categories of tinnitus: objective tinnitus, caused by a real internal sound source inside the body and subjective tinnitus, an auditory phantom phenomenon caused by “a reorganization of the central auditory tract and auditory cortex, with a loss of suppression of neural activity” (p. 4). While Van de Heyning et al. give detailed causative variables for both objective and subjective forms of tinnitus, they suggest that subjective tinnitus primarily involves physiological, cochlear, phantom, central nervous system (CNS), and somatic variables.

Levine (2004) suggests that some subtypes of subjective tinnitus can result from multiple factors that synergistically produce the tinnitus symptoms. Factors such as pathological processes, certain classes of medications, psychosocial stress, sound exposure, or muscle activity related to head and neck maneuvers could all serve as "triggering factors" that can cause or can exacerbate symptomatic tinnitus.

Somatic Tinnitus Model

Clinical tinnitus has been linked to the somatosensory system (Levine, Abel, & Cheng, 2003) and to limbic/thalamic involvement (Leaver et al., 2010; Mühlau et al., 2005). Aside from the auditory sensory system, only the somatosensory system has been shown to be closely related to tinnitus (Levine, Nam, Oron, & Melcher, 2007). Human brain imaging studies have indicated that the neural generators for tinnitus might involve CNS as well as auditory and nonauditory pathways, in which movements and manipulations of certain upper extremities may increase (but usually not decrease) tinnitus severity (Simmons, Dambra, Lobarinas, Stocking, & Salvi, 2008). The contribution of nonauditory centers in the pathogenesis and regulation of tinnitus is reinforced by studies showing that many patients have somatic tinnitus in which movements and manipulations of the eyes, head, neck, jaw, and shoulder can modulate the loudness and pitch of their tinnitus (Simmons et al., 2008). Levine suggests that variations in tinnitus perception may have somatic influences (i.e., increased severity upon waking may be due to nocturnal bruxism, or increased severity several hours into the day may be due to somatic movements reactivating the tinnitus severity; tinnitus upon waking from a nap may be due to poor head and neck posture while napping, etc.). It is possible that in some cases auditory or neurological pathogenesis combines with a triggering factor such as a somatic variable to onset tinnitus symptoms.

Levine and colleagues found that approximately 80% of their patients with tinnitus could transiently modulate their tinnitus with isometric head, neck, and jaw contractions. Levine (1999) purports that somatic modulation seems to be a fundamental attribute of tinnitus and that "somatic modulation may also account for reports of controlling tinnitus with physical methods such as acupuncture, manipulation, or scalp electrical stimulation" (p. 7). Levine et al. (2007) suggest there is evidence that the somatic tinnitus subgroup is most likely to respond to somatosensory-based treatment modalities. Some forms of tinnitus may lack this somatic component and be less likely to respond to physiological interventions.

Central Nervous System Sensitivity Model of Tinnitus

Patients with medically unexplained disorders or with symptoms such as tinnitus, that do not possess a manifest organic basis, are challenges for healthcare practitioners. Yunus (2009) was among the first to reconceptualize the traditional disease-illness model and subsume symptomatically and diagnostically overlapping disorders under the unifying label of "central sensitivity disorders." According to Yunus, "central sensitivity syndromes (CSS) comprise a group of disorders that have overlapping clinical features, lack structural pathology, are based on neuroendocrine-immune dysfunction, and are bound by a common pathophysiological mechanism of central sensitization (CS). The common clinical features of these diseases include pain, fatigue, disturbed sleep, and hypersensitivity to various stimuli, including pain (e.g., pressure, heat, and electric) and environment (e.g., noise, stress, and chemicals). The Yunus criteria for categorizing symptoms as CSS involve two components: mutual associations among symptoms and evidence of CNS sensitivity among symptom clusters included in members. Both components need to be satisfied for inclusion in the CSS family (p. 400). Thus, CSS examples include irritable bowel syndrome (IBS), fibromyalgia (FMS), myofascial pain syndrome (MPS), headache/migraine, and temporomandibular disorder (TMD). While tinnitus is not yet considered a CSS condition, there are strong associations between tinnitus and other somatoform disorders. Hiller, Janca, and Burke (1997) reported the results of an international study conducted by the World Health Organization (WHO) that indicated tinnitus was more frequent among patients with somatization disorder (42%) or hypochondriacal disorder (27%). Tinnitus was also observed to occur in greater frequency than numerous other symptoms considered common to somatoform disorders. Tinnitus was associated with anxiety, depression, and with symptoms indicative of autonomic arousal. Headache (46%), followed by rapid heart beating (34%), chest pain (29%), back pain (24%), and abdominal pain (22%) had the highest associations with tinnitus. Hiller et al. concluded that idiopathic tinnitus may be a somatoform symptom, that there may be substantial comorbidity among tinnitus and overlapping conditions, and that common mechanisms of arousal and somatic anxiety may link tinnitus with other forms of somatization, such as temporomandibular disorder (TMD).

Van de Heyning et al. indicated that “somatosensory modulation of the auditory system can be caused by influences emanating from, in particular, the jaw and masticatory muscles and from the neck” (p. 5). Wright and Bifano (1997) reported a much higher incidence of tinnitus among patients with temporomandibular disorder (TMD) compared to age-matched controls. They also found that TMD therapy improved tinnitus in 46–96% of their patients who had these coexisting symptoms.

Relationships Between Central Nervous System Overarousal, Chronic Pain, and Tinnitus

Given the strong association between somatization and tinnitus, it seems relevant to consider the relationship between pain and tinnitus. Similarities between tinnitus and phantom (missing limb) pain have brought attention to the role that the CNS may play in these conditions (De Ridder, Elgoyhen, Romo, & Langguth, 2011; Saunders, 2007). Møller (1997) compared chronic pain mechanisms with that of tinnitus and concluded there is strong evidence that chronic pain and certain types of tinnitus are similar in that each appears to have a peripheral etiology but may actually be caused by central nervous system pathophysiology.

Hiller et al. (1997) hypothesized that tinnitus and somatization might be linked through common mechanisms of arousal and somatic anxiety (p. 613). Sleep bruxism has been construed as an oromotor manifestation of microarousal in which anxiety is an underlying component. Bracha, Ralston, Williams, Yamashita, and Bracha (2005) suggest that clenching-grinding spectrum behaviors be construed in a neuroevolutionary perspective as fear-circuitry disorders linked to the activation of fear circuits and anxiety and that clenching-grinding, sleep bruxism, myofascial pain, craniomaxillofacial pain, musculoskeletal pain, temporomandibular disorders, crofacial pain, sleep bruxism, fibromyalgia/chronic fatigue spectrum disorders are all linked—possibly all or most indicating persistent fear-circuitry activation. These researchers noted the risk factors for sleep bruxism, which has been associated with increased tinnitus severity, include anxiety, a highly stressful life, excessive caffeine consumption, hypnopompic/hypnagogic imagery, and various sleep disorders. They also noted that prolonged jaw clenching has been clinically observed among developmentally disabled populations during episodes of fear or rage. Suggestive of the role of anxiety and stress in tinnitus as well as the possible effectiveness of addressing physiological or somatosensory variables in treatment of tinnitus is the fact that Nakai et al. (2008) reported the successful treatment of a deaf patient’s tinnitus using an autogenic relaxation training method.

Treatment Response of Somatosensory Subgroup of Tinnitus

Levine et al. (2007) identified tinnitus subgroups that may respond well to somatosensory-based treatment modalities. “Somatosensory tinnitus” refers to tinnitus that can be activated through disorders of the upper cervical region and head. They summarized studies that included cervical manipulation, acupuncture, trigger point injections, TMD therapy, and electrical stimulation of the scalp and auricle. They reported that the characteristics of responders to cervical manipulation are largely unknown. Individuals likely to respond to acupuncture were characterized by symmetric hearing and tinnitus lateralized mainly to one side. This combination of symmetrical hearing and unilateral tinnitus suggests it is unlikely this condition is solely auditory in origin. An intervention using trigger point injections at cervical and jaw muscle locations transiently abolished tinnitus. This was found more often for patients with higher cervical tension on their tinnitus side. Wright and Bifano (1997) found that many times TMD therapy improved or resolved tinnitus symptoms in patients with coexisting TMD and tinnitus and developed a list of questions that could help practitioners determine which patients were likely to benefit from this approach. Most patients who responded positively to this treatment had normal hearing and their tinnitus was ipsilateral to their TMD. Levine also summarized three studies using electrical stimulation of the scalp and auricle in which the best responders shared characteristics of symmetric hearing and unilateral tinnitus, again suggesting somatically-induced tinnitus.

Neurophysiological and Electrophysiological Models of Tinnitus

Saunders (2007) noted that a neurophysiological model of tinnitus accredited to Jastreboff (1990) considers additional central nervous system (CNS) contributions. Many cases of tinnitus occur with hearing loss due to intense sound exposure, aging factors, or from exposure to certain drug agents (salicylates, aminoglycoside antibiotics, quinine, or cisplatin; König, Schaette, Kempter, & Gross, 2006; Sindhusake, et al., 2004). Anatomic alterations due to peripheral injury may result in maladaptive neuroplastic alterations. Saunders suggests that tinnitus may be the result of maladaptive alterations in brain neuroplasticity: “One theory proposes that these changes upset the balance between excitatory and inhibitory brain processes with the result being neural hyperactivity" (p. 314).

A recent study showed that tinnitus is much more frequently reported in patients who are electromagnetically hypersensitive when compared to controls (Landgrebe, Frick, Hauser, Hajak, & Langguth, 2009); and Vernon (1987) summarized attempts, primarily in the 1980s, to employ different types of electrical administration at a variety of cranial locations to suppress tinnitus. Many of these attempts involved surgically implanted electrodes. There have also been a small number of studies using noninvasive methods to apply electrical stimulation to treat tinnitus, one of which involved a transcutaneous headband device that had a small degree of success (Dobie, Hoberg, & Rees, 1986).

Saunders states that tinnitus should be viewed as a complex constellation of neural changes in which no one brain location is implicated, and this may explain why it is not amenable to any single treatment. In fact, studies have identified a number of specific alterations to brain regions and brain wave patterns during active tinnitus. Dohrmann, Weisz, Schlee, Hartman, and Elbert (2008) proposed that at least three neural network regions (temporal, frontal, and limbic) are involved in tinnitus. Citing electroencephalographic (EEG) studies, they noted that individuals with tinnitus abnormalities tend to exhibit increased delta band activity in the 1.5–4 Hz frequency range and reduced alpha band activity in the 8–12 Hz range. Weisz, Moratti, Meinzer, Dohrmann, and Elbert (2005) found this abnormal activity to be especially pronounced in right temporal and left frontal areas. Dohrmann et al. applied neurofeedback to 21 subjects (for ten 30-min sessions at frontal sites (C3, C4, FC1, and FC2) and found that patients who successfully modified their brain activity at these sites had the greatest reductions in their tinnitus. However, only the patients who successfully modified both alpha and delta frequency bands achieved the strongest relief.

Likewise, Kahlbrock and Weisz (2008) found that patients who were able to normalize their brain activity patterns achieved significant reductions in their tinnitus severity. Furthermore, significant reduction of delta (1.3–4.0 Hz) frequency band power was observed in temporal regions while residual inhibition occurred. "Delta activity is a characteristic oscillatory activity generated by deafferented/deprived neuronal networks. This implies that RI (residual inhibition) effects might reflect the transient reestablishment of balance between excitatory and inhibitory neuronal assemblies" (p. 1). These researchers concluded that the ability to decrease delta frequency amplitude and increase alpha frequency amplitude in temporal regions predicted lowered tinnitus volume.

Weiler, Brill, Tachiki, and Schneider (2002) demonstrated that brainwave biofeedback (neurofeedback) successfully disrupted a woman's chronic bilateral tinnitus to a point where it occurred only occasionally. Treatment reduced delta and theta power and increased alpha band power. The success of this brainwave modification approach suggests that other neuromodulation methods might also be effective with tinnitus.

Cranial Electrotherapy Stimulation (CES)/ Microcurrent Electrical Therapy (MET)

The cranial electrotherapy stimulation (CES)/ microcurrent electrical therapy (MET) brain stimulation devices have been used to treat anxiety, depression, sleep, and pain. Mercola and Kirsch (1995) explain that "MET works because of its ability to stimulate cellular physiology and growth [and] correct application of MET to an injured site augments the endogenous current flow, allowing cells in the traumatized area to regain their capacitance. Resistance is reduced, thereby allowing bioelectricity to flow through and re-establish homeostasis. This process helps to initiate and perpetuate the many biochemical reactions that occur in healing" (p. 110). In an application of this MET mechanism, McMakin (1998), noting that "repeated experience of a sympathetic stress response will cause predictable tissue changes leading to tightening of the myofascia and muscle contracture and promoting formation of a trigger point" (p. 30), used microcurrent therapy delivered through graphite/vinyl gloves to significantly reduce myofascial pain in four of five chronic cervical pain patients.

In a 2006 unpublished dissertation, Richard Kennerly used quantitative electroencephalography (qEEG) to measure the effect of cranial electrotherapy stimulation (CES) on brainwave activity. He found that a single 30-min administration of CES treatment with the Alpha-Stim AID Cranial Electrotherapy Stimulator unit (Electromedical Products International) produced an increase in alpha relative power along with a concomitant decrease in both delta and beta relative power. These changes in pre- and post-qEEG relative power bands were consistent with the effects of CES reported in the literature, such as increased relaxation and decreased anxiety. These results also involved the same frequency bands targeted in the neurofeedback studies reported above that resulted in tinnitus improvements.

Engelberg and Bauer (1985) reported using the Alpha Stim 2000 microcurrent electrotherapy (MET) instrument to treat tinnitus and obtained symptom improvement in 82% of 33 ears of 20 subjects. Subjects received 1 to 17 treatments to the outer ear, with most receiving just one or two treatments. In most cases, electrical stimulation administered to 13 specific auricle points ipsilateral to the tinnitus resulted in amelioration of the tinnitus. The lasting effects of the improvements ranged from 20 minutes to 6 months. Most subjects reported the improvement lasted 3 days or less. The procedure was applied with the subject holding a ground in one hand ipsilateral to the tinnitus while the therapist stimulated a circular pattern of aurical points on the outer ear with a single microcurrent probe

The research cited above appears to provide strong support for neurophysiological and electrophysiological explanatory models of tinnitus as well as the involvement of CNS/sympathetic overarousal mechanisms. The preliminary research cited has demonstrated good success using electrotherapy stimulation (CES and MET) devices such as the Alpha-Stim instrument to affect the particular brainwave frequencies involved in tinnitus. In addition, these devices have proven effective for CNS overarousal and pain disorders, suggesting that CES and MET hold promise for the treatment of tinnitus, especially the somatosensory subtype.

Somatosensory Subtype

An ongoing review of relevant literature led to speculation that the tinnitus somatosensory subtype would be most likely to respond to treatment. The somatosensory subtype profile included three components: 1) asymmetric tinnitus (i.e. more unilateral than bilateral), 2) fluctuations in tinnitus percept (i.e. volume/intensity fluctuates as opposed to remaining stable and consistent), and 3) tinnitus changes can be influenced by head/neck neuromuscular activity. The following study was an effort to provide additional data to test this clinical hypothesis.

Methods

Participants

Subjects for this study were eight individuals who completed neurofeedback, CES, or MET as part of their treatment at a university-based neurotherapy clinic or at a private mental health clinic. In addition to the primary symptoms for which four subjects sought treatment, the other four subjects all sought treatment for unilateral or bilateral tinnitus. Table 1 shows the demographic characteristics of the subject group. Participants included seven Caucasian females and one male with ages ranging from 27 to 70. Most had experienced tinnitus symptoms for several years. Data for these subjects was collected from 2009–2010 archived records of the university clinic and 2012–2013 archived records from the private mental health clinic.

As a prerequisite to treatment, clients whose records were used in this study were required to have read and signed an informed consent document that explained the neurotherapy treatment requirements and possible side effects or risks of the treatments. Clients also gave written permission for any information gained through their treatment to be used anonymously for educational or research purposes. Each client provided medical and family history and completed intake assessments. History included screening for pregnancy and demand-type cardiac pacemakers, that are contraindications for treatment with electrical stimulation (See Table 1).

All subjects were assessed pre- and posttreatment using the following psychometric instruments: Tinnitus Severity Scale (TSS), Tinnitus Handicap Inventory (THI), and Pittsburgh Sleep Quality Index (PSQI). Tinnitus subtype classification was based on subjective self-report prior to treatment. Five of the eight subjects also completed BAI, BDI, and BHS measures (See Table 3). However, these measures were not included in the statistical analysis.

Table 1
Demographic Summary

Case (*N* = 8)	Age	Gender	Ethn[a]	Side	Length[b]	Fluc[c]	Musc[d]	Improved?[e]
1	56	F	C	Left	6 years	Yes	Yes	Yes
2	61	F	C	Left/Bi	2 years	Yes	Yes	Yes
3	27	F	C	Same	4 years	Yes	No	No
4	60	F	C	Same	3 years	Yes	No	No
5	70	F	C	Same	30 years	No	No	No
6	39	F	C	Bi	1 year	Yes	Yes	Yes
7	25	F	C	Uni	2 years	Yes	Yes	Yes
8	32	M	C	Bi	5 years	Yes	Yes	Yes

Note. [a]*Participant's reported ethnicity.* [b]*Length of sustained tinnitus since onset.* [c]*Fluctuation in pitch (Yes/No).* [d]*Musculoskeletal influence.* [e]*Tinnitus symptoms improved (Yes/No). "Same" refers to tinnitus being consistent on both sides versus bilateral or unilateral with inconsistency.*

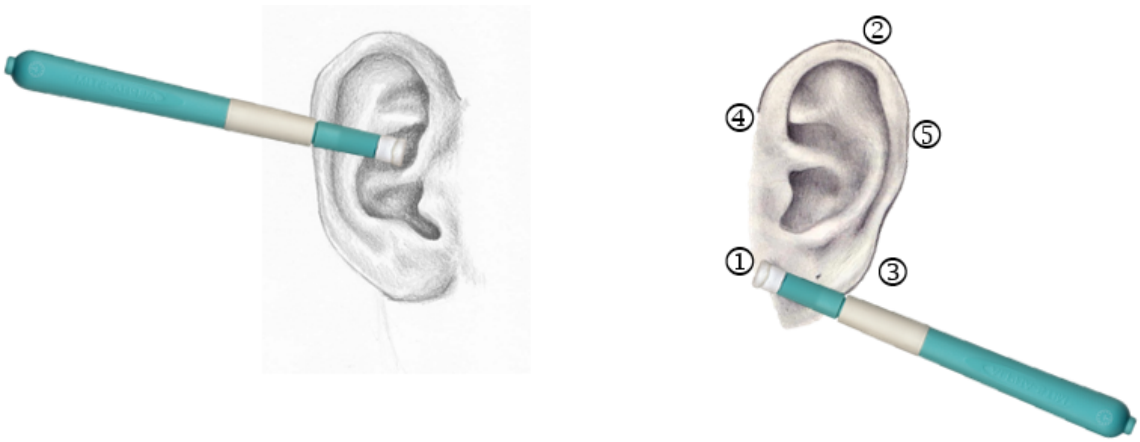
Instrumentation

Neurofeedback Instrumentation and Protocol

Brainwave training in the form of EEG biofeedback or neurofeedback was provided using BrainMaster Atlantis version 3.0 software (*n* = 1). BrainMaster equipment was set to include a 60-Hz notch filter, 256 data-sampling rate, 125μv artifact threshold, and peak-to-peak amplitude scale. This equipment was set to inhibit delta (1.5–4.0 Hz) and high beta (20–30 Hz) and to reward alpha (8–12 Hz). Active electrode placements were guided by qEEG to target the signature tinnitus activity in the delta and alpha ranges. The left (A1) and right (A2) ears were used for reference and ground sites.

CES and MET Device

[Electromedical Products International, Inc.] Alpha-Stim 100 combined microcurrent and cranial electrotherapy stimulators were used. These battery-powered devices generate current at 0 to 500 microamperes continuously adjustable. The frequency is 0.5 Hz (pulses per second) combined with a constant 0.4 Hz. The average pulse rate is 0.8 Hz. Pulse widths vary between 0.25, 0.5, 0.75, and 1 s. At 500 μA the charge per pulse varies between 125, 250, 375, and 500 microcoulombs (μC). Every 10 s the total charge is 1.25 millicoulombs (mC) in each direction. The impedance ranges within which the waveform parameters remain valid are from 100 Ω to 10 KΩ. The waveform is composed of bipolar asymmetric rectangular waves at a 50% duty cycle repeating periodically at 10-s intervals. The waveform is balanced to achieve 0 net current in either direction. Current alternated (10 s on, alternating with 2 s off) when using the probe function, which applies current to sites using two electrically conducting, manually administered probes. When treatment included the use of the microelectric current therapy using the probes, clients were asked to provide a subjective rating of their tinnitus severity, based on a scale of 0 to 10 (0 = percept inaudible; 1 = barely noticeable; 10 = intolerable), following each auricle administration of the current (See Figure 1).



Step 1: Insert probe in concha cymba or concha cavum of left ear (not in canal).
Step 2: Treat in 10-s intervals at locations 1–5 in star-shaped pattern of contralateral ear.
Step 3: Switch ears and repeat this procedure (i.e. 1 round of treatment).
Step 4: Repeat process while monitoring symptom reduction or until treatment plateau occurs.
*Our study averaged approximately 6 rounds (with breaks) for approximately 20–30 minutes of treatment.

Figure 1. Tinnitus MET Protocol.

Case 1

A 56-year-old female developed constant severe unilateral, left-side tinnitus immediately following a hysterectomy surgical procedure. Her tinnitus had persisted for the past 5 years and fit the somatosensory subtype profile. The client was treated with qEEG-based neurofeedback at T4 with a 2–9 Hz and 20–30 Hz inhibit protocol. On the eighth day of training at this site, the client reported her tinnitus had disrupted for a full day for the first time in years. Training was continued at temporal/parietal (T4/T6/P4) sites, which continued to produce a fluctuation in her tinnitus between sessions (and, at times, modulate pitch or intensity within sessions). By session 14, the client reported that her tinnitus was suppressed 50% of the time (either completely on, or completely off). The client's baseline qEEG indicated the highest delta amplitude and lowest alpha amplitude at site F3. Additional gains were reported by the client after receiving neurofeedback treatment at this site. She reported that the tone and severity of the tinnitus improved, and usually within an hour following each session her tinnitus would attenuate and remain suppressed 75% of the time thereafter.

Given that the Alpha-Stim 100 has been shown to produce a similar increase in alpha while decreasing delta and high beta (Kennerly, 2006), it was hypothesized that adding CES to the treatment regimen might augment clinical results. The client used the CES component of the Alpha-Stim 100 (attached by ear lobe clips) for > 20 sessions at home. She reported that using the CES device seemed to keep her tinnitus subdued and better managed when not receiving tinnitus NF training. The therapist then speculated that treating auricle sites on the outer ear that may have more precise correlation with tinnitus might be more helpful, such as in the case of treating pain with MET at the physical location of the pain sensation. The therapist then administered the microcurrent electrical therapy component of the Alpha-Stim 100 using the probes, in the same manner as would be used with this MET instrument for a pain protocol. A succession of repeated administrations of MET at five points (in a star-shaped pattern) around auricle with a simultaneous probe in a centered location of the opposite outer ear (not in the canal) gradually suppressed the active tinnitus into full remission within the first treatment administration. The client then self-administered this protocol at home and found the tinnitus to be suppressed 80–90% of the time and found it to be otherwise barely audible. However, the client noted that when she stopped using the Alpha-Stim/MET for periods of time, her tinnitus returned within "several days." Client's resuming use of the device would reinstate tinnitus suppression (subjective rating from an 8 to a 3 on a scale of 0 to 10).

Case 2

A 61-year-old female developed bilateral tinnitus with spontaneous onset 2 years prior to her clinical treatment. This client also met criteria for somatosensory subtype, having significant muscle tension in shoulder and neck areas. She was initially treated with the CES component of the Alpha-Stim 100 (attached by ear lobe clips) for 20 sessions with no change in tinnitus symptoms. However, a single treatment session using the MET modality of the Alpha-Stim 100 resulted in nearly complete suppression of the tinnitus. The same pain protocol consisting of a succession of repeated administrations at five points in and around each auricle (first on her left ear, and then eventually on the right ear) gradually reduced the tinnitus to nearly full remission (subjective rating from a 5 to a 0.5 on a scale of 0 to 10). Her tinnitus had not returned at a 1-month follow-up. Interestingly, the client also reported modulation of her tinnitus when the probe was placed on her upper trapezius/neck muscle (a divergence to address upper back/neck tension), adding further support to the musculoskeletal involvement in this subtype.

Case 3

A 27-year-old female developed bilateral tinnitus with spontaneous onset 5 years prior to initiating treatment. She did not meet the usual criteria for a somatosensory subtype and had a complex history and clinical presentation. This client had received audiological testing and learned she had nerve damage and hearing loss. She also reported a history of TMD. Her tinnitus was severe and consisted of three different pitches bilaterally. She was initially treated with CES, but discontinued after six sessions due to headaches, dizziness, and fatigue. MET was then tried, but discontinued after six sessions when client reported an increase in tinnitus pitch loudness. The loudness returned to its previous level 1 to 2 weeks later (subjective rating from a 10 to a 10 on a scale of 0 to 10).

Case 4

A 60-year-old female developed bilateral tinnitus with spontaneous onset 3 years prior to entering treatment. She reported a history of TMD and did not meet criteria for somatosensory subtype. She received 20 CES and 20 MET treatments with no reported improvement from either modality (subjective rating from a 4 to a 6 on a scale of 0 to 10).

Case 5

A 70-year-old female had developed bilateral tinnitus with spontaneous onset 30 years prior. She did not meet criteria for somatosensory subtype. She received 20 CES and 20 MET treatments with no reported change from either modality (subjective rating from a 3 to a 2 on a scale of 0 to 10).

Case 6

A 39-year-old female developed bilateral tinnitus following a postcraniotomy for left-frontal meningioma that was resected 1 year prior to her treatment. The resection resulted in the client experiencing constant headaches and a continuous “clicking sound.” She fit the somatosensory subtype profile and was treated with MET. Her tinnitus almost fully remitted in a single session (subjective rating from an 8 to a 1 on a scale of 0 to 10). At a 1.4-year follow-up, her tinnitus remained in remission.

Case 7

A 25-year-old female developed unilateral tinnitus with an onset that occurred 2 years prior to her clinical treatment. Her tinnitus may have resulted from an automobile collision after which she experienced onset of frequent headaches (1–3 times per week) and persistent tinnitus in the form of a “whooshing sound” that progressively worsened, especially over the 4 months prior to treatment. The subject noted that her tinnitus was unilateral, in the left ear, and fluctuated both with movement and body position (i.e. her tinnitus worsened when changing from standing to seated or lying down positions). She met criteria for somatosensory subtype. She received an initial CES treatment for headache (using ear clip locations) that resulted in remission of both her headache pain and her tinnitus (subjective rating from a 6 to a 0 on a scale of 0 to 10). At a 1.7-year follow-up, her tinnitus remained in remission.

Case 8

A 32-year-old male reported being diagnosed with a hemangioblastoma that was resected in February 2007. He reported that he had radiation, but eventually the tumor returned and metastasized and spread to bone and other areas. After exhaustive treatment, he eventually went into remission of the cancer, but reported a subsequent history of tinnitus that met criteria for somatosensory subtype. His tinnitus was suppressed to full remission following a single treatment (subjective rating from a 6 to a 0 on a scale of 0 to 10). At a 1-year follow-up, he reported his tinnitus had remained fully suppressed for 3 months, then resumed, but at a lesser and more tolerable level. He did not receive follow-up treatment because his cancer had returned, and he was involved in additional treatment for that condition.

Analysis of Results

Paired *t*-tests were performed to determine if the difference scores between the pre- and posttests for the TSS, THI, and PSQI were statistically significant. In addition, discriminant function analyses (DFA) were completed to determine the efficacy of using the difference scores on the TSS, THI, and PSQI to classify participants in either the somatosensory or nonsomatosensory groups. DFA also was used to predict whether participants reported that tinnitus symptoms were better or worse after exposure to NF, CES, or MET treatments. Because only one participant received NF treatments before exposure to CES and MET, NF was excluded as a predictor in the second discriminant analysis. DFA normally uses continuous variables to predict membership in two or more mutually exclusive groups, which was the case in the first analysis. However, the second DFA used categorical variables to predict the likelihood that participants indicated their tinnitus symptoms improved after each treatment. Both paired sample *t*-tests and DFA require exogenous variables that are normally distributed, but each analysis is fairly robust to violations to the underlying assumptions during each test. The results below were validated using nonparametric bootstrapping methods, which produced nearly identical results for both the paired *t*-tests and each DFA. However, since the sample size in this exploratory study consisted of only eight individuals, which by itself limits the generalizability of the findings, only the parametric results for each analysis conducted will be described.

Paired-sample *t*-tests showed the scores for the Tinnitus Severity Scale (TSS), $t_{(df=7)} = -2.94$, $p = .022$, and the PSQI, $t_{(df=7)} = -2.53$, $p = .039$, were statistically different following treatment. The posttreatment Tinnitus Handicap Inventory (THI), $t_{(df=7)} = -1.94$, $p = .047$, one-tailed, had a statistically significant result from pretreatment, indicating that tinnitus handicap indicators subsided after neuromodulation treatment. The difference scores from the pre- and posttests on the TSS, THI, and PSQI were then used to classify participants into one of two groups, somatosensory and nonsomatosensory. With only two groups, DFA yields only one discriminant function. The first discriminant analysis using difference scores had an Eigenvalue of 9.56 that accounted for 100% variance, with a canonical correlation of .952. The canonical correlation when squared is the proportion of the total variability explained by differences between groups. Stated differently, a canonical correlation near 1 suggests that the function discriminates well (1.00 is perfect). The analysis had a Wilks' $\lambda = .094$, $X^2_{(df=3)} = 10.62$, $p = .014$. The calculated η^2 is $1 - \lambda = .91$, indicating that 91% of the variance in the categorical grouping variable is shared with the linear combination of the TSS, THI, and PSQI difference scores. A chi-square transformation of Wilks lambda was used to determine significance of Wilks' λ, and *p*-values smaller than .10 are significant, indicating that the group means differ. Similarly, the high chi-square, 10.6, indicated the difference scores on the three measures discriminate well between somatosensory and nonsomatosensory participants. Table 4 presents the classification table for the DFA predicting membership in either the somatosensory or nonsomatosensory groups. By using the difference scores from the TSS, THI, and PSQI, the discriminant function correctly classified all participants and supports a tentative conclusion from this study that the neuromodulation methods of neurofeedback, CES and MET had a differential impact on symptom reports of subjects having the somatosensory subtype of tinnitus.

Categorical variables representing whether participants were classified as somatosensory or nonsomatosensory and received either CES or MET were used to predict if participants reported better or worsening tinnitus symptoms after each individual treatment during the study. There were $N = 149$ subjective measures of whether tinnitus symptoms improved, one following each respective treatment (including in-session trials of MET). The second discriminant function analysis had an Eigenvalue of 1.327 that accounted for 100% variance with a canonical correlation of .755. Wilks' $\lambda = .43$, $X^2_{(df=3)} = 122.89$, $p < .001$. The calculated η^2 is $1 - \lambda = .57$, indicating that 57% of the variance in the categorical grouping variable is shared with the linear combination for the somatosensory, CES, and MET categorical variables. The X^2 of 122.9 was significant and its value suggests these variables discriminate well between those who reported subsiding symptoms and those who did not. Table 5 presents the classification table for the DFA, predicting membership in either the "better or not-better" groups. The categorical variables indicating whether individuals were somatosensory and received CES and/or MET correctly classified 94.6% of the subjective responses recorded after each neuromodulation treatment. In other words, knowing whether a participant was somatosensory or not, together with the type of treatment received, strongly supports the contention that neuromodulation methods, especially MET, can substantively reduce tinnitus symptoms after each treatment. These findings are consistent with those obtained in the much earlier study done by Engelberg and Bauer (1985) who used the Alpha-Stim 2000, a large (MET) clinical device.

Table 2

Tinnitus Severity, Handicap, and Sleep Inventory Pre and Post Scores

Case	TSS[a]		THI[b]		PSQI[c]	
(*N* = 8)	Pre	Post	Pre	Post	Pre	Post
1	8	3	60	34	13	7
2	5	0.5	20	12	5	5
3	10	10	64	62	23	2
4	4	6	6	4	3	2
5	3	2	4	8	2	3
6	8	1	100	4	18	6
7	6	0	40	6	13	7
8	6	0	28	14	14	7

Note. [a]*Tinnitus Severity Scale.* [b]*Tinnitus Handicap Inventory.* [c]*Pittsburgh Sleep Quality Index.*

Table 3

Pre- and Posttreatment Scale Scores

Case	BAI[a]		BDI[b]		BHS[c]	
(*N* = 8)	Pre	Post	Pre	Post	Pre	Post
1	36	10	23	5	10	4
2	4	1	0	1	1	1
3	16	5	7	3	2	1
4	0	2	2	1	9	1
5	4	3	1	6	4	2
6	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A

Note. [a]*BAI – Beck Anxiety Inventory.* [b]*BDI – Beck Depression Inventory.* [c]*BHS – Beck Hopelessness Scale.*

Table 4

Discriminant Function Analysis Somatosensory Classification Results

Somatosensory			Predicted Group Membership NS	S	Total
Original	Count	Nonsomatosensory	3	0	3
		Somatosensory	0	5	5
	%	Nonsomatosensory	100.0	0.0	100.0[a]
		Somatosensory	0.0	100.0	100.0[a]

Note. [a]*100.0% of original grouped cases correctly classified.*

Table 5

Discriminant Function Analysis Better/Not-Better Classification Results

Better			Predicted Group Membership Not better	Better	Total
Original	Count	Not better	104	7	111
		Better	1	37	38
	%	Not better	93.7	6.3	100.0[a]
		Better	2.6	97.4	100.0[a]

Note. [a]*94.6% of original grouped cases correctly classified.*

Conclusions

Microcurrent electrical therapy (MET) at sequential auricle sites appears to provide a method of reorganizing and re-establishing neural homeostasis at the intercept of the involved somatic and auditory pathways of somatosensory tinnitus. While neurofeedback has shown some possibility of tinnitus interruption, and CES has also demonstrated limited success, the specificity of MET at particular auricle sites seems to show the most promise and the most efficiency. Results of this clinical case series suggests that the somatosensory subgroup of tinnitus sufferers respond better to these neuromodulation treatments than other tinnitus subgroups. This somatosensory subgroup is characterized by nonbilateral tinnitus pitch, pitch that may fluctuate in tone/intensity, and EMG modulation of pitch. Further, both CES and MET appeared to reduce symptoms for postcraniotomy (“clicking” or “wooshing” sounds) and/or TBI-induced tinnitus. Even though this study was limited by such a small number of participants, the somatosensory subgroup responded to the MET treatment in single sessions, indicating that it, as well as CES, are promising treatments for tinnitus that warrant further exploration.

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NeuroRegulation

Proceedings of the 2016 ISNR Conference: Keynotes, Invited, and Student Award Presentations

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KEYNOTE PRESENTATIONS

Closed-Loop Control of Corticothalamic Circuits to Prevent Seizures with Light

Jeanne Paz
Neuroscience and Biomedical Science graduate programs at the University of California San Francisco, San Francisco, California, USA
Gladstone Institute of Neurological Disease, San Francisco, California, USA

Thalamocortical communication drives conscious sensory experience as well as sleep and epileptic seizures associated with synchronized brain rhythms and loss of consciousness. Treating seizure disorders requires knowledge of active network nodes as potential targets. Evidence suggests that the thalamus is the pacemaker for sustaining seizures, but an alternative argument is that seizures are inherited passively from cortex. To directly test for an active thalamic role, we used opsins to specifically drive or disrupt synchronous firing of thalamocortical neurons in acquired and genetic epilepsy models of rats and mice. Driving synchronized thalamic bursts evoked absence seizures or sleep spindles, while driving tonic firing desynchronized oscillations and abruptly terminated sleep and seizures, switching behavior from unconsciousness to exploration. These results resolve a long-standing controversy regarding the role of the thalamus in corticothalamic rhythms by demonstrating both the sufficiency of thalamus in generating thalamocortical rhythms and its necessity in maintaining these states. These results support development of therapies specifically targeting phasic thalamic activity.

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Self-Organized Criticality as a Theoretical Framework for Neurofeedback

Tomas Ros
Department of Fundamental Neurosciences, University of Geneva, Geneva, Switzerland

Despite a rise in empirical evidence attesting to its benefits, a unifying theoretical basis is still lacking on the manner in which neurofeedback (NFB) is able to achieve clinical outcomes. Starting with mechanisms of neural synchronization, it is argued that hyper- and hyposynchronous oscillations reflect diametrically opposite states within a dynamical systems framework. Utilizing Hebbian as well as homeostatic models of brain plasticity, the effects of NFB are examined in several brain disorders including attention-deficit/hyperactivity (ADHD) and posttraumatic stress disorder (PTSD). Importantly, brain oscillations demonstrate fluctuations over extended spatial and temporal scales, manifesting as scale-free EEG and fMRI signals. Here, we report novel evidence that NFB re-tunes pathological oscillations toward normal levels of synchronization and temporal complexity, consistent with mechanisms of self-organized criticality (SOC).

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Genes, Brains, and Neuroplasticity in Developmental Dyslexia

Karen Waldie
University of Auckland, Auckland, New Zealand

Dyslexia is a developmental disorder characterized by reading and phonological difficulties, yet important questions remain regarding its underlying neural correlates. In this presentation, I will take the audience through the most accepted research into dyslexia and other neurodevelopmental disorders. We will cover diagnoses, cognitive research, longitudinal research, and neurological findings. In our most recent functional magnetic resonance imaging (fMRI) study, we conducted a multivariate Partial Least Squares (PLS) analysis of the neural networks used by dyslexics while performing a word-rhyming task. Although the overall reading network was largely similar in dyslexics and typical readers, it did not correlate with behavior in the same way in the two groups. In particular, there was a positive association between reading performance and both right superior temporal gyrus and bilateral insula activation in dyslexic readers but a negative correlation in typical readers. Together with differences in lateralization unique to dyslexics, this suggests that the combination of poor reading performance with high insula activity and atypical laterality is a consistent marker of dyslexia. These findings emphasize the importance of understanding right-hemisphere activation in dyslexia and provide promising directions for the remediation of reading disorders.

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INVITED PRESENTATIONS

Reward Deficiency Solution System: Neurogenetic and Neuroimaging Translational Neural Regulation Having Clinical Relevance

Kenneth Blum
University of Texas, Austin, Texas, USA
Keck School of Medicine, University of Southern California, Los Angeles, California, USA
LaVita RDS, Lehi, Utah, USA
Igene, LLC, Columbia, Maryland, USA

Following the first association between the dopamine D2 receptor gene polymorphism and severe alcoholism, there has been an explosion of research reports in the psychiatric and behavioral addiction literature and neurogenetics. Along with Functional Genome Convergence, the multiple-candidate gene approach still has merit and is considered by many as the most prudent approach. Since 1996, our laboratory has coined the umbrella term Reward Deficiency Syndrome (RDS) to explain the common neurochemical and genetic mechanisms involved with both substance and non-substance, addictive behaviors. Importantly, the proposal is that the real phenotype is RDS and impairments in the brain's reward cascade, either genetically or environmentally (epigenetically) induced, influence both substance and non-substance, addictive behaviors. Understanding shared common mechanisms will ultimately lead to better diagnosis, treatment, and prevention of relapse. Our neurogenetic and neuroimaging data is dedicated to all the people who have lost loved ones in substance abuse and "reward deficiency syndrome" related tragedies. Why are we failing at reducing the incidence of 'Bad Behaviors'? Are we aiming at the wrong treatment targets for behavioral disorders? Can we couple NFB with Pro-Dopamine regulation as a paradigm shift and call it "Reward Deficiency Solution System" providing evidence for its adoption?

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Brain Connectivity and Neural Dynamics – Principles and Applications

Iman Mohammad-Rezazadeh
Department of Psychiatry and Biobehavioral Sciences, Semel Institute for Neuroscience and Human Behavior, David Geffen School of Medicine, University of California, Los Angeles, Los Angeles, California, USA

Recently, many neuroimaging studies have shown that individuals with autism spectrum disorder (ASD) exhibit different brain connectivity patterns compared to typically developing controls. While the findings of many studies largely based on functional magnetic resonance imaging (fMRI) are often summarized as local hyperconnectivity and long-range hypoconnectivity in ASD, a number of current connectivity studies using cortical recording methods such as electroencephalography (EEG) and magnetoencephalography (MEG) do not match this simple explanation. There are many reasons behind this controversy in findings, including (1) the task during EEG recording, (2) the age of patients examined, (3) the anatomical region(s) examined, (4) the time intervals and frequency band(s) in which connectivity was analyzed, and (5) the way the connectivity between brain regions measured—the connectivity estimator.

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Eating and the Brain: Using EEG to Understand Eating Behavior and Weight Gain Proneness

Samantha Winter
Drexel University, Philadelphia, Pennsylvania, USA

Battling obesity and obesity-related diseases is now a $300 billion industry. Understanding who is susceptible, identifying underlying causes and developing targeted interventions for obesity is now more important than ever. A subset of research outside of the eating field is beginning to use electroencephalography (EEG) in order to provide real-time feedback on brain functioning in attempts to modulate behavior. We provide early evidence for the potential utility of EEG in the conceptualization and, ultimately, treatment of obesity. Our major findings have linked specific patterns asymmetrical activation in the frontal lobe to dietary restraint and susceptibility to the food environment, respectively. Furthermore, frontal asymmetry in the same sample predicted weight gain 1 year later. Together, our findings demonstrate the efficacy of EEG and potential for neurofeedback as a preventative treatment for obesity.

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STUDENT AWARD WINNERS – PLENARY PRESENTATIONS

Riding the Wave to Recovery: sLORETA qEEG in Sport-Related Concussion

David Ims

Chesapeake Neurology Associates, Prince Frederick, Maryland, USA

Introduction/Support. Concussion is a complex pathophysiologic process affecting the brain, induced by biomechanical forces (McCrory et al., 2013). Trauma-induced diffuse axonal injury disrupts neuronal membrane electrolyte equilibrium and increases the metabolic load on affected neurons, compromising neuronal restoration to healthy functioning. Electroencephalography (EEG) measures differences in neuron-generated electrical potentials, and concussion results in measurable EEG abnormalities (Rapp et al., 2015). Three-dimensional current source density analysis utilizing standardized low resolution electromagnetic tomography (sLORETA) integrated with Quantitative EEG (qEEG) normative database techniques allows for high-precision localization of cerebral physiology. The advent of concussion management protocols such as the XLNTbrain Sport concussion management program utilizing internet-based computerized neurocognitive testing and symptom tracking allows for simplified management of concussion.

Hypothesis/Justification. As the majority of CT and MRI studies are normal in concussed individuals (Tator, 2013), qEEG warrants further investigation as an objective concussion assessment measure. It then follows that qEEG analysis can be integrated into a comprehensive symptom and cognitive performance based program to further our understanding of the concussion recovery process. We hypothesize that qEEG, particularly sLORETA analysis parallels concussion injury recovery.

Methods. The sport arena provides a semicontrolled environment where the effects of brain trauma can be observed, presenting a unique opportunity to study the natural course of concussion injury and recovery in athletes by standard concussion management programs integrated with qEEG. The XLNTbrain Sport concussion management program monitors changes in symptoms and computerized neurocognitive measures. Comparison of neurocognitive measures postinjury, and after return-to-baseline demonstrate change in cognitive performance and symptoms over the course of the recovery from injury. qEEG data is acquired postconcussion and when cognitive measures return-to-baseline. qEEG and sLORETA data at these time points are compared. We examine the relationship between qEEG metrics and neurocognitive measures in the recovery process.

Results. Two patterns of qEEG changes emerge in this analysis: (1) regional increase in delta/theta activity, particularly in the frontal and temporal lobes, and (2) regional and often generalized increase in beta/gamma activity. Resolution of the increased slow wave activity parallels symptom and cognitive performance recovery from concussion injury, while changes in gamma activity are more often persistent after clinical resolution.

Conclusion. This study suggests that changes in cerebral electrophysiology persist beyond current standards of determination of clinical recovery. We hypothesize the generalized increase in gamma activity represents cortical-cortical communication in the wake of deafferentation from deeper thalamic and brainstem structures due to axonal injury, while increased slow wave activity depicts regional cortical dysfunction due to direct trauma. Our findings suggest persistent pathophysiologic changes that may play a significant role in clinical return to play decision making and neurotheraputic protocol design. We propose that qEEG analysis should be included in baseline assessments of athletes and other individuals prone to concussion injury so direct within-subject comparisons can be made. Further research is needed to more definitively characterize the relationship between qEEG and recovery from injury.

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Finding the Beat: Simultaneously-Recorded Cortical and Subcortical Steady-State Responses to Missing Pulse Rhythms

Charles Wasserman, Jung Nyo Kim, Edward Large, and Erika Skoe
University of Connecticut, Storrs, Connecticut, USA

Many rhythm perception experiments employ simple isochronous rhythms, in which synchronous neural or behavioral responses are observed. However, responses at the stimulus frequency do not allow one to distinguish whether synchrony occurs as a response to a common input or as the result of an emergent population oscillation that entrains at a particular frequency. Stimulus complexity can be increased by manipulating the number of events that occur anti-phase (180°) versus in-phase (0°) with the basic rhythmic cycle. It is possible to create a rhythm with no spectral energy at the pulse frequency, however, by manipulating the number of events that occur anti-phase (180°) versus in-phase (0°) with the basic rhythmic cycle. Dynamical analysis predicts neural oscillation will emerge at such a "missing" pulse frequency, where a complex rhythm contains no spectral energy. Previous studies have shown that subjects are able to tap along to complex rhythms that contain no spectral power at the missing pulse frequency—a finding that supports the prediction. This study aimed to investigate whether the auditory sensorimotor system, as measured by 32-channel cortical EEG, would entrain to a complex rhythm at the pulse frequency of a complex rhythm even when the complex rhythm has contained no spectral power at that pulse frequency. The experiment utilized four different rhythms of varying complexity (1 simple, 2 complex, and 1 random) created from 150-ms tones with a 200-Hz fundamental frequency (F0). For the simple rhythm, Fast Fourier Transform (FFT) of the Hilbert envelope showed energy at the repetition (pulse) frequency (2 Hz) for the simple rhythm and its harmonics (4 Hz). For the complex rhythm there was no spectral energy at the missing pulse frequency (2 Hz) for the complex rhythms. EEG responses to these stimuli were recorded to look for the neural oscillations at the missing pulse frequency predicted by dynamical analysis. FFT of the cortical steady-state response showed energy at the "missing" pulse frequency (2 Hz) for both the simple and complex rhythms. These data support the theory that this rhythmic synchrony occurs as the result of an emergent population oscillation that entrains at this particular frequency. Additional analyses examined whether the Frequency Following Response (FFR) to the 200 Hz F0 is modulated by whether the stimuli are in-phase versus anti-phase with the entrained cortical rhythm.

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STUDENT AWARD WINNERS – POSTER PRESENTATIONS

Differences in Theta Power Between Experts and Novices in the Preparation Phase of Golf Putting

Yen-Yo Tsai[1], Kuo-Pin Wang[1], Tai-Ting Chen[1], Kuan-Fu Chen [1], Cheng-En Chiang[1], Chung-Ju Huang[2], and Tsung-Min Hung[1]
[1]National Taiwan Normal University, Taiwan
[2]University of Taipei, Taiwan

Purpose. The theta activity is an indicator of action monitoring, cognitive control, and reflecting an engagement of volitional attentional control. Previous electroencephalographic (EEG) studies have demonstrated higher Fz theta power in experts than novices in the golf putting task. This study extended this knowledge base by including a measure of self-report attention engagement score to supplement the EEG measurement.

Methods. The 13 skilled golfers (mean handicap = 4.4, *SD* = ± 2.2) and 16 novices were recruited, and all participants performed 60 putts in 6 separate blocks on artificial golf green while EEG data and self-report attention engagement score as measured by from visual analogue scale were obtained.

Results. The 2 (Group: expert, novice) x 6 (Electrode: Fz, Cz, Pz, Oz, T3, T4) ANOVA revealed a significant interaction effect between groups and electrodes. Post hoc simple main effect analysis indicated that the expert's theta power at Fz, Pz, and T3 was higher than that of novice's, whereas theta power at T4 was lower than that of novice's. On the other hand, novices revealed higher attention score than experts.

Discussion. The finding of this study is consistent with previous EEG and behavioral studies and also supports previous research that experts felt effortless and involved in effective allocation of the neural resources associated with the attention network for golf putting task. The results also show that expert has better attention engagement allocation (higher Fz theta power), better motor control (higher Pz theta power), and effective retrieval motor memory encoding (higher T3 and lower T4 theta power) during the preparation phase.

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Hemispheric Difference on EEG 8–13 Hz Between Skilled Golfers and Novices During the Aiming Period of Golf Putting

Cheng-En Chiang[1], Kuo-Pin Wang[1], Tai-Ting Chen[1], Kuan-Fu Chen[1], Yen-Yo Tsai[1], Chung-Ju Huang[2], and Tsung-Min Hung[1]
[1]National Taiwan Normal University, Taiwan
[2]University of Taipei, Taiwan

Purpose. Previous studies focused on the difference of a single frequency band between experts and novices in golf putting task. Higher cognitive functions such as perception, spatial cognition, and attention show some degree of hemispheric specialization (Hellige, 1993; Davidson & Hugdahl, 1995). Specifically, increased alpha power of the left hemisphere has been related with visuospatial and motor coordination, relative to that observed in the right. However, whether this hemispheric asymmetry can be observed between skilled golfers and novices during an aiming period of golf putting remains unknown. Therefore, the purpose of this study was to compare hemispheric differences on the 8–13 Hz between skilled golfers and novices during an aiming period of golf putting.

Methods. The 13 skilled golfers (mean handicap = 4.4, *SD* = ± 2.2) and 18 novices volunteered. All participants performed 60 putts in 6 separate blocks in golf putting task. EEG from the left and right frontal (F3, F4), central (C3, C4), temporal (T3, T4), parietal (P3, P4), and occipital (O1, O2) sites were recorded and alpha (8–13 Hz) from the last 2 seconds prior to putting were analyzed.

Results. The 2 (Group: expert, novice) x 5 (Regions: frontal, central, temporal, parietal, and occipital) x 2 (Hemisphere: left, right) ANOVA revealed a significant interaction effect between groups and hemisphere. Post hoc simple main effect analysis indicated that the alpha power from both hemispheres are higher in experts than that of novices. This result suggests that experts exhibit less cortical effort to process visuospatial and motor coordination during the aiming period of golf putting, which is according with neural efficiency hypothesis.

Conclusion. The finding of this study is consistent with previous study that showed a superior engagement of visuospatial resources for effective performance in expert than novices during golf putting task. On the other hand, novices would cost more cortical effort to process the information required to successfully aim the golf on the target. Therefore, the present results lend support to suggest that reduced activation in the whole brain area is a key to producing better performance in skilled athletes (Baumeister, Reinecke, Liesen, & Weiss, 2008).

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Changes in Neural Resting State Cortical Activity During Putting Skill Learning

Tai-Ting Chen[1], Chen Shen[1], Kung-Fu Chen[1], Kuo-Pin Wang[1], Yen-Yo Tsai[1], Cheng-En Chiang[1], Chung-Ju Huang[2], and Tsung-Min Hung[1]

[1]National Taiwan Normal University, Taiwan

[2]University of Taipei, Taiwan

Spontaneous activation in the resting state of the brain can be affected by learning. Motor skill learning could be rapid during the very early stages of learning, which is accompanied by changes in the strength of connections within frontal, central, parietal, and occipital areas. Moreover, it requires intense top-down attention to perceptual-motor skills. However, no study has investigated changes in the resting state cortical activity during the verbal-cognitive stage of skill learning. Therefore, the purpose of the present study was to examine changes in cortical activity associated with novice golf putting learning in three different learning stages [baseline, improved by 50% (I50%), and improved by 80% (I80%)]. We hypothesized that sustained attention (frontal midline theta power) is the most critical factor for putting skill learning. Fourteen participants, right-handed, between 18 and 22 years of age, were recruited and practiced golf putts in one session of 60 putts two or three times a week. Participants would move to the next stage if he or she practiced at least six times and hit the targeting score in the last three consecutive times. EEG activities were recorded for 1-min, eyes-open in the resting state at baseline, I50% and I80% scores during golf putting practice. EEG power at Fz, Cz, Pz, and Oz was computed for the theta (4–8 Hz), alpha (8–13 Hz), and beta (15–30 Hz) bandwidths. Three 3 × 4 (stage × electrode) ANOVAs with repeated measures were conducted separately for theta, alpha, and beta power. The results demonstrate that only theta power at Fz significantly increased during putting skill learning, which suggests that top-down sustained attention plays an important role through the verbal-cognitive stage of golf putting learning. Perceptual-motor information processing seems to play a less important role in golf putting learning.

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Neurofeedback Treatment in Response to Veterans Arrested for Domestic Violence with History of Traumatic Brain Injury: A Pilot Study

Linda Larson Spagon[1], Karen Neil[1], and Myron Thurber[2]

[1]Idaho State University, Pocatello, Idaho, USA

[2]Neurotherapy Northwest, Spokane Valley, Washington, USA

Background and Description. Domestic violence, also referred to as intimate partner violence (IPV) is recognized as a complex, significant public and social health problem. The intersection of IPV and combat-related issues, such as TBI among returning veterans, is the focus of this study. Veterans who have experienced injuries to the head and neck during deployment to Iraq and Afghanistan are estimated at 30% of over 2.5 million, with 70% to 80% considered mTBI. Veterans are arrested for domestic violence in significant numbers with the link to TBI established in the current literature. Across the U.S., the judicial response to domestic violence (DV) as a treatment approach consists of mandated, cognitive-based group, one-size-fits all programs which are based on established state standards. The current research on the outcomes of these programs indicate little to no effect on reducing DV recidivism. There is a need to consider new and innovative approaches for addressing DV offender treatment and neurofeedback treatments for TBI has shown positive effects.

Methods. The study design will be a randomized clinical trial pilot. The purpose of the study is to investigate the addition of neurofeedback as treatment modalities for veterans mandated to a domestic violence treatment program, presenting with a history of TBI. Research hypotheses will include statements of prediction related to pre- and postmeasurement of brain map outcomes, heart rate variability, anger and aggression with neurofeedback treatment as an additive component to mandated state-approved domestic violence treatment (control). The population will include veterans arrested for domestic violence and mandated to a state-approved treatment program through a single Veteran's Judicial Court in the northwest. The sample (*n* = 20; 10 assigned to each group) will consist of veterans arrested for domestic violence with a history of head injury noted on initial intake into a single state-approved offender intervention program. Veterans will be randomly placed in either the control group or the treatment group. Measures will include pre- and post-qEEG brain map, comparing LORETA progress reports of deviations from normal, and pre- and post-heart rate variability, as well as variables of anger and aggression. Instruments with strong psychometric properties will be used to measure anger and aggression pre- and posttreatment in all groups. SPSS will be used for analysis of data collected.

Results. Outcomes to be measured in terms of significance pre- to posttreatment in both groups.

Summary – Justification. TBI is a major issue in veterans returning home from combat and is a risk factor for IPV. Innovative treatments such as Neurofeedback will provide the judicial system with options for the veteran population with a history of TBI. There is a dearth in the literature in regards to these treatment modalities in response to domestic violence. Research in this area will provide further evidence around the usefulness of other treatment options in addressing IPV in this population.

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NeuroRegulation

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Be CALM & Pay ATTENTION! An Overview of Assessment Findings and Intervention Strategies for Attention-Deficit/Hyperactivity Disorder (ADHD)

Lynda Thompson and Michael Thompson
ADD Centre and Biofeedback Institute of Toronto, Mississauga, Ontario, Canada

Participants will learn about diagnosis and intervention. Diagnosis will cover both a brief overview of DSM-5 criteria for both Inattentive and Combined presentations of Attention-Deficit/Hyperactivity Disorder (ADHD) and also mention of comorbidities. An explication of how adding additional measures from single-channel EEG data collection and administration of continuous performance tests supports the diagnosis. The salient areas to be covered during the clinical interview will also be covered; namely, the person's strengths, family matters (with mention of Judith Lubar's use of genograms), social functioning, school and/or work performance, medical factors (allergies, sleep apnea, head injuries, etc.), and extracurricular interests. Data from questionnaires and, for more objective test data, continuous performance tests (Test of Variables of Attention [T.O.V.A.] and Integrated Auditory and Visual Continuous Performance Test [IVA]) will be shown. The various patterns found on single-channel (Cz) EEG assessment will be discussed in the light of the published norms for theta/beta power ratios. EEG patterns (excess theta, excess alpha, spindling beta, all seen with single channel assessment) will be shown. Recent updates on the utility of theta/beta as a marker for ADHD will be shared. Patients who have a diagnosis of ADHD symptoms can vary from children with a relatively simple difficulty with attention span to patients who have a complex array of other difficulties and comorbidities that involve other networks, such as learning disabilities, Asperger's syndrome, autism spectrum disorders, affect disorders, and movement disorders, including Tourette syndrome. This will be acknowledged but not expanded upon in this presentation. Finally, intervention will be discussed with mention of diet, sleep, and exercise but with the main focus being on how to do effective neurofeedback intervention combined with biofeedback with this population. Finally, there will be mention of research that addresses the question of whether neurofeedback can be considered an efficacious treatment for ADHD.

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Words that Don't Work: Frontal Gamma Asymmetry Examination of Precognitive Responses

Ronald Bonnstetter[1] and Nancy Wigton[2]
[1]Target Training International, Scottsdale, Arizona, USA
[2]Applied Neurotherapy Center, LLC, Scottsdale, Arizona, USA

Objective. The purpose of this study was to explore the concept behind Newberg and Waldman's 2012 book, *Words Can Change Your Brain*, by capturing brain activation while being confronted with words that have been previously identified as correlating to specific behavioral typologies. The null hypothesis was that these "trigger words" would have the same reaction no matter what behavioral group was being tested.

Methods. The first step was for participants to take a behavioral assessment, known as Target Training International, Ltd. (TTI) Style Insights (Bonnstetter, 2014). This well-researched assessment has consistently shown that behavioral characteristics can be grouped together into four quadrants, or styles. The acronym DISC stands for: D = Dominance, I = Influence, S = Steadiness and C = Compliance. This instrument is based on William Moulton Marston's *Emotions of Normal People*. As stated by Marston, "All people exhibit all four behavioral factors in varying degrees of intensity." Therefore, each behavioral factor may be exhibited along a continuum from high to low, thus creating eight extremes. Participants exhibiting each of the DISC extremes underwent an EEG recording in our lab, while observing key behavioral terms. Prior to the initiation of the EEG recording, the subjects' primary behavioral style was noted. During the EEG data collection session, each subject was exposed to words previously established as words that elicit a negative reaction in a person of a certain primary style. Observations of gamma brain activity in the frontal cortex were classified as depicting acceptance, avoidance, or a neutral symmetry. Gamma is the primary focus of our measurements as it provides an immediate emotional response to a stimulus, even before a conscious thought has formed.

Results. Where avoidance to a word was observed, there was a greater amount of gamma activation in the right prefrontal lobe as opposed to the left.

Conclusions. Analyzing the data through the lens of DISC, it was observed that those with primary styles of Dominance and Compliance demonstrated significantly more avoidance than those with the Influence and Steadiness behavioral styles. Subjects with a primary Dominance style had the most favorable responses to their own terms, but were more critical than all other styles on all other words. Dominance behavioral style also had the most intense bursts of activation and avoidance. Subjects with an Influence behavioral style had the most varied and inconsistent responses. Overall, they were the most forgiving by not having many strong negative reactions. Subjects with a Steadiness behavioral style demonstrated the least amount of avoidance and very little change in activation. Overall, they were most critical of some Steadiness words and some Dominance words. Subjects with a Compliance behavioral style had the most avoidance of all groups, even to their own descriptive terms.

Significance. Certain words not only cause a sudden negative response in conversation, but work at a neurological level to alter brain patterns and obstruct communication. Given the intensity and duration of these reactions, these trigger words have the potential to build or break a relationship. Trigger words can set the tone for the conversation and for the outcome of conversations.

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Getting to Know LORETA: Evaluating and Training Surface and Internal Brain Structures

Joel Lubar
Southeastern Neurofeedback Inst., Pompano Beach, Florida, USA

In this presentation, I will present the groundwork for the development of LORETA which was first developed at the Key Institute in Zürich, Switzerland, by Roberto Pascal Marqui and Dietrich Lehman in 1994. LORETA allows one to visualize as many as 6,239 areas of the cortex and other regions including the hippocampus, the amygdala, the cingulate gyrus, and other areas where there are sufficient pyramidal cell generators. These areas that contain pyramidal cells are divided into three-dimensional cubes known as voxels. These cubes can be either 7 x 7 mm or 5 x 5 mm and comprise almost 70% of all the areas in the brain. I will discuss and illustrate how LORETA neurofeedback protocols are developed for more than 150 clinical disorders for which there is sufficient literature to support its application. I will then discuss the clinical application of LORETA neurofeedback with illustrations from cases of its effectiveness. These cases will cover the areas of depression, addiction disorders, and seizure disorders. LORETA neurofeedback complements and contrasts with fMRI neurofeedback. LORETA neurofeedback can train both specific regions of interest as well as the connection metrics between these regions of interest. These metrics include coherence, phase, phase shift, and phase lock and measures of effective connectivity which deal with the direction of flow of information from one brain region to another. This presentation will be at the elementary level for the new ISNR-lite format. Since this is an introductory presentation regarding LORETA which is a complex area I would like to have enough time to answer questions from the audience or to clarify anything which is not completely clear. If there is time, I would also like to mention graph theory since it allows the ability to visualize complex brain networks. There is now an extensive literature showing how these complex brain networks are linked to specific clinical entities. Examples of this are networks correlated with IQ, executive function, and many others.

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Comparing Bivariate and Multivariate Coherence Neurofeedback for Autism Spectrum Disorder

Morgan Middlebrooks and Robert Coben
Integrated Neuroscience Services, Fayetteville, Arkansas, USA

Autism spectrum disorder (ASD) can be described as a "group of developmental disabilities that can cause significant social, communication, and behavioral challenges." The epidemiological data presented by the CDC reported that 1 in 68 children are currently diagnosed with ASD (CDC, 2016). The CDC has noted an increase in the prevalence of ASD since the 1990s, making effective treatment an important part of the conversation. Neurofeedback therapy has been shown to be an effective treatment for ASD, specifically two-channel neurofeedback therapy (NFB). A review of data of 150 clients with ASD showed that neurofeedback therapy can be appreciated as a viable treatment for those on the spectrum (Thompson, Thompson, & Reid, 2009). Research by Coben and others has shown that while two-channel NFB has been an important step in our understanding of NFB, there are many problems with using a two-channel modality. He asserts that four-channel multivariate coherence training provides advantages over the more widely used two-channel treatment (Coben, 2014). Our study aims to provide empirical evidence of the advantages of four-channel multivariate coherence NFB by comparing two groups of patients who have been diagnosed on the ASD spectrum.

Methods. A total of 80 children on the autistic spectrum were assigned to two treatment groups inclusive of two-channel coherence and four-channel multivariate coherence training groups. Changes in power and coherence and autistic symptoms generally and various aspects of social skills will serve as the dependent variables. We will create a session score that appreciates coherence changes globally per session. Analysis will include the use of SPSS software for a MANOVA analysis. It will also include the use of NRep software suite to measure global changes in power and coherence.

Assessments. Quantitative electroencephalogram studies were performed pre- and posttreatment, followed by parent report measures of the Social Responsiveness Scale–Second Edition (SRS-2; Constantino & Gruber, 2012) and Autism Treatment Evaluation Checklist (ATEC), a parent-rated scale (Rimland & Edelson, 1999). QEEG data was then analyzed with the NeuroRep software suite. ASD symptomology will be rated using the ATEC and parent rated social skills will be appreciated using the SRS-2.

Results. Results evaluating changes in global coherence and power measures in addition to changes in ASD symptoms, parent-rated social skills, and other aspects of ASD are anticipated to support our hypothesis that four-channel multivariate coherence training helps to improve coherence in the brain more efficiently than the more commonly used two-channel bivariate coherence training.

Discussion/Conclusion. Using the information from the above study we hope to add to the growing knowledge base regarding the use of neurofeedback therapy to help reduce symptoms in individuals with ASD.

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NFB for Optimal Performance and Sport

Leslie Sherlin

Nova Tech EEG, Inc., Mesa, Arizona, USA

Largely in the past, athletic performance has been focused on training the body from an anatomical and muscular performance approach. As understanding and technology have emerged, the focus has broadened from simply being exercise physiology to true sports performance science that includes physiology, psychology, biomechanics, and nutrition. The term *brain training* is not an unfamiliar term but its definition and application are as diverse as the users. Quantitative electroencephalography (qEEG) and biofeedback modalities have been well established over the past 40 years to reflect and provide operant conditioning to the levels of cognitive engagement and arousal. An athlete who can exercise volitional control of these aspects of brain and body state has a supreme advantage during competition. This concept has received resistance and underutilization because research has spanned the observed, imagined, and performance of specific skills; however, to date the ideal mental states of performance and specific outcomes on performance has eluded investigators. The reinvention of brain wave technologies that is both practical to implement by not requiring a laboratory setting or advanced technical training for use has allowed us to build upon the previous years of research in brain electrophysiology and theory. Measuring the elite athlete brain has provided significant understanding of processes that now can be applied in a training tool that is both practical and effective to be implemented across a wide variety of sport performance settings for all skill levels. Some of these outcomes and experiences will be shared with practical information to be utilized in conducting sessions in this population.

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Relative Efficacy of Two Different Forms of Coherence Neurofeedback for Seizure Disorders

Morgan Middlebrooks, Robert Coben, and Janease Traylor
Integrated Neuroscience Services, Fayetteville, Arkansas, USA

The CDC describes epilepsy as an umbrella term for a brain disorder that causes seizures. The CDC estimates that nearly 1.8% of adults and 1% of children have had a diagnosis of epilepsy or seizure disorder (CDC, 2016). Many of those diagnosed with a seizure disorder are resistant to pharmaceutical intervention, which poses a need for alternative forms of treatment. Drug-resistant seizures are called many things (refractory, uncontrolled, intractable, etc.), but the International League Against Epilepsy defines drug-resistant epilepsy as occurring when a person has failed to stay seizure-free with adequate trials of at least two appropriate seizure medications. Most reports agree that drug-resistant epilepsy occurs in about one-third of the epileptic population (Sirven & Shafer, 2014). High prevalence rates of epilepsy have led researchers to seek understanding of the neurological underpinnings of the disorder using a range of measures including EEG, MEG, and MRI connectivity. Coben and Mohammad-Rezazadeh (2015) have shown that the use of Granger causality with EEG data can help determine the source foci of these ictal events and related connectivity patterns. In a review of the scientific literature, a meta-analysis of neurofeedback treatment with epilepsy resulted in 10 studies that reported overall mean decreases in seizure incidence following treatment for 64 of 87 patients (Tan et al., 2002). Using the information obtained with qEEG and Granger causality to guide neurofeedback, we hope to provide examples of the benefits of four-channel multivariate coherence training to the epileptic population. Neurofeedback therapy has traditionally centered on a one- or two-channel approach, but we hypothesize that using four-channel multivariate coherence neurofeedback therapy will enhance outcomes with seizure disorders.

Methods. A total of 60 individuals diagnosed with seizure disorder were assigned to two treatment groups inclusive of two-channel coherence and four-channel multivariate coherence training groups. Changes in coherence, power, seizure events and autistic symptoms will serve as the dependent variables. Analysis will include the use of SPSS software for MANOVA analysis. It will also include the use of NRep software suite to measure changes in coherence and power.

Assessments. Quantitative electroencephalogram studies were performed pre- and posttreatment. Dependent variables will be measured with the NeuroRep Compare program, Persyst II/Spike Detection software and ATEC (Rimland & Edelson, 1999).

Results. Our initial findings using two-channel bivariate coherence neurofeedback reduced seizure events for those on or off meds. It also showed that patients who received the two-channel treatment and meds would see a diminishing of seizure events when the meds were removed. We hypothesize that four-channel multivariate coherence neurofeedback will have greater enhancements of coherence while also decreasing power and seizure events. It is further hypothesized that parent-rated autistic symptoms will show greater and more efficient reductions.

Discussion/Conclusion. Using the information from the above study we hope to add to the growing knowledge base regarding the use of neurofeedback therapy to help reduce the symptoms experienced by those diagnosed with seizure disorders.

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Science and Clinical Application of Instantaneous *Z*-Score Neurofeedback

Thomas Collura[1] and Robert Thatcher[2]
[1]Brain Enrichment Center, Bedford, Ohio, USA
[2]Applied Neuroscience, Inc., Largo, Florida, USA

Objectives. The objectives are to explain and present the history, science, and clinical applications of instantaneous *z*-score neurofeedback (NFB). The two presenters will split time and present their different histories and different approaches to instantaneous *z*-score NFB. The topics will include the technical underpinnings of the computation of instantaneous *z*-scores using a reference database and clinical evidence that the proposed mechanism are supported by electrophysiological and outcome data. Special emphasis will be placed on scientific standards of instantaneous *z*-scores and comparisons to standard raw *z*-score NFB will be discussed. Both presenters will provide demonstrations of different methods of implementing *z*-score NFB.

History. *Z*-score NFB was first conceived and planned in 1999 for a new distribution of Lexicor, Inc. software. However, it was not until 2004 that Applied Neuroscience, Inc. completed the computer programming and developed a dynamic link library (DLL) for distribution that can be used by a wide number of different EEG amplifiers and software environments. In 2006 the ANI DLL was licensed to BrainMaster Technologies, Inc. and Thought Technology, LLC. From 2007 to 2010 the ANI instantaneous *z*-score DLL was also licensed to Deymed, Inc., EEG Spectrum, Mind Media, and Neurofield, Inc. The ANI *z*-score DLL is now used by over 3,000 clinicians located worldwide. In 2012, BrainDx, LLC developed a *z*-score DLL based on the NYU database, that is offered with BrainMaster; QEEG Professionals further developed a *z*-score DLL that is also offered by BrainMaster. The two presenters will show their respective software implementations and inventive ways to utilize instantaneous *z*-scores for NFB. Emphasis will be placed on the commonalities and differences between in the implementation of *z*-score NFB.

Clinical Applications. The clinical applications of *z*-score NFB will be contrasted with “raw” score NFB, and the clinical literature will be explored and discussed. *Z*-score NFB only has a 10-year history but nonetheless has resulted in numerous publications and successes in obtaining in good clinical outcome in fewer sessions. There are four main advantages of *z*-score NFB: (1) Simplification where different EEG metrics are unified to a single metric, the metric of a *z*-score which is the distance the EEG measure is from an age-matched reference normal population, (2) elimination of guessing about what the threshold for NFB for a given metric or set of metrics should be set at, (3) efficiency by improved guidance with respect to a healthy reference population for all EEG metrics and, (4) physiological validity of simultaneously reinforcing multiple metrics toward increased stability in brain network hubs and connections between hubs.

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Integrating Neurofeedback and Photobiomodulation in the Treatment of Neuropsychiatric Disorders and Neurodegenerative Disease

Lew Lim[1] and Marvin H. Berman[2]
[1]Vielight Inc., Toronto, Ontario, Canada
[2]Quietmind Foundation, Plymouth Meeting, Pennsylvania, USA

The use of low levels of visible or NIR light for reducing pain, inflammation, and edema; promoting healing of wounds, deeper tissues, and nerves; and preventing tissue damage has been known for almost 40 years since the invention of lasers in the early 1960s (Karu, 1998). Despite many reports of positive findings from experiments conducted in vitro, in animal models, and in randomized controlled clinical trials, LLLT remains controversial. Karu (2008) has proposed that mitochondria are a likely site for the initial effects of light, specifically that the enzyme cytochrome c oxidase (unit four in the mitochondrial respiratory chain) absorbs photons and increases its activity leading to increased ATP production, modulation of reactive oxygen species, and induction of transcription factors (Karu, 2008). The suggestion that cytochrome c oxidase is the photoacceptor molecule was confirmed using functionally inactivated primary neurons, proposing that light upregulates this enzyme (Wong-Riley, 2005). More recent animal studies have demonstrated positive effects of brief red +NIR stimulation as comparable to SSRI in treating symptoms of anxiety and depression (Salehpour, Rasta, Mohaddes, Sadigh-Eteghad, & Salarirad, 2016). Recent human clinical trials conducted at Quietmind Foundation have demonstrated that either neurofeedback training or repeated brief transcranial near infrared light stimulation can positive improvements in neuropsychiatric, neuropsychological, and qEEG measures. Clinical trials combining these two approaches are in the planning stages and anecdotal data from combining these interventions with patients in the clinic support their hypothesized synergistic potential (Berman, 2012; Berman & Frederick, 2009). The impact of NIR stimulation was demonstrated during a live demonstration at ISNR last year using the Vielight Neuro 810nm transcranial and intranasal unit. Initiating the stimulation at the Rich Club network locations (Fz, P3, Pz, P4) resulted in a rapid normalization of the volunteer subject's *z*-scores with subsequent reported improvement in TBI-related cognitive and motor planning symptoms. Lim had reported improvements in case studies of Alzheimer's patients using the Vielight 810. He and his collaborators have also just completed a randomized, single-blind controlled pilot study, treating subjects with dementia with the Vielight devices. The results were significantly better (with no side effects) than those reported by the FDA-approved donepezil ("Aricept") by Pfizer in their clinical study. The workshop will present a model for integrated NIR+NFB therapy using clinical case series data of patients diagnosed with TBI on the combination of NIR stimulation using the Vielight Neuro technology. We further intend to provide a model using predictive analytics that can show the expected level of improvement from the combined LORETA *z*-score neurofeedback and NIR treatment. The study is now being conducted and will be completed August 2016. The combined intervention was demonstrated at ISNR 2015. NFB and NIR treatment have been studied separately and the predictive analytic component will be the only novel element in the study design and subsequent presentation. Sample size will be at least 10 subjects with diagnoses of memory loss with and/or without TBI. Subjects will be pretested using standard eyes open and closed qEEG, ADAS-cog neuropsychological assessment, and the IVA-2 visual and auditory continuous performance test.

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Why Supplementation of the Functional Forms of Vitamin B12 May Be Helpful to Brain Health, Particularly for the Elderly, Under Conditions of Oxidative Stress and Inflammation

Robert Boddington
Private Researcher, New York, New York, USA

A recent major editorial in the Journal of Alzheimer's Disease signed by 33 senior scientists and clinicians concluded that diminished immune system competence in controlling common long-resident microbes was the most likely cause of Alzheimer's Disease (AD), and that amyloid beta plaque is, at least initially, only a defense mechanism (Itzhaki et al., 2016). This hypothesis is supported by a previous study reporting that levels of methylcobalamin (Methyl-B12), one of the two metabolically active or functional forms of Vitamin B12, was 12.4-fold lower in 61- to 80-year-old autopsied human prefrontal cortex than in 0 to 20-year-olds and 6.7-fold lower than in 41- to 60-year-olds. A sharp fall-off was also reported in the oldest age group for adenosylcobalamin (Adeno-B12). Material lower levels for Methyl-B12 were also found in age-matched young autistic and middle-age schizophrenic subjects (Zhang et al., 2016). The implied connection: In addition to the important roles B12 has in the formation and maintenance of myelin sheath, protecting nerve function, and modulating cellular inflammation, it also enhances immune function by modulating CD8+ T lymphocytes and natural killer (NK) cell activity (Tamura et al., 1999). There is a recent report that regulatory T cells delay disease progression in AD-like pathology (Dansokho et al., 2016). Elderly patients with low vitamin B12 levels also have impaired antibody responses to pneumococcal vaccine (Fata, Herzlich, Schiffman, & Ast, 1996).

Why not just measure serum B12 lab results and supplement as appropriate? Oxidative stress and inflammation, frequently associated with diminished levels of the body's principal antioxidant, glutathione, can impair serum B12 accuracy (Solomon, 2015). Which implies both aging and many psychiatric disorders may be associated with this issue. While there is no problem about the accuracy or importance of low serum B12 readings, the literature suggests that oral or parenteral supplementation to address this problem with a nonfunctional form of B12 under conditions of oxidative stress may or may not increase levels of the functional forms. Rietsaema (2014) describes the unexpected reversal of dementia in an 83-year-old woman after substituting Methyl-B12 for a non-functional form. McCaddon (2006) describes similar benefits in eight cases of mild cognitive impairment after nonfunctional forms had no effect by administering the glutathione enhancing supplement n-acetylcysteine. The separate benefits of Methyl-B12 and Adeno-B12 supplementation will be discussed as well as oral glutathione or its amino acid precursors (Sekhar et al., 2011), along with some other complementary supplements for which there is significant evidence in the literature for improving brain function.

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What the Sham Is Going On? Redefining Attention Deficit/Hyperactivity Disorder (ADHD) and the Inherent Problems with Neurofeedback Sham (Placebo–Controlled) Protocols in an Operant Conditioning Model

Rex Cannon[1] and Spencer Carroll[2]
[1]Neural Potential, LLC, Lake Worth, Florida, USA
[2]Knoxville Neurofeedback group, Knoxville, Tennessee, USA

There have been scarce advances in the uncovering of the etiology of Attention-Deficit/Hyperactivity Disorder (ADHD) over the past 30 years, despite advances in neuroimaging and neurophysiological methodologies. However, the amount of data accrued is extensive, yet an integrative model has yet to be constructed with clarity and standardization. In any type of problem in which a solution is evasive the primary lack of clarity and integration may be attributed to the operational operant definition given to the topic under investigation, as opposed to the methods used to investigate and treat the particular issue. ADHD is the most commonly diagnosed disorder in children and is projected to affect 5% to 7% of children worldwide and often continue on into adolescence and adulthood causing moderate difficulties for individuals across numerous adaptive contexts (Polanczyk, de Lima, Horta, Biederman, & Rohde, 2007). Importantly, recent data indicate there has been no increase in the prevalence rate of ADHD worldwide when tightly controlled analytics are used. This does not account for analytic methods or diagnostic criteria and variability (Polanczyk, Willcutt, Salum, Kieling, & Rohde, 2014). Additional problems exist in the accurate diagnosis of a “pure” ADHD sample since the comorbidity rate has been estimated to be as high as 80% (Pritchard, Nigro, Jacobson, & Mahone, 2012) and variable cases of ADHD may also classify with up to five comorbid psychiatric diagnoses. Additionally, ADHD as a single diagnostic indicator occurs in less than 20% of the cases, or even less (Barkley & Brown, 2008; Yaryura-Tobias, Rabinowitz, & Neziroglu, 2003). There has been an increasing discourse over neurofeedback techniques and outcomes using sham/placebo-controlled methods yet the aforementioned difficulties remain everpresent (Arns, de Ridder, Strehl, Breteler, & Coenen, 2009; Gevensleben et al., 2014; Guez et al., 2015; Hale et al., 2014; Lenartowicz & Loo, 2014; Loo, Lenartowicz, & Makeig, 2015; Micoulaud-Franchi et al., 2014; Polanczyk et al., 2007; Pritchard et al., 2012; Steiner, Frenette, Rene, Brennan, & Perrin, 2014; van Dongen-Boomsma, Vollebregt, Slaats-Willemse, & Buitelaar, 2013; Vollebregt, van Dongen-Boomsma, Buitelaar, & Slaats-Willemse, 2013). Current problems, diagnostic issues, and recommendations for a concise, standard set of metrics and interventions will be presented and discussed.

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Domestic Violence and Brain Injury: A New Approach. Using Neurofeedback in a Domestic Violence Program

Joshua Brown, Huda Shaikh, and Peggy Wright
Fort Bend County Women's Center, Richmond, Texas, USA

In recent years, general awareness of traumatic brain injury (TBI) has increased substantially. A significant reason for this may be the media's coverage linking increased TBI diagnoses and symptoms with combat veterans and athletes. Despite this increased awareness, one population is still largely overlooked in terms of screening and treatment of TBI. Survivors of domestic violence (otherwise known as Intimate Partner Violence or IPV) have been shown to have a high likelihood of head and neck injuries due to violence. In light of the seemingly high correlation between IPV and TBI, the Fort Bend Women's Center (FBWC) began a program to screen for and address TBI in this population. As a result of preliminary screening, it was determined that well over half of current FBWC adult clients screened positive for a potential brain injury. Recognizing that TBI symptoms could adversely affect an IPV survivor's self-sufficiency and safety, FBWC sought out effective interventions. FBWC discovered neurofeedback and the promising evidence of its effectiveness in addressing TBI symptoms. FBWC launched a pilot program to address TBI-related symptoms using qEEG-guided neurofeedback as a cornerstone. Utilizing both quantitative and qualitative pre/post measures, FBWC sought to determine the extent to which neurofeedback could remediate TBI-related symptoms experienced by survivors of IPV. To determine the impact of the neurofeedback training, FBWC's program uses standardized written pre/post measurements for assessing overall disability, psychiatric symptoms, depression, anxiety, posttraumatic stress, and substance use. The program also utilizes pre/post qEEG recordings and pre/post videotaped interviews for further evidence of behavioral change. Early results are promising and indicate significant positive changes in scores for disability, depression, anxiety, posttraumatic stress, and substance use. Quantitative EEG comparisons reveal significant changes toward the norm, and videotaped interviews signify noticeable qualitative changes, including changes in grooming and dispositional affect. As of March 2016, the program has recruited 68 participants who have completed at least some of the requirements. Nine participants have completed all pre/post measures and a complete round of individualized neurofeedback training (average = 42 sessions). Average written assessment results for those who have completed the program include:

- 22% reduction in disability scores on the World Health Organization Disability Assessment Schedule
- 42% reduction in scores on the DSM-5 Self-Rated Level 1 Cross-Cutting Symptom Measure – Adult
- 57% reduction in scores on the DSM-5 Severity Measure for Depression – Adult
- 49% reduction in scores on the DSM-5 Severity Measure for Generalized Anxiety Disorder – Adult
- 45% reduction in scores on the DSM-5 Severity of Posttraumatic Stress Symptoms – Adult
- 100% reduction in scores on the DSM-5 Level 2- Substance Use – Adult (only two participants reported substance use)

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Exploring the Impact of Single-Channel, Bivariate and Multivariate Coherence Training on mu Suppression Deficits in Autism Spectrum Disorders

Janease Traylor and Robert Coben
Integrated Neuroscience Services, Fayetteville, Arkansas, USA

Autism spectrum disorder (ASD) can be described as a "group of developmental disabilities that can cause significant social, communication, and behavioral challenges." The epidemiological data presented by the CDC reported that 1 in 68 children are currently diagnosed with ASD in the United States (CDC, 2016). The CDC has noted an increase in the prevalence of ASD since the 1990s, making effective treatment an important part of the national health conversation. A review of the scientific literature yielded studies that indicated connectivity in the brain to have a major impact on autistic symptoms and indicated neurofeedback therapy to be an effective treatment for ASD (Coben & Hudspeth, 2006; Coben, Mohammad-Rezazadeh, & Cannon, 2014); however, sufficient literature was not found to explore differing modalities of neurofeedback treatment. Research, by Pineda, showed ASD symptomology to have ties with mirror neuron systems and mu rhythm suppression deficits (Pineda, 2005). One particular study indicated proof that coherence training is more effective in treatment than bipolar training, supporting the idea that the problems in ASD are, at least in part, also related to challenges in coherence (Coben & Hudspeth, 2006).

Methods. A total of 42 individuals diagnosed on the autism spectrum, were randomly assigned to three treatment groups. They received treatment including bipolar power training, two-channel coherence training, and four-channel multivariate coherence training. Changes in mu rhythm, mu rhythm suppression, power and coherence, and general autistic symptoms and various aspects of social skills will serve as the dependent variables. We will create a session score that appreciates coherence changes globally per session. Analysis will include the use of SPSS software for a MANOVA analysis. It will also include the use of NRep software suite to measure global changes in power and coherence.

Assessments. Quantitative electroencephalogram studies were performed pre- and posttreatment, followed by parent report measures of the Social Responsiveness Scale–Second Edition (SRS-2; Constantino, 2012) and Autism Treatment Evaluation Checklist (ATEC), a parent-rated scale (Rimland & Edelson, 1999). QEEG data was then analyzed with the NeuroRep software suite. ASD symptomology will be rated using the ATEC and parent rated social skills will be appreciated using the SRS-2.

Results: Results of comparison of the first two treatment groups, 2 channel coherence training and bipolar power training, done through statistical analysis using ANOVAs, revealed significant differences with 2 channel coherence training being more effective in lessening mu suppression deficits. Full statistical analysis and discussion of the current data will be presented, using ANOVA and post hoc statistical tests, to evaluate changes in parent reported symptoms, mu rhythm, mu rhythm suppression, and coherence. Our hypothesis that 4 channel multivariate coherence training is more beneficial than bipolar power training and 2 channel coherence training in lessening deficits in social interaction and mu suppression deficits in individuals with ASD diagnoses. Discussion/Conclusion: We hope to help expand the growing knowledge base with this study to further explore the efficacy of different treatment modalities on this group of disorders to help reduce symptoms in individuals with ASD.

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Does Neurofeedback Reduce the Incidence of Behavioral Incidents in an Adolescent Residential Treatment Facility

J. Michael Griffin
Commonwealth Behavioral Healthcare, LLC, Emporia, Virginia, USA

Adolescents in long-term residential facilities often have histories of abuse and neglect as well as family histories of mental illness. Often these youths have received years of outpatient treatment, multiple in-patient psychiatric hospitalizations in acute care facilities, foster placements, and multiple behavioral health residential admissions. Multiple treatment modalities have conventionally been used, including counseling, psychopharmacology, recreational therapy, therapeutic horticulture, equestrian therapy, and others. Despite these interventions, significant acting out behaviors may persist to a degree in which their families and professionals continue to look for more effective means of treatment. A simple Google internet search for “residential treatment programs for adolescents” returns a number of hits, indicating the inclusion of neurofeedback in these programs is fairly commonplace. Yet, a Medline search fails to find efficacy studies supporting the practice in neurofeedback in these facilities, while a discussion with administrators of these programs yield the strong opinion that they are beneficial adjunctive treatment, reducing the frequency and intensity of adverse behavioral events, including aggression to staff, resident-to-resident aggression, stealing, destruction of property, and so on. The current study, performed at Jackson-Feild Behavioral Health Services in Jarratt, VA, seeks to determine whether neurofeedback may be an effective adjunctive treatment in residential behavioral health facilities. Adolescents 13 to 18 years of age were selected by their treatment team for neurofeedback due to continued acting out in their cottages or elsewhere at the facility. Diagnoses include disruptive mood dysregulation disorder, bipolar disorder, obsessive-compulsive disorder, posttraumatic stress disorder, attention-deficit/hyperactivity disorder, oppositional-defiant disorder, conduct disorder, and (emerging) borderline personality disorder. The literature contains numerous peer-reviewed papers describing the benefit of neurofeedback in addressing these issues. All individuals in the study continued to receive psychopharmacology in the form of antidepressants, mood stabilizers, stimulant medications, antihypertensives, and so on, as determined appropriate by their psychiatrist. They also attended the school located on the campus, attend groups and individual counseling, as scheduled by their treatment teams. The outcome measure used in this study was simply the number of incident reports for each adolescent in the study, preneurofeedback and postneurofeedback. After compiling these data, descriptive statistic and nonparametric methods were used to analyze the findings.

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The Effects of Side Effects

Ainat Rogel, Khaled Nasser, and Elizabeth Southwell
The Trauma Center at JRI, Brookline, Massachusetts, USA

There is a preponderance of evidence demonstrating neurofeedback training (NFT) as an effective therapeutic intervention for various disorders such as attention-deficit/hyperactivity disorder (ADHD; Arns, de Ridder, Strehl, Breteler, & Coenen, 2009; Beauregard & Levesque, 2006; Lubar, 2003) and epilepsy (Sterman & Egner, 2006; Tan et al., 2009). As with therapeutic interventions, there are adverse side effects. Although side effects were reported since the early days of NFT (e.g., Hammond, Stockdale, Hoffman, Ayers, & Nash, 2001; Lubar & Shouse, 1976), there are only a few rigorous studies (Rogel et. al, 2015). This presentation tackles the effects of side effects by focusing specifically on their prevalence, severity, detection, and treatment.

Adverse side effects may be prevalent. In a study of 30 young healthy adults, 70% reported 78 side effects. Most were mild and transient, for example, headaches, fatigue, and mood swings (Rogel et al., 2015). Adverse side effects can be divided into nonspecific, associated with the training in general, and specific, associated with the particular protocol (Matthews, 2007; Ochs, 2007; Rogel et al., 2015). Applying inappropriate NFT protocols has been found to be a major cause while certain protocols are more likely to cause specific side effects, for example, increasing power (Hammond & Kirk, 2008; Lubar et al., 1981; Whitsett, Lubar, Holder, Pamplin, & Shabsin, 1982). Although many side effects are transient and will be resolved on their own (e.g., headaches, fatigue, irritability, or long-term pain; Hammond & Kirk, 2008; Hammond et al., 2001), some are severe and persistent, for example, memory problems (Todder, Levine, Dwolatzky, & Kaplan, 2010), depression, seizures, depression, manic attacks. Adjusting the protocol, augmenting treatment with additional protocols, or terminating a protocol often eliminate side effects (Hammond & Kirk, 2008). We focus on assessment and effective elimination strategies in an ongoing study. Our unpublished data collected from 18 children, ages 6–13, who suffered from at least two stressors, have shown that 88% of participants reported at least one side effect. Moreover, 50% reported at least five. Anxiety, increase of energy level, and sleep disturbance were common. Severity varied from tiredness to dizziness, bed wetting, suicidal ideation, and worsening tics. All were addressed and resolved. We focus on assessment and effective elimination strategies in an ongoing study. Currently we are unaware of standard detection tools. Although it is common to track the symptoms that the protocol is meant to address, we recommend tracking changes over a wide range of known effects. Clients may not be obviously associating adverse effects with the NFT, therefore, we have found it beneficial to not only ask the client of symptoms but also to complete a questionnaire. In addition, we recommend that NFB trainees sign a consent form, similar to that involved in medical procedures. Justifiably, the scientific community feels suspicious of an intervention claiming only positive outcomes. Therefore, the study of side effects is important for NFT in order to be accepted as a valid intervention. Detecting and addressing side effects cannot only improve the outcome but also be an ethical obligation of the NFT practitioners.

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Auditory Integration Training (AIT) in Children with Autism Spectrum Disorder: Effects on Auditory Evoked Potentials and Mismatch Negativity

Estate Sokhadze[1], Manuel Casanova[1], Allan Tasman[2], and Sally Brockett[3]
[1]University of South Carolina School of Medicine, Greenville, South Carolina, USA
[2]University of Louisville, Louisville, Kentucky, USA
[3]IDEA Training Center, North Haven, Connecticut, USA

Background. Autism is a pervasive developmental disorder of childhood characterized by deficits in social interaction, language, and stereotyped behaviors along with a restricted range of interests. It is further marked by an inability to perceive and respond to social and emotional signals in a typical manner. This might due to the deficits of sensory information integration. According to several recent theories, sensory processing and integration abnormalities may play an important role in impairments of perception, cognition, and behavior in individuals with autism spectrum disorder (ASD). Among these sensory abnormalities auditory perception distortion may contribute to many typical symptoms of Autism. The pilot study used Berard's technique of auditory integration training (AIT, Brockett, Lawton-Shirley, & Giencke-Kimball, 2014) to improve sound integration in children with Autism. It also aimed to understand the abnormal neural and functional mechanisms underlying sound processing distortion in Autism by incorporating behavioral, psychophysiological, and neurophysiological outcomes.

Methods. It was proposed that exposure to twenty 30-min AIT sessions would result in improved behavioral evaluation scores and positively affect both early (N1, mismatch negativity [MMN, Näätänen, Paavilainen, Rinne, & Alho. 2007]) and late (P3) components of evoked potentials in auditory oddball task. Twenty children with ASD participated in the AIT research study. A group of 16 typically developing children served as a contrast group in the auditory oddball task. Eighteen participants with ASD completed 20 sessions of the training and allowed collection of all required outcomes.

Results. Behavioral questionnaires showed significant symptom severity decrease post-AIT. Comparison of evoked potential characteristics of children with ASD vs. typically developing children revealed several interesting group difference findings, more specifically a delayed latency of N1 to rare and frequent stimuli, larger mismatch negativity; higher P3a to frequent stimuli, and at the same time delayed latency of P3b to rare stimuli in the Autism group. Post-AIT changes in evoked potentials could be summarized as a decreased magnitude of N1 to rare stimuli, marginally lower negativity of MMN, and decrease of the P3a to frequent stimuli along with shorter latency of the P3b to the rare stimuli. These evoked potential changes following completion of Berard AIT course are in a positive direction, making them less distinct from those recorded in age-matched group of typical children, thus could be considered as changes towards normalization. Parental questionnaires clearly demonstrated improvements in behavioral symptoms such as irritability, hyperactivity, repetitive behaviors, and other important behavioral domains.

Conclusions. The results of the study propose that more controlled research is necessary to document behavioral and psychophysiological changes resulting from AIT and to provide explanation of the neural mechanisms of how sensory integration training may affect behavior and psychophysiological responses of children with ASD.

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Event-Related Potential and Induced Gamma Oscillations During Emotional Facial Expression Processing in Autism Spectrum Disorder

Estate Sokhadze[1], Manuel Casanova[1], Ayman El-Baz[2], and Yao Wang[2]
[1]University of South Carolina School of Medicine, Greenville, South Carolina, USA
[2]University of Louisville, Louisville, Kentucky, USA

Background. Autism spectrum disorder (ASD) is one neurodevelopmental disorder which presents with impairments in communication and social skills as well as stereotyped, repetitive patterns of behavior. Disturbances of affective reactivity and innate inability to perceive and respond to social cues including facial emotional expressions in a typical and appropriate manner are the hallmark deficits of ASD. There are several theories describing the neurobiology of underlying deficits. The study used event-related potentials (ERP) and single-trial induced EEG gamma oscillations recording in a modification of a "Theory-of-mind" (ToM) test (Sabbagh, 2004) using facial emotional expression recognition to test emotional responsiveness in children with Autism and typical age-matched children.

Methods. Autism is featured by difficulty in decoding affective facial cues. The goal of the study was to find the differences between ASD group (N = 19, mean age = 16.3 years, SD = 4.9 years) and typically developing children (CNT group, N = 21, mean age = 14.9 years, SD = 4.5 years) in behavioral (reaction time and accuracy), induced gamma and ERP correlates of processing emotional information from facial expressions. Children with ADHD (N = 14, mean age = 14.4 years, SD = 3.9 years) served as a contrast group in induced gamma analysis. Task had four different conditions: either to identify the gender or the emotion of the face. Dense-array EEG was recorded using EGI system. The ERP components analyzed in the study were parieto-occipital N170, frontal P3a, and parietal P3b, while induced gamma oscillations were recorded at eight frontal and parietal sites.

Results. ERP measures yielded the following group differences: N170 showed a more negative amplitude in the ASD group than controls when identifying emotional faces (F = 5.66, p = .023). The latency of N170 was prolonged in the ASD group (F = 7.54, p = .01). The ASD group had a larger frontal P3a amplitude as compared to controls when differentiating emotions (F = 5.15, p = .03). In the emotion recognition conditions, P3b had larger amplitude in Autism (F = 4.17, p = .049). Induced gamma (35–45 Hz) oscillations in ASD showed significant differences from controls at all eight sites of recording in facial emotion discrimination condition (p < .05).

Discussion and Conclusions. These results indicate that more effort is required for an individual with Autism to recognize emotion rather than gender from viewing a face. Abnormal processing of emotional stimuli may provide an explanation for some of the social and communicative deficits observed in Autism. The results of the study contribute to better understanding of possible neurobiological mechanisms resulting in abnormal processing of facial information and in deficient social communication and mentalizing abnormalities in autism spectrum disorders.

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Effects of Repetitive TMS on Autonomic Activity in Children with Autism Spectrum Disorder

Estate Sokhadze[1], Yao Wang[2], Emily Casanova[1], Manuel Casanova[1], and Guela Sokhadze[2]
[1]University of South Carolina School of Medicine, Greenville, South Carolina, USA
[2]University of Louisville, Louisville, Kentucky, USA

Background. Autism is a pervasive developmental disorder marked by difficulty in social interaction, impairments or lack of communication, and restricted range of interests. In addition, many children with Autism exhibit symptoms associated with autonomic dysfunctions, which are presented as abnormalities in regulation of blood pressure, temperature, heart rate, and other body functions by the autonomic nervous system (ANS). The main findings of autonomic abnormalities studies in autism spectrum disorders (ASD) point at reduced baseline parasympathetic activity in association with evidence of increased baseline sympathetic tone resulting in autonomic disbalance, which negatively affects physiological functions and manifests in alterations of various electrophysiological measures.

Objectives. Aim of the study was to investigate electrophysiological measures reflecting ANS activity in two cohorts of children with ASD during 12 and 18 weekly sessions of the low-frequency repetitive Transcranial Magnetic Stimulation (rTMS) over dorsolateral prefrontal cortex (DLPFC). Hypotheses to be tested in the study were as follows: (1) low-frequency (0.5 Hz) rTMS of prefrontal cortex may lower ANS hyperactivation in children with Autism through activation of frontal inhibitory tone controlling ANS, and (2) lower ANS arousal post-TMS will be reflected in decrease of skin conductance level (SCL), heart rate (HR) and increased HR variability, and in improvement of behavioral evaluation scores.

Methods. We investigated autonomic activity in 30 children with ASD during 12 sessions of rTMS and 18 children with ASD during 18 sessions of rTMS over DLPFC. Physiological activity measures such as skin conductance level (SCL), heart rate (HR), and HR variability (HRV) were recorded during rTMS sessions with a C-2 J&J Engineering Inc. physiological monitoring system. Behavioral evaluations were conducted using Aberrant Behavior Checklist (ABC, Aman & Singh, 1994) and Repetitive Behavior Scale (RBS-R, Bodfish, Symons, & Lewis, 1999).

Results. Post 12-session rTMS measurements showed a decrease of low-frequency (LF) component of HRV with statistical changes in HR regression and standard deviation of HR, though without any significant changes in SCL. Post 18-session rTMS outcomes showed slower heart rate accompanied by increase of high-frequency (HF) component of HRV (as indicated by R-R intervals of ECG), higher deviation of R-R, and lower LF/HF ratio.

Conclusions. Our findings show reduced sympathetic activation after rTMS resulting in lower HR predominantly through withdrawal of sympathetic tone (LF of HRV) and increase of parasympathetic cardiac neural control activity post 12 rTMS sessions. Neuromodulation using prolonged 18-session rTMS course in children with ASD resulted in a more pronounced HR slowing, a higher power of HF of HRV and time domain measures of HRV after 18 rTMS course in Autism. Behavioral evaluations based on ABC and RBS-R scores showed similar improvements in 12 and 18 sessions of rTMS. Low-frequency rTMS activates inhibitory tone of the frontal cortex resulting in a lower excitation of the ANS probably through the inhibitory fronto-limbic circuits.

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QEEG-Guided Neurofeedback for Autism Spectrum Disorder (ASD): A Validating Case Study

Justin Leiter, Jeremy London, and Thomas Collura
ADD Centre and Biofeedback Institute of Toronto, Mississauga, Brain Enrichment Center, Bedford, Ohio, USA

Autism spectrum disorder (ASD) consists of persistent deficits in social communication and restricted repetitive patterns of behavior, interests, and/or activities (American Psychiatric Association, 2013). Individuals with ASD can also experience neurocognitive disturbances in voluntary behavior, social interaction/facial recognition, as well as executive function, specifically in shifting attention (Courchesne et al., 1994; Mosconi et al., 2009; Ozonoff, Pennington, & Rogers, 1991). Treatment for ASD comes in the form of off-label medications, various behavioral interventions usually in the form of Early Intensive Behavioral Interventions (EBIB), and specialized diets such as gluten-free and casein-free or GFCF (Elder, 2008; Howlin, Magiati, & Charman, 2009). Further research into additional interventions is needed. Currently, the implications of neurofeedback as a treatment for ASD are being explored, and recent research is promising.

Neurofeedback is on the rise as it offers noninvasive treatment through simple operant conditioning. Some neurofeedback has been focused on the suppression of theta power to increase the mind-body connection and thus decrease deficits in executive function, as well as a focus on the mirror neuron system (MNS) to improve social interaction. (Kouijzer, de Moor, Gerritis, Buitelaar, & van Schie, 2009; Pineda, Carrasco, Datko, Pillen, & Schalles, 2014). Both studies showed significant improvement. This case study will focus on quantitative electroencephalogram (qEEG)-guided

neurofeedback as it allows for the individualization of treatment. Through qEEG mapping, unique dysregulations can be synchronized with the individual's reported and collected symptomology. This harmonization allows for neurofeedback to directly target the implicated dysfunction. In recent research, it has been found that a reduction in cerebral hyperconnectivity through qEEG-guided neurofeedback can lead to symptom relief (Coben & Padolsky, 2007). Executive function deficits have also been relieved though qEEG-guided neurofeedback in individuals with ASD (Kouijzer, de Moor, Gerrits, Congedo, & van Schie, 2009).

This case study will compare its treatment progression with recent literature, as well as reporting qEEG-guided neurofeedback's effectiveness on relieving psychological and neurocognitive disparities. This case study may also provide treatment guidance for neurofeedback clinicians with clients presenting with ASD.

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Change of Power Spectral Density and Coherence Following Acupuncture Treatment in Patients with Insomnia

Go Eun Lee[1], Hyung Won Kang[2], Lakhyung Kim[3], Jung-Hwa Lim[4], Jong-Hyang Yoo[5], Sujeong Mun[5], and Young Man Wei[6]

[1]Korean Rehabilitation Center, Seoul, South Korea
[2]Sanbon Hospital of Wonkwang University, Gunpo-city, Gyeonggi-do, South Korea
[3]Woosuk University, Jeonju, Jeonbuk, South Korea
[4]Pusan National University School of Korean Medicine, Yangsan, Gyeongsangnam, Korea
[5]Mibyeong Research Center, Korea Institute of Oriental Medicine, Daejeon, South Korea
[6]Hyooclinic, Seoul, South Korea

Background. Insomnia is one of the common symptoms in primary medical care. Insomnia usually distracts the attention and worsens daytime dysfunction and the depressive or anxious symptom. Recent studies of acupuncture for isomnia reported that acupuncture groups showed significant improvements compared with control groups. While the neurophysiological mechanism of acupuncture hasn't been revealed for insomnia, a few studies measured the effect of acupuncture treatment using qEEG. Our objective was to investigate the characteristics of the quantitative Electroencephalography (qEEG) at pre- and postacupuncture treatment on patients with insomnia.

Methods. Participants who have some problems initiating or maintaining sleep, or nonrestorative sleep more than 3 days a week and ISI over 8 and below 21, were treated by acupuncture for 2 weeks (3 times a week, total 6 times). We assessed the effectiveness of acupuncture for insomnia by ISI (Insomnia Severity Index), PSQI (Pittsburgh Sleep Quality Index), BDI (Beck Depression Inventory-K), STAI (State-Trait Anxiety Inventory-K), EQ-5D (EuroQol-5 Dimension), general health state VAS (Visual analogue scale). We also measured and analyzed power spectral density (delta 1–4 Hz, theta 4–8 Hz, alpha 8–12 Hz, beta 12–25 Hz) and coherence at baseline and the end of treatment

(second week) on linked ear montage using the NeuroGuide software program.

Results. Thirty-two participants were enrolled; 2 participants dropped out because of personal reasons. During the study period, there were no adverse events. The RMANOVA model demonstrated that total score of ISI was significantly decreased between baseline and the end of treatment (second week) and baseline and 2 weeks after treatment (fourth week), but not the end of treatment (second week) and 2 weeks after treatment (fourth week). During eye-closed state, on O1 in theta, T5 in beta, and O1 in beta, absolute power (AP) significantly increased. Moreover, on the same site in the same band, deviation from midpoint (zero) of *z*-scored absolute power (ZAP) also decreased significantly ($p < .05$). The total number of *z*-scored absolute power exceed range of 90% (±1.65) or 95% (±1.96) decreased after treatment during eye-closed state, but not significantly. Coherence in delta (FP2-T4, Fz-T5, F4-T4, F8-T4, T3-T5, C3-T5, C3-P3, Cz-T5, C4-T4, T4-P4, T4-T6, T5-P3, T5-Pz, T5-O1, T5-O2, P3-Pz, P3-O1, Pz-O1), theta (T4-T6, T5-P3, T5-O1, T6-O2) and alpha (FP1-T5, FP2-T5, FP2-P3, F7-T5, F7-O2, F3-T5, Fz-T5, F4-T5, T3-O1, T3-O2, C3-O1, Cz-T5, T5-P4, T5-T6, T5-O2, P3-Pz, P3-P4, P3-T6, Pz-P4, P4-O1, T6-O1, T6-O2) significantly increased on temporofrontal, temporooccipital, temporocentral and temporoparietal regions. Coherence in beta (FP1-O2, FP2-O2, F7-T6, F7-O1, F7-O2) significantly increased between frontal and occipital region.

Conclusion. Acupuncture would be effective for insomnia affecting neurophysiological aspects. The deviation of ZAP from midpoint (zero) was decreased after acupuncture treatment, but not significantly, and coherence-based functional network in theta and alpha range was increased between temporal and other regions. However, our study had a limitation of small sample size and non-control group. Therefore, a larger sample size and controlled study are needed to confirm the effectiveness and neurophysiololgical changes of acupuncture for insomnia.

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Effects of Prefrontal Neurofeedback on Perceived Emotional State and Cognitive Functioning in Adolescents with Drug Abuse History: A Pilot Study

Estate M. Sokhadze[1], Jonathan Cowan[2], Yao Wang[3], Manuel Casanova[1], Eva Lamina[3], and Allan Tasman[3]
[1]University of South Carolina School of Medicine, Greenville, South Carolina, USA
[2]Neurotek LLC, Goshen, Kentucky, USA
[3]University of Louisville, Louisville, Kentucky, USA

Background. In addition to well-known cognitive impairments, there are disruptions in processing emotion in individuals with substance dependence and in those predisposed to drug abuse (Sokhadze, Stewart, & Hollifield, 2007). Neurofeedback training-based intervention is one of the potentially efficacious nonpharmacological treatment options for substance use disorders (Sokhadze, Cannon, & Trudeau, 2008; Horrell et al., 2010). There have been used several neurofeedback protocols (e.g., Peniston & Kulkosky, 1989; Scott, Kaiser, Othmer, & Sideroff, 2005, etc.) that reported success in treating addictive behaviors. However, there are practically no studies on the use of neurofeedback in occasional drug users who have drug use history but did not yet develop substance dependence (Sokhadze, Stewart, Tasman, Daniels, & Trudeau, 2011). We developed protocol that might be used to prevent drug abuse through self-regulation training aimed to enhance EEG measures of positive emotional states.

Methods. One of the aims of this pilot study was to determine the dynamics of self-reported perceived positive emotional state rating before, during, and after twelve 25-min long neurofeedback training course in two groups of subjects. One group of subjects had documented drug use history (*N* = 6), most of them referred from Louisville Adolescent Network for Substance Abuse Treatment (LANSAT); and another one was a group of drug-naïve subjects (*N* = 6, recruited mostly from undergraduate students). Our hypothesis was that the prefrontal gamma power increase over 12 training sessions is possible and will be accompanied by increased rating of positive affect. As a preferred neurofeedback protocol, we used enhancement of gamma range (centered around 40 Hz) activity and inhibition/suppression of other frequencies at the prefrontal site (FPz).

Results and Discussion. Neurofeedback training at the midline prefrontal site after 12 sessions resulted as predicted in better performance on MicroCog and IVA+Plus tasks and improved scores on emotional self-reports (i.e., happiness) and clinical (BDI-II) status. Individual reports of self-received happiness scores assessed during each neurofeedback session using Continuous Response Digital Interface showed significant positive correlation with relative gamma power during individual training sessions. Analysis of EEG showed positive changes in the pattern of theta/beta ration and relative power of gamma. Neurofeedback was accompanied by positively correlated subjective self-reports of positive emotional feelings during sessions and resulted in improved performance on IVA+ and MicroCog tests during postneurofeedback evaluations. Posttraining evaluations and 3-month follow-up showed decrease in depression scores and increased happiness rating in both groups of subjects in this study.

Conclusions. Neurofeedback training aimed at inhibiting high amplitude EEG rhythms and upregulating high frequency rhythms in a group of adolescents at risk of drug abuse was accompanied

by increase of self-reported rating of positive emotional states and completion of the course resulted in improved mood, enhanced performance on selective attention test and neurocognitive tests. The findings in this pilot warrant further research to investigate potential clinical efficacy of the method.

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EEG Phenotypes in Obsessive-Compulsive Disorder (OCD)

Antonio Martins-Mourao[1] and Stig Hollup[2]

[1]Open University/London Scientific Neurotherapy, London, United Kingdom

[2]Norwegian University of Science and Technology, Trondheim, Norway

OCD is a complex and disabling form of anxiety disorder affecting 2–3% of the general population. It is characterized by recurrent intrusive thoughts (obsessions) that typically cause distress and by repetitive behavioral acts (compulsions) that are performed to reduce severe anxiety levels. Over 40% of patients currently fail to respond to psychotherapy and/or medication treatments (Bandelow, Seidler-Brandler, Becker, Wedekind, & Rüther, 2007; Pallanti et al., 2002), especially when physicians base their judgments on the DSM-IV diagnostic categories and remain blind to patient neurophysiological subtypes (or EEG-phenotypes) underpinning the illness. Although knowledge of such subtypes has been found to predict depressed patients' response to medication (Cook et al., 2013), little is still known about the EEG-phenotypes in OCD.

The present study explores the relationship between EEG frequency bands and clinical symptoms of OCD. The EEG recordings of 60 patients with OCD and 60 healthy controls were correlated with behavioral measurements using the Yale Brown Obsessive Compulsive Scale (Y-BOCS) and the Minnesota Multiphasic Personality Inventory-2-RF (MMPI-2-RF). Statistical analyses revealed three main EEG phenotypes for OCD characterized by increased midline theta ($p < .01$), frontal beta2 power ($p < .01$), and a posterior beta1 power ($p < .01$). A subgroup was also found to have increased alpha peak frequencies (i.e. 11 Hz or above), suggesting sympathetic overarousal. Pearson statistics showed that beta2 power correlated positively with obsession and compulsions severity (Y-BOCS) and thought dysfunction (MMPI-2-RF). Regression analysis showed significant correlation ($p < .05$) between beta2 in posterior regions and total Y-BOCS score and several MMPI clinical scales. Applying a two-parameter linear model (obsession and compulsion score) suggested that this dependence is driven by the obsession component.

The above results suggest that the same DSM-based diagnostic category (i.e. OCD) may present very diverse neurophysiological profiles, or EEG-phenoptypes. The use of the above data will predict appropriate medication for individual cases and is likely to increase the specificity and efficacy of future neurofeedback protocols for this patient group potentially leading to increased health comes.

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Equivalence of a Continuous EEG Discrimination Task to Standard Operant Control Training

Jon Frederick[1], Casey Klein[2], Heim Andrew[2], Kelli Dunn[3], and Julia Schreiber[2]
[1]St. Cloud State University, Murfreesboro, Tennessee, USA
[2]Middle Tennessee State University, Murfreesboro, Tennessee, USA
[3]Centerstone, Nashville, Tennessee, USA

Biofeedback is commonly believed to train increased awareness and voluntary control over physiological processes that would otherwise remain unconscious and involuntary (Frederick, in press; Olson, 1987; Plotkin, 1981). Brener (1974) argued that repeated pairing of external feedback with internal afferents related to the response lead to the awareness and learning of a "response image," which allowed control of the response without external feedback. However, relatively little research has examined the relationship between awareness and control of physiological states. Most clinical and experimental biofeedback research has emphasized operant control, by rewarding subjects for producing desired physiological states. Discrimination training is another form of operant conditioning, that rewards subjects for increased awareness, that is, for correctly reporting their physiological state. For instance, the first historical report of operant conditioning of the EEG was a discrimination task in which subjects were prompted to guess whether they were in a high or low alpha amplitude state and immediately informed if their response was correct (Kamiya, 2011). Since similar kinds of self-monitoring and evaluation have been found to facilitate learning of motor skills (Boutin, Blandin, Massen, Heuer, & Badets, 2014; Kolovelonis, Goudas, & Dermitzaki, 2011), we hypothesized that combining discrimination training with standard neurofeedback would facilitate learning of operant control of EEG alpha (8–12 Hz) amplitude. However, Heim, Dunn, Klein, Powers, and Frederick (2016) argued that Kamiya's "discrete" discrimination paradigm resulted in very slow learning because it provides relatively few trials per minute. The present study examined the effect of a continuous discrimination task (CDT) on learned operant control of EEG alpha. In the CDT, participants manipulated a controller indicating their subjective rating of their alpha amplitude on a 10-point scale. The changing pitch of a tone (presented about 120/min) represented the absolute difference between the participant's rating and their actual alpha amplitude. One group (n = 9) received seven 40-min sessions of standard operant control training to increase and decrease alpha in eight alternating 5-min runs. The CDT-mixed group (n = 9) received only half of that training per session, instead performing the CDT during the 11–20th and 31–40th minutes of each session. Performance in the alpha operant control task was defined as the percent average difference between the increase and decrease conditions. The CDT group performed nonsignificantly higher than the control group (mean session improvement over first session baseline 14.0% vs. 6.8%, one-tailed $t[16] = 0.822$, $p = .22$, d = 0.39). Although these results do not demonstrate that the CDT facilitates learning of voluntary control of EEG alpha, the fact that the CDT can be substituted for standard operant control training during half of the session time without a deficit in learning suggests that these two tasks are functionally equivalent and may have substantial similarity in the skills required. While results in this sample of mostly normal subjects show a small effect size, the CDT may have some clinical utility to provide additional motivation to clients who show deficient attention toward standard neurofeedback tasks.

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