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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, Knoxville Neurofeedback Group, 7147 Kingston Pike, Ste 103, Knoxville, TN 37919, USA. Email: rcannonphd@gmail.com

Welcome to *NeuroRegulation* Volume 5, Issue 2. Thank you for joining us for the latest issue.

In the current issue Javier Vigil provides a review of Francisco de Goya's history of psychological and physiological issues. In doing so, he also provides data pointing out that electrophysiological interest in medicine dates back farther than might typically be considered. Jeff Tarrant and Hannah Cope provide proof-of-concept data concerning the combination of neurofeedback and virtual reality and its effects on mood and frontal asymmetry measures. These types of data are important to the continued evolution of the interface between technology and neurophysiology. Erik Peper, Richard Harvey, Lauren Mason, and I-Mei Lin present data concerning posture and its relationship to perception and performance in mathematics. These authors have examined the importance of posture across numerous domains and continue to provide insight into the effects of posture on human performance and functionality. Rex Cannon, Whitney Strunk, Stephanie Carroll, and Spencer Carroll present a case study of LORETA neurofeedback in a 3-year-old female with intrauterine drug exposure. The population of children exposed to drugs in utero continues to grow, and the foster care and education systems are being overwhelmed by this problem.

NeuroRegulation thanks these authors for their valuable contributions to the scientific literature for neurofeedback and learning. 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. We encourage researchers, clinicians, and students 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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NeuroRegulation

Sparks over Saturn: A Revision on Francisco de Goya's (1746–1828) Disorders

Francisco Javier Vigil Morant

Licensed Health Psychologist (PGS), Madrid, Spain

Abstract

In 2012, the official curator of the Prado Museum, Gudrun Maurer, revealed a letter which showed that the famous painter Francisco Joseph de Goya y Lucientes (1746–1828) took electrotherapy sessions with a "Glass Disc Machine" (a Ramsden machine) to cure his deafness. The 1793 "illness of Goya" seems still to be an enigma. We will briefly review the use of electrotherapy circa 1800 and make a revision, with DSM-based criteria, of the diseases and mental disorders (Bipolar II, PTSD) that could have affected Goya during his life, especially syphilis, malaria, typhus, and a lifelong heavy metal poisoning.

Keywords: Goya; electrotherapy; bipolar; depression; lead; neurosyphilis

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***Address correspondence to**: Francisco Javier Vigil Morant, Calle Juan Díaz Mula, 4, Pozuelo de Alarcón 28224, Madrid, Spain. Email: newrofeedback@gmail.com

Edited by:
Rex L. Cannon, PhD, Knoxville Neurofeedback Group, Knoxville, Tennessee, USA

Reviewed by:
Rex L. Cannon, PhD, Knoxville Neurofeedback Group, Knoxville, Tennessee, USA
Randall Lyle, PhD, Mount Mercy University, Cedar Rapids, Iowa, USA

Structure

Materials and Methods

A search was conducted in articles in PubMed and Google Scholar on previous hypothesis about Goya's illnesses, his deafness, and possible interactions. Theories were checked for specific symptoms like the ones described by his friends, doctors, and the painter himself. We have used only the highest credible institutional, scientific, university, and museum sources.

Introduction

In 1777, Dr. Maudyt records one of the first cases of electricity applied to medicine. The case describes a person who had a stroke and suffered a left-sided hemiplegia, rendering his members cold and faint. The treatment was conducted in baths with triboelectricity currents and Leyden bottles' discharges to force mobility response. After 10 months, Maudyt reports an improvement in the mobility, blood circulation, and strength (Rozier, 1781).

Triboelectricity became a topic in Medicine books. In 1835, the existing electricity treatments were reviewed (Guerard, 1835). For the physician who wanted to use electricity, a simple friction machine was recommended, together with a set of Leyden bottles. The protocols were electric baths and spark discharges. The usual goal of the treatments was restoration of secretions and blood circulation. We have to note that depression and deafness were included as potential indications of the treatment. The effect of polarity is described (phosphene color and mouth taste), but there is no other significant advice regarding application or treatment effectiveness.

The author suggests more rigorous studies, with a call to certify which illnesses might be the true object of the therapies. We must underline the fact that deafness was one of the prevalent diseases without cure at that time.

In September 1794, a letter was written by an official from the Court of King Charles IV of Spain. The letter was addressed to F. Chavaneau, director of the Royal Laboratory, saying that the Court was going to cover the costs of the glass disc that had been broken by Goya, provided the machine stayed at the Laboratory after being fixed (Maurer, 2012). From this letter, we can note the following facts: that Goya was using an electrotherapy treatment for his deafness until 1793, and that he broke the disc. The machine was restored, but we don't know whether Goya used it ever again.

Even though there were other models at that time, the machine described could have been a Ramsden machine. Chavaneau describes a standard friction machine as one with a rotating glass disc and skin or leather pads (Chavaneau, 1790, pp. 191–194). We have traced several Ramsden models in Spain, most of them being built later than 1800. These devices can deliver thousands of volts at a very low intensity.

The protocol is described in Maurer's article and Varela's Otology review (Varela, 2005). One of the electrodes was placed in the ear with a salty solution, the other in the contra lateral ear or the arm. The current was set when the disc was turned, creating a positive accumulation in the disc and a continuous electric discharge through the collectors.

1

2

3

1 Small Ramsden Machine, the type probably used by Goya.
2 A detail of the collector, near the glass disc.
3 In the last image, a student handles a Leyden bottle facing it to an electrode.
All Images kindly authorized by Colegio Inmaculada , Gijon, Spain.
Detail photo by Javier Valdes Gomez, Colegio Inmaculada.

Figures 1–3. Ramsden machine, circa 1800.

Goya's Disease or Goya's Diseases

The main hypothesis of many authors and biographers of Goya is that he suffered a strange disease in 1793 that completely changed his vision of the world and turned him into an artist of the insane and obscure (Vallejo-Nagera, 1982).

However, Goya suffered from more than one disease. As Felisati and Sperati (2010) say, Goya suffered diseases which had a high prevalence in the 19th century. Goya was probably affected by syphilis before 1780 and was diagnosed in 1825 of a Tabes Dorsalis due to urinary problems (Gómiz León, 2007). This was a neurological consequence of years of suffering the disease. He also suffered from malaria (1786), lead intoxication (1792; Canellas, 1981) and typhoid fever (1819; Gómiz León, 2011), and finally died from a stroke (1828) at the age of 82.

The famous 1793 "Goya illness" (which started with a two-month lead colic crisis) provoked a debilitating state in which sudden vertigo, tinnitus and deafness, and paralysis, occurred in a brief period of time (probably weeks; Canellas, 1981). The interaction of lead toxicity, two months before, a possible use of mercurial medication, and a crisis of encephalitis due to secondary syphilis could explain the episode. Gordon is one of the authors who support the thesis of Goya's having syphilis (Gordon, 2009).

Lead and Mental Disorders in the Present Time

Lead is known to affect cell and neuron metabolism. The effects might include impairment in rods activity, impairing vision, hearing problems, and brain hypertension. The effects of lead poisoning have also been studied in cognitive and EEG domains. Studies commonly reflect the relationship between lead blood content and a lesser IQ.

Lead levels are said to be related to psychological disorders. A major United States study shows that lead even in so-called safe levels has been found to be linked to depression and, especially, panic disorder but not schizophrenia (Bouchard et al., 2009). On the other hand, lead and cadmium are elevated in bipolar patients. Zinc is elevated in the manic phase (González-Estecha et al., 2011). Goya also reportedly smoked tobacco, which increases cadmium levels.

Regarding toxic levels in adults as found in EEG, a study shows that exposure to lead fumes increase 4–6 Hz amplitude, decreasing the total amplitude of the rest of frequencies, from 6 to 16 Hz in the parietal zone, depending on the level of poisoning (Saito & Abe, 1965). Eyes-closed alpha slowing of about two Hz, which is reversible, is noted in a case of lead encephalopathy, but convulsive symptoms do not improve in adults (Simpson, Seaton, & Adams, 1964).

Chronic lead encephalopathy can lead to seizures (Rao, Vengamma, Naveen, & Naveen, 2014). In the case of Van Gogh, lead could be the reason of his mood and epileptic symptoms. Van Gogh reportedly shares with Goya (1793) the symptom of vertigo when climbing stairs (González Luque & Montejo González, 1997, p. 15).

Lead intoxication theory is based on the addition of two levels of exposure, the environmental, documented in Europe, due to use of lead glazing in food cooking earthenware (Nriagu,1991) and the occupational. Critics of this theory say that Goya had a color mixing assistant while he was painter in the Court. The 1792 lead colic crisis is, however, a testimony of occupational poisoning, and it's the origin of the health rest permission that led to his 1793 illness. Goya's lead intoxication is supported by Niederland (1973).

Goya's Mental Disorders

Several authors have studied the case of Goya in order to understand or analyze his art and behavior. The cyclothymic behavior seems evident due to his own description of altered mood states, reflected in his correspondence (Canellas, 1991). Hyperthymic behavior, as a characteristic of his biography, has been confirmed by Dervaux, but, having in mind the problems and diseases that Goya had to face, the author cannot confirm a bipolar disorder (Dervaux, 2007). Bipolar disorder and bipolar cycles in adulthood and senescence have been analyzed by Alonso-Fernández (1999). Fernandez-Doctor investigated the record of two possible family members (one male, one female) of Goya's mother, who were incarcerated because of dementia in Zaragoza_Asylum, and this supports the possible existence of a familiar diathesis (Fernandez-Doctor, Seva, & Dening, 1994).

PTSD, on the other hand, could explain a period from 1800 to 1820, caused by death of family and friends, war exposure (Bouvier, 2011), famine, and financial difficulties.

Finally, Spanish psychiatrists such as Antonio Vallejo-Nagera have supported the existence of schizophrenic or schizoaffective traits in Goya (Vallejo-Nágera, 1982).

Goya seems to have experienced bipolar cycles in his life and his mood turned from hyperthymic and productive to depressed, agitated, or irritated. A cycling bipolar period could be identified in the years from 1780 to 1797, then some periods of depression and PTSD from 1802 to between 1820 and 1823, and a euthymic period from 1823 to 1828. Lack of direct and reliable sources have hindered any study on Goya's youth period.

Discussion

As we have seen, Goya suffered several illnesses which might have affected his character. If we analyze all of them (excluding infectious diseases or autoimmune diseases, which we can´t confirm), we can find that most of them lead to encephalitis or similar symptoms. This happens in the case of lead intoxication, cerebral malaria (Ravin & Ravin, 1999), and syphilis. In 1819, Goya was about to die of typhus and probably suffered a prolonged, severe state of coma (Gómiz León, 2011).

On the other side, his bipolarity could explain some of his health crisis. Hypomanic behavior led him (1794) to paint during the day and concentrate on the details in the night (Canellas, 1981), which seems a bipolar trait. He painted very quickly, and probably he got exhausted because of this hard work and exposure to small amounts of heavy metals present in the paint. After some period of rest, he resumed his work again. The cycle of activity leading to depression could have been increased by the lead intoxication.

A recent scientific session (Gil-Carcedo García, 2017) on the Royal Academy of Medicine of Spain focused on the existence of a neurosyphilis (from the medical point of view) and a bipolar disorder (from the psychiatric point of view).

Conclusion

Goya received electric therapy in 1793, making it probably the first case ever recorded in Spain. Deafness and depression were two conditions for which triboelectricity was used. He likely still hoped to improve his total deafness, which didn't happen, even though he operated the machine for a long period of time, breaking the disc. Regretfully, there is no exact record of the technique or protocol used.

Goya's personality may have been affected by a bipolar disorder, specially remarkable in his adulthood, and the interactions of environmental, occupational, medications, life events, and several diseases that affected his life.

Limitations of the Study

Many authors have approached the study of Goya from different perspectives; the vision of this article has been to consider simple explanations of Goya's health and his psychological issues. The article admits the difficulties to diagnose Goya's case, where symptoms are so similar and the interactions with mental disorders many. Possible psychological disorders of Goya are also merely hypothetical since they are based only in documents and testimonials.

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Combining Frontal Gamma Asymmetry Neurofeedback with Virtual Reality: A Proof-of-Concept Case Study

Jeff Tarrant and Hannah Cope*

NeuroMeditation Institute, Corvallis, Oregon, USA

Abstract

The current proof-of-concept case study was designed to determine if a consumer-grade neurofeedback system (Muse) could be used in conjunction with specially designed virtual reality (VR) environments (Positivity by Healium) to impact gamma frontal asymmetry as well as create positive changes in mood states. Four firefighters served as subjects and completed pre–post mood rating scales as well as 19-channel EEG recordings. An examination of sLORETA frontal lobe ROIs demonstrated a postintervention gamma asymmetry shift to the left in three of the four subjects. In addition, subjects generally reported changes in mood consistent with the frontal asymmetry changes. Overall, these results provide initial support for the idea that a consumer-grade brain computer interface (BCI)/VR intervention can potentially have therapeutic utility and deserve further study.

Keywords: virtual reality; positivity; gamma; frontal asymmetry; sLORETA; Muse

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***Address correspondence to**: Dr. Jeff Tarrant, 873 NW Grant Avenue, Suite A, Corvallis, OR 97330, USA. Email: dr.tarrant@hotmail.com

Edited by:
Rex L. Cannon, PhD, Knoxville Neurofeedback Group, Knoxville, Tennessee, USA

Reviewed by:
Rex L. Cannon, PhD, Knoxville Neurofeedback Group, Knoxville, Tennessee, USA
Randall Lyle, PhD, Mount Mercy University, Cedar Rapids, Iowa, USA

Introduction

Virtual reality (VR) is a computer-generated environment that simulates a realistic experience in three-dimensional space. Typically, this illusion is accomplished by having the user wear headgear, which covers the eyes and utilizes a stereoscopic display, displaying two slightly different angles of the scene to each eye, providing the experience of depth. This, in combination with other strategies, such as parallax and shading, creates a very realistic experience. While this technology has been primarily associated with the video game industry, it is increasingly being utilized as a clinical intervention for a variety of medical and mental health concerns (Rizzo & Koenig, 2017).

As a mental health intervention, VR has primarily been used as a sophisticated addition to exposure therapy in the treatment of phobias (e.g., fear of heights, flying, etc.; Lamson, 1994; Rothbaum et al., 1995). Because specific environments can be created in a multidimensional, controlled platform, it provides a unique opportunity to address these fear-based concerns beyond imagining a scenario or attempting to create a live experience.

In addition to specific phobias, a recent review of VR research shows that this modality is a promising intervention used in the treatment of a variety of mental health concerns, including social anxiety, posttraumatic stress disorder (PTSD), panic disorder, generalized anxiety disorder, obsessive-compulsive disorder, schizophrenia, acute and chronic pain, addictions, eating pathology, and autism (Maples-Keller, Bunnell, Kim, & Rothbaum, 2017). As these applications gain traction, an increasing number of companies are beginning to create VR systems that interface with various bio- and neuromodulation techniques.

To date, the only published study combining VR with neurofeedback utilized a single channel (Cz) beta reward protocol in combination with VR environments as an intervention for inattention and impulsivity. Cho et al. (2004) compared the impact of VR with neurofeedback, VR without neurofeedback, and a control group as an intervention for 14- to 18-year-old boys with "social problems." After eight sessions, both the VR and the non-VR groups showed improvements on a continuous performance test, while the control group did not. In addition, it was noted that the VR group showed nonsignificant trends toward more improvement than the non-VR group. This study provides initial evidence that neurofeedback combined with a therapeutic VR environment can be used successfully in the treatment of mental health concerns.

The current proof-of-concept case study was designed to determine if a consumer-grade neurofeedback system (Muse) could be used in conjunction with specially designed VR environments (Positivity by Healium) to impact gamma frontal asymmetry as well as create positive changes in mood states. If successful, such an intervention could be combined with other therapeutic modalities for the treatment of depression. The intervention in this case study has two active components: gamma frontal asymmetry neurofeedback and an Open Heart VR meditation experience.

Frontal Asymmetry Neurofeedback

The frontal asymmetry model of arousal suggests that hyperactivation in left frontal areas is associated with approach behaviors and positive mood, while hyperactivation in right frontal areas is associated with withdrawal behaviors and negative mood (Sutton & Davidson, 1997). Not surprisingly, these patterns have also demonstrated a relationship to mental health. For example, greater left-sided activation has been associated with emotional flexibility (Papousek, Reiser, Weber, Freudenthaler, & Schulter, 2012), emotion regulation (Jackson et al., 2003), and reductions in negative affect (Tomarken, Davidson, Wheeler, & Doss, 1992). Extreme right frontal asymmetries have been linked to depression (Thibodeau, Jorgensen, & Kim, 2006) and social anxiety (Moscovitch et al., 2011).

Neurofeedback interventions that shift this asymmetry toward left activation (or right deactivation) have been shown to lead to improvements in mood and an alleviation of depression symptoms. For example, Baehr and colleagues used an alpha asymmetry protocol in two different sets of case studies to successfully treat depression in patients also being treated with psychotherapy (Baehr & Baehr, 1997; Baehr, Rosenfeld, Baehr, & Earnest, 1999). Quaedflieg et al. (2016) showed that frontal alpha asymmetry neurofeedback can result in changes in relative frontal asymmetry at rest, suggesting it is potentially a powerful tool for use in the treatment of depression. Mennella, Patron, and Palomba (2017) extended these findings by showing that frontal alpha asymmetry neurofeedback led to significant changes in resting asymmetry as well as changes in negative mood and anxiety. Other researchers have taken the same concept but applied it by rewarding left frontal beta activity while inhibiting alpha and theta activity (Hammond, 2000, 2005a, 2005b).

While much of the historical research in this area has focused on alpha asymmetries, other research has indicated that the gamma frequency band shows the strongest and most consistent relationship to frontal lobe glucose metabolism (Oakes et al., 2004) and may be an important measure of frontal activation patterns (Davidson, 2004). For example, Ramsøy, Skov, Christensen, and Stahlhut (2018) recently found that frontal gamma asymmetry was a better predictor of motivation than alpha asymmetry. Another recent study demonstrated that gamma frontal asymmetry is a reliable metric for assessing shifts in emotional states (Bonnstetter, Hebets, & Wigton, 2015).

Utilizing the two frontal sensors on the Muse headset (AF7, AF8), StoryUp XR (Columbia, MO) in coordination with the NeuroMeditation Institute designed a gamma (30–44 Hz) frontal asymmetry protocol. The protocol provided a reward when the ratio of left frontal gamma was greater than right frontal gamma. Positive feedback was provided by the VR meditation scene advancing when criterion was met.

Open Heart VR Meditation

In addition to using frontal gamma asymmetry neurofeedback, the experience in this study incorporated a guided meditation to facilitate a positive mood state. Researchers have successfully categorized meditation styles based on how attention is directed, the intention of the meditator, and which brain waves are activated and in which brain regions (Tarrant, 2017). Based on this understanding, meditation styles that emphasize activation of a positive emotional state consistently result in increased left frontal activation and frequently in the gamma EEG band. For example, Engström presented data on a Tibetan Buddhist with many years of compassion meditation practice (Engström & Söderfeldt, 2010). During meditation, fMRI imaging revealed activation of several brain regions involved in sustained attention and empathy.

However, the strongest findings were related to activation of the left prefrontal cortex.

In a study comparing eight long-term meditators with eight novice meditators, there were common activation patterns found in the adepts when engaged in a compassion form of meditation. Among the findings, expert meditators showed large increases in gamma brainwave activity during the meditation in several areas of the brain including the left prefrontal cortex (Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004).

The current report examines the impact of a brief Open Heart VR experience combined with a gamma asymmetry neurofeedback protocol. Specifically, this proof-of-concept case study is designed to determine the feasibility of combining VR and brain computer interface (BCI) to shift frontal gamma activity and positively influence mood states. Changes in mood were assessed through self-report questionnaires (PANAS and STCI-S<30>) as well as gamma asymmetry patterns measured in the frontal lobes with sLORETA analyses.

Material and Methods

Participants

Participants were four male, Caucasian firefighters with a mean age of 39.5 (*SD* = 5.6). Participants self-reported their experience with meditative practices (i.e., seated meditation, yoga, qigong, chanting, prayer, or other practice) over the last 6 months and amount of time engaged in these practices each week. This information along with education level in listed in Table 1. The study was performed in a private office of a firefighter union hall. It was approved by the Quorum Institutional Review Board, Seattle, WA.

Table 1
Demographic Data

Client #	Age	Gender	Ethnicity	Education	Meditative Practice Over the Last 6 Months[a]	Time in Meditative Practice Weekly[b]	Mental Health Diagnoses Within Last 12 Months
1	44	Male	White	Bachelor's	None	0	PTSD
2	43	Male	White	Some College	None	0	Depression
3	30	Male	White	Associate	None	0	None
4	41	Male	White	High School	1–2x/week	1–60 min	Anxiety, Depression, PTSD

[a] Time participant engaged in meditative practice on a weekly basis, in the last 6 months. Example of meditative practice examples in questionnaire include: seated meditation, yoga, qigong, chanting, prayer, or other practices.
[b] Amount of minutes spent in meditative practice each week.

Intervention

Brain Computer Interface. In an effort to make this intervention accessible, the authors sought to utilize a wireless BCI in combination with a wireless VR headset (Samsung Gear VR powered by an Android s7 phone; see Figure 1). We elected to use the Muse EEG headband as it was found to have better usability than the primary competitor in this market (Peining, Tan, & Phyo Wai, 2017). In addition, the Muse headband has demonstrated its usefulness in mindfulness training (Bhayee et al., 2016), the ability to distinguish "pain" versus "no pain" brain states (Karydis, Foster, & Mershin, 2016), and as a neurofeedback device to teach mental states of concentration and relaxation (Kovacevic, Ritter, Tays, Moreno, & McIntosh, 2015).

Figure 1. Participant with wireless VR headset.

The Muse headband consists of four active electrodes at sites AF7, AF8, TP9, and TP10, with the reference position at FPZ. For the current application, software was developed by StoryUp XR and the NeuroMeditation Institute which calculated the ratio of gamma activity (30–44 Hz) between sites AF7 and AF8. The protocol was designed such that a relative shift in gamma power to the left electrode site resulted in a designated action in the VR experience. Electrode sites TP9 and TP10 were not utilized in this protocol design.

Virtual Reality Meditation. Positivity by Healium is a commercially available VR meditation experience designed to work in conjunction with the Muse headband. The experience is produced by StoryUp XR using 360-degree video photography. The initial scene displays a blue line graph indicating gamma asymmetry, with a red line indicating the threshold level (see Figure 2).

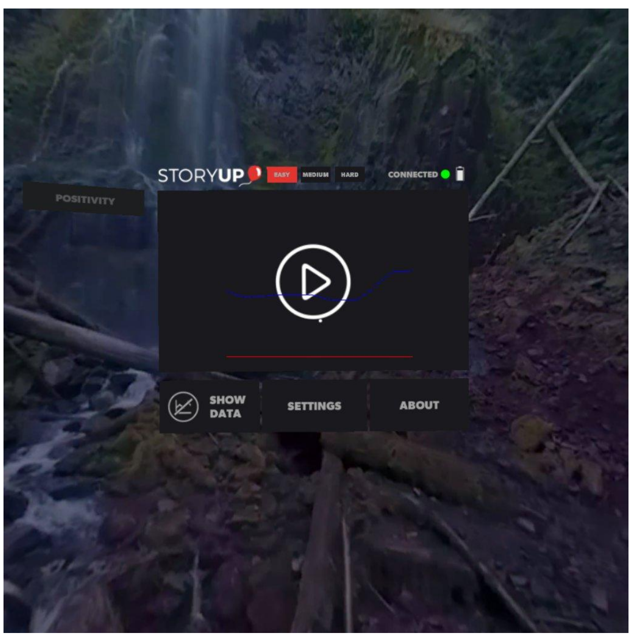

Figure 2. Initial scene in VR experience with blue line graph indicating gamma asymmetry and a red line indicating the threshold level.

Threshold can be adjusted in the VR headset, determining the degree to which left frontal gamma must be greater than right frontal gamma to meet criterion. In the current study, all subjects engaged the experience at the lowest challenge setting. Following approximately 20 seconds of calibration, the scene shifts to the base of a waterfall. There is soft piano and violin music playing in the background. Approximately 20 seconds into the experience, a woman's voice begins guiding the viewer through a positivity meditation, directing the user to recall a time in their lives when they felt grateful, appreciative, or happy. As the gamma asymmetry shifts to the left and remains above the threshold, the camera in the VR experience slowly glides up the waterfall and then back down. If at any point during the experience the gamma asymmetry indicator falls below the threshold, the scene freezes, the screen is filtered in red, and the voice returns to coach the attention back to a positive emotional state. Based on the number of stops and starts, most experiences last between four and five minutes.

Measures

Demographic Questionnaire. This questionnaire asked subjects to identify information related to their sex, age, race, education level, and history of mental illness.

Positive and Negative Affect Schedule (PANAS). This 20-item self-report scale asks subjects to identify how much they feel particular emotions in the present moment. Response options include *very slightly or not at all*, *a little*, *moderately*, *quite a bit*, or *extremely*, scored 1 through 5 respectively. The scale is composed of two separate mood scales, one that measures positive affect (PA) and one that measures negative affect (NA). Reliability and validity reported by Watson, Clark, and Tellegen (1988) was moderately good. For the Positive Affect Scale, the Cronbach alpha coefficient was .86 to .90; for the Negative Affect Scale, .84 to .87. Over an 8-week time period, the test–retest correlations were .47–.68 for the PA and .39–.71 for the NA. The PANAS has strong reported validity with such measures as general distress and dysfunction, depression, and state anxiety.

State-Trait-Cheerfulness-Inventory<30> (STCI-S<30>). This 30-item self-report scale measures three dimensions including state-cheerfulness, state-seriousness, and state-bad mood. The 4-point Likert scale of responses include *strongly disagree*, *moderately disagree*, *moderately agree*, and *strongly agree*, scored 1 through 4 respectively. The three states, or subscales, can be divided further into subclusters. State-cheerfulness clusters include cheerful and hilarity. State-seriousness includes clusters earnest, pensive, and sober. State-bad mood includes clusters sad and ill-humored. Ruch and Köhler (1999) demonstrated the scale had good internal consistency for the state-cheerfulness and state-bad mood subscales, .91 and .93, respectively.

State-seriousness had the lowest Cronbach's α, .79. Test–retest reliability for STCI-S<30> (English version) is not available (Ruch & Köhler, 1999). For the current study, only the cheerfulness and bad mood subclusters were examined.

EEG Data Collection. The EEG data in this study was sampled with 19 electrodes in the standard 10–20 International placement referenced to linked ears. Data was collected for 5 min of baseline (eyes open), during the VR Positivity experience (4–5 min), and 5 min postintervention (eyes open). Each raw EEG file was processed through the qEEG-Pro (qEEG Professionals, The Netherlands) Standardized Artifact Rejection Algorithm (S.A.R.A). This process removes segments from an EEG recording that are likely due to other sources, such as eye blinks, muscle tension, etc. Using an automated process such as this ensures that each file is handled in the same manner and reduces the possibility of bias in the artifact removal process. Raw files were then manually inspected. Of the 12 EEG recordings, all of the EEG samples recorded during the VR experience were eliminated due to excessive artifact (primarily eye movements). All pre–post EEG data samples were acceptable.

Procedures

The four subjects in this case study were firefighters who volunteered to test the intervention as a potential tool to assist with occupational burnout. The firefighters met at the firefighter union hall and took turns participating in the intervention in a private office. After a verbal description of the study process and completing consent forms, subjects completed a demographic form, PANAS, and STCI-S<30> questionnaires. Subjects were fitted with a 19-channel EEG electrocap (Electro-Cap International, Inc., Eaton, OH). Each electrode was prepared using electrogel conductance paste (Electro-Cap International, Inc., Eaton, OH). Impedences for all sites were assessed and kept below 10 kΩ. Subjects completed a 5-min, eyes-open EEG baseline, recorded using a BrainMaster Discovery amplifier (BrainMaster Technologies, Inc., Bedford, OH). Following the initial baseline recording, subjects were assisted in putting on the Muse headband and VR headgear. The subject was then instructed to simply enjoy the VR experience, follow along with the guided meditation, and attempt to keep the blue line above the red line. At the conclusion of the Positivity VR experience, the headgear was removed and a post-VR, 5-min EEG was recorded using the same instructions as the previous recordings. Following the final EEG recording, the subject completed a post-VR PANAS and STCI-S<30> questionnaire.

Data Analysis

Artifact-free files were processed through BrainAvatar sLORETA analysis software (BrainMaster Technologies, Inc.) to obtain current source density (CSD) estimates for the Gamma band (30–44 Hz). These values were obtained for the left and right "frontal lobe" regions of interest (ROIs) as defined in the BrainAvatar Imaging software (BrainMaster Technologies, Inc., Bedford, OH). Consistent with previous research utilizing these values as a measure of frontal asymmetry (see Bonnstetter et al., 2015), a left versus right frontal ROI ratio score was calculated before and after the VR intervention. This value was comprised of the average of the 1,088 left hemisphere voxels divided by the average of the 1,088 right hemisphere voxels. Values greater than 1.0 indicate greater gamma activation in the left hemisphere, while values less than 1.0 indicate greater activation in the right hemisphere. The pre–post asymmetry ratios were then compared to produce a percent of change for each subject using the following equation: (time 2 ratio − time 1 ratio) / time 2 ratio.

Self-report scale scores for the PANAS and STCI-S<30> were examined by comparing pre and post scores for each subject and calculating a percent of change. Percent change values were calculated by dividing the difference of specific pre and post subscales by the maximum possible score for the given subscale.

Results

Subject 1

Subject 1 began with a symmetrical gamma pattern (1.01), which shifted slightly to the left following the intervention (1.08). Similarly, most of the self-report scales demonstrated only minor shifts (see Table 2).

Subject 2

This subject began with a slight gamma asymmetry to the left, which became more prominent after the intervention, shifting from 1.10 to 1.20, an increase of nearly 9%. On the PANAS, this subject showed a 10% increase in his positive affect score as well as a 10% decrease in negative affect score. On the STCI scale, this subject demonstrated a 15% increase in state-cheerfulness and a 15% decrease on the state-bad mood scale a well as on both of the state-bad mood sub clusters (i.e., sad, ill-humored).

Subject 3

Subject 3 began with an asymmetry to the right (0.84), which moved further in this direction following the intervention (0.72). While the PANAS ratings showed a significant increase in positive affect (10%), there was very little change in negative affect (-4.0%). On the STCI, cheerfulness decreased by 20% while bad mood ratings stayed the same.

Subject 4

This subject began with an asymmetry to the right (0.65) but ended with a strong asymmetry to the left (1.52), a change of 133%. There were only minor changes in the self-report scores on the PANAS, positive affect and negative affect decreasing by 6% and 4%, respectively. On the STCI, cheerfulness increased by 15% and the ill-humored sub cluster of the state-bad mood scale decreased by 20%. A visual representation of positive and negative mood in relation to gamma asymmetry is shown in Figures 3 and 4, respectively.

Table 2
Percent Change

	Subject 1			Subject 2			Subject 3			Subject 4		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Gamma Ratio in Frontal Lobe [a]	1.01	1.08	6.29%	1.10	1.20	8.94%	0.84	0.72	-14.70%	0.65	1.52	133.14%
PANAS [b]												
Positive Affect	29	27	-4.00%	35	40	10.00%	37	42	10.00%	45	42	-6.00%
Negative Affect	14	13	-2.00%	15	10	-10.00%	14	12	-4.00%	31	29	-4.00%
STCI [c]												
State-Cheerfulness	23	22	-2.50%	28	30	5.00%	37	32	-12.50%	30	34	10.00%
Cheerful	10	11	5.00%	13	16	15.00%	18	14	-20.00%	14	17	15.00%
Hilarity	13	11	-10.00%	15	14	-5.00%	19	18	-5.00%	16	17	5.00%
State-Bad Mood	17	18	2.50%	19	13	-15.00%	10	10	0.00%	27	24	-7.50%
Sad	7	8	5.00%	8	5	-15.00%	5	5	0.00%	14	15	5.00%
Ill-humored	10	10	0.00%	11	8	-15.00%	5	5	0.00%	13	9	-20.00%

[a] Values > 1.0 indicate greater gamma activation in the left frontal ROI. Values < 1.0 indicate greater activation in the right frontal ROI. Pre and post values are the left to right gamma ratio in the frontal lobe.
[b] Maximum possible score for each PANAS subscale is positive and negative affect is 50.
[c] Maximum score for STCI State-Cheerfulness is 40 with divided sub-clusters, cheerful and hilarity, equaling 20 each. Maximum score for State-Bad Mood is 40 with divided subclusters, sad and ill-humored, equaling 20 each.

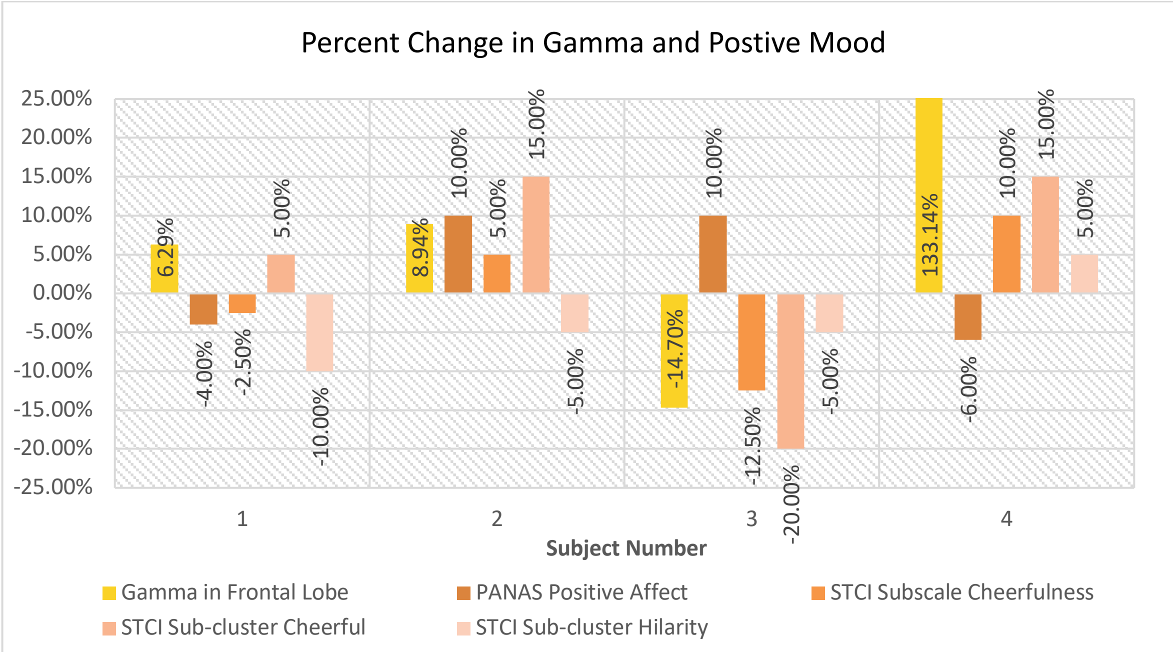

Figure 3. Percent changes of left–right gamma wave ratio and positive mood subscales of PANAS and STCI-S<30> before and after VR experience.

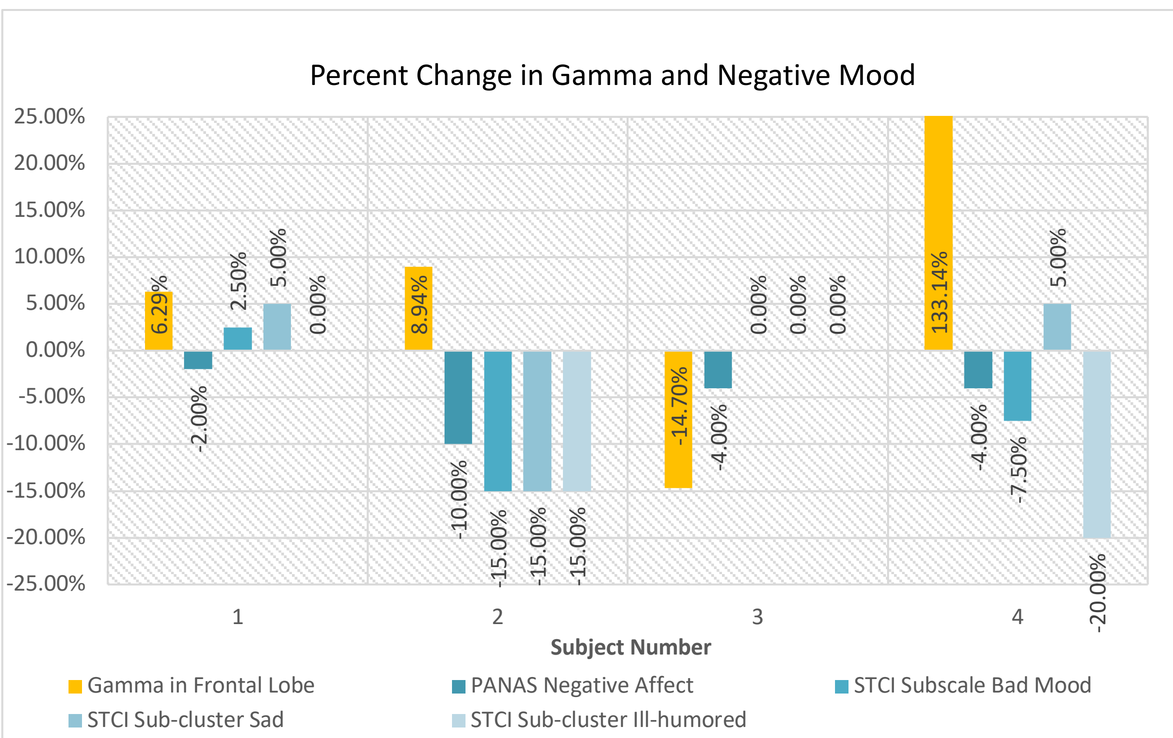

Figure 4. Percent changes of left–right gamma wave ratio and negative mood subscales of PANAS and STCI-S<30> before and after VR experience.

Discussion

To date, this is only the second study to examine the combination of neurofeedback with virtual reality. It was designed as a proof of concept to determine a) if such an intervention could be successfully used to administer a gamma asymmetry protocol and b) to determine if such an intervention could be linked to changes in mood.

To address the first of these considerations, it was noted that three of the four subjects showed changes in the expected direction (increased left gamma asymmetry). It is interesting that the only subject to show changes in the opposite direction (Subject 3) started with an asymmetry toward the right. While Subject 4 demonstrated that you could begin this intervention with an asymmetry on the right and end on the left, it is also possible that the intervention was not enough to shift the asymmetry for Subject 3 or it was not enough to shift the asymmetry beyond the duration of the intervention. We know that frontal asymmetry is a moderately stable condition in adults (Deldin & Chiu, 2005), and it is possible that this subject showed a shift in asymmetry toward the left during the intervention but then returned to his baseline asymmetry as soon as the intervention ended. It is also possible that Subject 3 is experiencing some level of rumination or brooding that is interfering with his ability to fully engage with the process. A study by Barnhofer and Chittka demonstrated that subjects scoring high in brooding were unable to shift frontal asymmetry toward left-sided activation in response to a loving-kindness meditation (Barnhofer, Chittka, Nightingale, Visser, & Crane, 2010). They speculated that the task of engaging positive emotional states was too far removed from their current state. These subjects were only successful with shifting frontal asymmetry when utilizing a focus meditation which drew their attention away from their negative thinking patterns toward a neutral stimulus (e.g., the breath). To extrapolate from these findings, it is possible that Subject 3 was unable to connect with the positivity meditation provided and may have been better served by a focus-style meditation (Tarrant, 2017). It is also possible that Subject 3's shift toward the right was influenced by other internal states or personal stressors that were not examined in this study.

The second objective of this study related to the notion that the intervention could have a positive impact on mood. A visual representation of positive and negative mood in relation to gamma asymmetry can be seen in Figures 3 and 4, respectively. While there were some small shifts in Positive and Negative Affect as measured by the PANAS, there were much greater shifts in State-Cheerfulness and State-Bad Mood as measured by the STCI-S<30>. Three of the four subjects showed increases in Cheerfulness, while one subject (Subject 3) showed decreases in this measure. Two of the subjects demonstrated large decreases of the subcluster "Ill-humored" (Subjects 2 and 4), while no subjects demonstrated an increase. Overall, these were positive findings and provide preliminary evidence that subjects can experience an increase of positive affect and/or a decrease of negative affect following a relatively brief neurofeedback/VR experience.

While there were not enough subjects in this study to conduct statistical analyses, it seems important to note that the two subjects reporting the largest positive changes in mood states were the two that showed the largest shifts in gamma asymmetry to the left. The only subject to report decreased cheerfulness was the same subject that showed increasing right asymmetry. The subject demonstrating only minor shifts in gamma also reported only minor changes in mood. These findings suggest that the asymmetry as measured in this study is, in fact, related to changes in emotional states.

An examination of subject demographics in relation to intervention response is also of interest. Subject 4 began with a strong right asymmetry and finished with a strong left asymmetry. This is also the only subject with any regular meditation practice. This subject also acknowledged three different mental health diagnoses. It is possible that this subject has engaged in previous psychological/emotional work which has enabled him to better utilize the intervention in this study. Interestingly, the only other subject to begin with a right asymmetry, ended with a stronger right asymmetry. This subject (Subject 3), denied any mental health concerns and has no history of meditative practice. As previous research has identified that a right asymmetry is frequently associated with depressed mood and/or anxiety (Moscovitch et al., 2011; Thibodeau et al., 2006), it is possible that this subject has less awareness of their psychological/emotional state and consequently was less able to effectively engage the intervention. These observations and speculations should be investigated further in a follow-up study which includes a more detailed examination of demographics and response to the intervention.

Overall, these results are promising as the intervention in question was only four to five minutes in length and the subjects were given very little context and minimal instruction. These results provide support for the idea that a consumer-grade BCI/VR intervention can potentially have therapeutic utility and deserves further study. Because the technology is relatively easy to use and inexpensive, it may serve as a wellness tool in work and school environments, as a calming technique for persons receiving medical/dental procedures, or as an adjunct to traditional therapeutic interventions for anxiety or depression. In fact, such an intervention may be appropriate as "homework" for clients enrolled in traditional neurofeedback training.

In the future, it would be helpful to explore similar interventions with larger sample sizes, clearly defined subject pools (e.g., depressed, anxious), and control conditions. In addition, it would be helpful to isolate the elements of the BCI/VR experience to more clearly define the relative contribution of each element to the overall impact. For example, viewing nature, engaging in an Open Heart meditation, and gamma asymmetry neurofeedback may each provide a unique impact on positive and negative emotional states. Because this is a relatively new and novel approach to neurofeedback, future studies with this type of experience should also include follow up questionnaires and/or participant interviews to better ascertain the internal state and reaction to elements of the VR experience. Beyond single experience research, it will also be important to examine the potential of such an intervention incorporated into a larger intervention. For example, could such an intervention be utilized as an adjunctive technique for someone enrolled in a traditional course of neuro-or psychotherapy? Could such an intervention be successfully included in a structured group experience for persons learning skills to manage anxiety or depressive symptoms?

Declaration of Interests

Jeff Tarrant, PhD, is contracted by StoryUp VR to assist in product development and assessment.

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NeuroRegulation

Do Better in Math: How Your Body Posture May Change Stereotype Threat Response

Erik Peper[1], Richard Harvey[1], Lauren Mason[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, Kaohsiung, Taiwan

Abstract

This study investigates posture on mental math performance. One hundred twenty-five students (M = 23.5 years) participated as part of a class activity. Half of the students sat in an erect position while the other half sat in a slouched position and were asked to mentally subtract 7 serially from 964 for 30 s. They then reversed the positions before repeating the math subtraction task beginning at 834. They rated the math task difficulty on a scale from 0 (*none*) to 10 (*extreme*). The math test was rated significantly more difficult while sitting slouched (M = 6.2) than while sitting erect (M = 4.9), ANOVA [$F(1,243) = 17.06$, $p < .001$]. Participants with the highest test anxiety, math difficulty and blanking out scores (TAMDBOS) rated the math task significantly more difficult in the slouched position (M = 7.0) as compared to the erect position (M = 4.8), ANOVA [$F(1,75) = 17.85$, $p < .001$]. Tor the participants with the lowest 30% TAMDBOS, there was no significant difference between slouched (M = 4.90) and erect positions (M = 4.0). The participants with the highest TAMDBOS experienced significantly more somatic symptoms as compared with the lowest TAMDBOS. Discussed are processes such as stereotypic threat associated with a "defense reaction" by which posture can affect mental math and inhibit abstract thinking. Moreover, clinicians who work with students who have learning difficulty may improve outcome if they include posture changes.

Keywords: posture; math; depression; stereotype threat; empowerment; stress

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***Address correspondence to**: Erik Peper, PhD, Institute for Holistic Healing 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, Knoxville Neurofeedback Group, Knoxville, Tennessee, USA

Reviewed by:
Rex L. Cannon, PhD, Knoxville Neurofeedback Group, Knoxville, Tennessee, USA
Randall Lyle, PhD, Mount Mercy University, Cedar Rapids, Iowa, USA

Introduction

Many students perform poorly on cognitive tasks such as mental arithmetic when under situations of perceived threat (Moore, Vine, Wilson, & Freeman, 2012; Schmader, Hall, & Croft, 2015). Math anxiety generally refers to a set of reactions to perceived threats related to performance on math tasks. For example, the term *stereotype threat* refers to a type of performance decline applied when "…people underperform relative to their ability merely because they are aware of a negative stereotype about how they should perform—e.g., a female student aware of the stereotype that 'boys are better than girls at mathematics'" (Maloney, Schaeffer, & Beilock, 2013, p. 116). When people are presented with a stereotype-based statement such as "extra pressure to succeed" as well as "threats to self-integrity and belonging," both result in anxiety reactions which reduce performing in math tasks (Spencer, Logel, & Davies, 2016).

Ramirez, Shaw, and Maloney (2018, p. 9) offer their "Interpretation Account" (IA) framework for understanding math anxiety, that includes a list of sample interpretations of threat:

- Existing cultural stereotypes (i.e., "Women hate math, so I must hate math as well"; Bieg, Goetz, Wolter, & Hall, 2015).
- Societal beliefs around disfluent learning (i.e., "If you are having trouble learning something, then you are probably not going to perform very well"; Benjamin, Bjork, & Schwartz, 1998; Koriat & Bjork, 2006; Stigler & Hiebert, 2004).
- Social interactions in the home ("My parents always help me with math homework because I am not very comfortable doing it on my own"; Maloney, Ramirez, Gunderson, Levine, & Beilock, 2015).
- Social interactions in class ("My teacher gets really stressed out teaching math"; Beilock, Gunderson, Ramirez, & Levine, 2010).
- Teaching pedagogy ("My teacher doesn't ask us questions or encourage us to think deeply about math because he/she believes that not everyone can be good at math"; Ramirez, Hooper, Kersting, Ferguson, & Yeager, 2018).
- Lay beliefs about the meaning of heightened physiological arousal (i.e., "My heart is beating fast, I must be really nervous"; Jamieson, Nock, & Mendes, 2012)."

Not only does the IA framework assist with distinguishing state-like and trait-like variations of math anxiety reactions, but it also provides a framework for identifying brain activity associated with math-anxiety reactions due to fact-based cognitions (e.g., I have not yet learned how to retrieve the answer to that math problem; however, I am capable of learning) versus stereotype-relevant cognitions (e.g., I am not expected to perform well because of a stereotype; Lamont, Swift, & Abrams, 2015; Ramirez, Shaw, et al., 2018). Erickson (2015) points out that Danker and Anderson (2007) suggest cognitive models are able to distinguish between math retrieval and other representations in the parietal cortex and prefrontal cortex; however, "…Their surprising result was that both brain regions were active for each step but at differing levels of activation" (p. 23).

Other researchers have examined various kinds of brain activity associated with math anxiety due to negative evaluative self-talk interpretations or threat appraisals such as "I will never be motivated to learn math because I do not feel math is useful," which is focused on the amygdala, posterior parietal cortex (PPC), and dorsolateral prefrontal cortex (DLPFC). Young, Wu, and Menon (2012) used functional MRI (magnetic resonance imaging) with 7- to 9-year-old children to visualize brain activity while performing math tasks. Their brain scans revealed hyperactivity in the right amygdala region, responsible for processing negative emotions, and also found reduced activity in the PPC and DLPFC regions which are typically active during mathematical reasoning, and state: "These effects were specific to math anxiety and unrelated to general anxiety, intelligence, working memory, or reading ability" (Young, Wu, & Menon, 2012, p. 492).

In contrast to negative evaluative self-talk (NEST) based on fact-based interpretations or threat appraisals of math performance, there are a variety of brain regions associated with persistent strain and stress under conditions of social-evaluative threat (SET). Whereas Ramirez, Shaw, et al. (2018) have provided types of interpretations or threat appraisals related to math performance, others such as Turner et al. (2002) suggest that math anxiety can result in toxic strain related to SET interpretations or appraisals when, for example, students perceive themselves as ''vulnerable to public displays of incompetence'' (p. 101). Similarly, Maloney et al. (2013), suggest that math performance may be interpreted as high stakes especially when the results are judged by those in power to decide whether they graduate or get a job in the future.

The consequences of SET based on interpretations or appraisals about math performance that are believed to be overwhelming and undermining are more profound than the consequences of NEST, based on interpretations or appraisals about math performance that are believed to be difficult yet manageable, with a bias towards a "growth mindset" (Boaler & Dweck, 2016; Pohl, 2017). The consequences are not only regarding the decline in math performance itself but also in the effects of SET on health. Olff (1999) suggests that negative interpretations and appraisals of threat, whether related to math performance or any other topic, influence the immune system abilities to fight off disease.

Acute stress brought on by SET appraisals about a classroom math task (or almost any type of exam) can impair higher cortical functions by inhibiting working memory. Qin, Hermans, van Marle, Luo, and Fernández (2009) showed that "induced acute stress resulted in significantly reduced working memory-related activity in the dorsolateral prefrontal cortex and was accompanied by less deactivation in brain regions that are jointly referred to as the default mode network." Chronic stress, such as repeated threat perceptions associated with poor math performance, influences the medial prefrontal cortex, cause debranching and shrinkage of dendrites which is related to cognitive rigidity (McEwen et al., 2015). With declines in working memory as well as chronic shrinkage of dendrites comes impairment not only with math performance but with other cognitive processes as well (McEwen et al., 2015).

Developing strategies to reduce stress and regulate emotions allows students to optimize performance in many cognitive tasks (Arroyo et al., 2014). For example, students who have a positive self-concept of their mathematics ability perform better in math classes, possibly because they do not attribute poor math performance as a SET, but rather interpret failure as information and as an opportunity for learning and growth. As a method for training students to interpret poor math performance as feedback rather than as a SET, Shapiro, Williams, and Hambarchyan (2013) have proposed a Multi-Threat Framework as a tool to illustrate how multiple personal and social influences impact girls' interest and performance in Science, Technology, Engineering, and Math (STEM) learning.

One aspect of the Multi-Threat Framework (Shapiro et al., 2013) includes raising awareness of physical body reactions to poor performance during STEM learning. For example, when students perform poorly on a math exam, they may slouch or collapse their posture, coincident with feelings of powerlessness, hopelessness, and defeat. The effect of expectancy related to future performance on STEM tasks or exams influences posture as well as other neuroendocrine responses. For example, if you feel that you are a "loser," not only might you slouch or collapse your posture, but testosterone levels may also continue to decrease (Smith & Apicella, 2017) and cortisol levels may continue to increase.

In contrast, if a student feels like a "winner," they may hold their head high in an upright body posture. An upright body posture is associated with increased testosterone, decreased cortisol, greater confidence, mood, and strength when compared to a sustained slouched posture, which is associated with greater chronic neck, shoulder, and back pain as well as lower confidence and energy, depressive memory bias, and failure-related emotions (Briñol, Petty, & Wagner, 2009; Canales, Cordás, Fiquer, Cavalcante, & Moreno, 2010; Carney, Cuddy, & Yap, 2010; Michalak, Mischnat, & Teismann, 2014; Peper, Booiman, Lin, & Harvey, 2016; Thrasher et al., 2011; Tsai, Peper, & Lin, 2016; Wilson & Peper, 2004).

Regardless of the source of negative thoughts associated with SET interpretations and stereotype threats, strategies for mitigating the effects of the negative thoughts include making physical body adjustments in posture. For example, when students change their posture during a 4-week posture feedback training period, they report significant improvements in physical functioning, energy levels, reduced fatigue, and health (Harvey, Mason, Peper, & Joy, in press).

When individuals are hypervigilant or anticipating danger, their capacity for abstract thinking is inhibited in favor of mobilizing resources to respond immediately to a perceived physical threat (Sapolsky, 2015). There is a competitive relationship between posture (e.g., slouching versus sitting erect), cognitive performance (e.g., performance on a mental arithmetic task), and affect (e.g., emotions such as state-dependent anxiety and/or depression) as suggested by Brauer, Woollacott, and Shumway-Cook (2001). Others have suggested that positive thought processes are significantly easier to maintain in an upright, erect posture, while negative thoughts are more easily produced with a slouched, collapsed posture (Peper, Lin, Harvey, & Perez, 2017; Tsai et al., 2016; Wilson & Peper, 2004).

People tend to adapt a slouched posture while looking down at digital screens, watching various kinds of digital media on computer screens, or even sitting collapsed in a chair or couch during therapy. Our posture may impact the way we perceive ourselves, as well as the way others perceive us (Briñol et al., 2009). An upright posture tends to project an assertive, dominant, and powerful person; whereas sitting in a collapsed posture may project a submissive, defeated, or depressed individual. These postural cues about the status of an individual are processed nonverbally through neuroception of the observer (Porges, 2009, 2015; Porges & Peper, 2015). Whereas many have examined the relationship between threat perceptions and math performance, the present study examined whether a postural intervention could mitigate poor performance on a simple math task. Therefore, the purpose of this study explores the extent to which adjustments in postural positions influence performance on a simple subtraction task under conditions of time pressure.

Method

Participants

One hundred twenty-five college students (33 males, 78 females, 10 nonbinary), average age 23.5 years (*SD* = 5.9) participated in a regularly planned classroom demonstration investigating the relationship between posture (slouched or upright), mood, cognitive performance (performance on a simple math task), and symptom history. As a report about an effort to improve the quality of a classroom activity, this report of findings was exempted from Institutional Review Board oversight.

Procedure

While sitting in a class, students filled out a short, anonymous questionnaire, which asked them to rate their anxiety while taking exams, difficulty in performing math, blanking out while taking exams, depression, anxiety, and somatic symptoms on a scale from 1 to 10. Two different sitting postures were clearly defined for participants: slouched/collapsed and erect/upright, as shown in Figure 1.

Figure 1. Sitting in a collapsed position and upright position. Photo from: http://news.sfsu.edu/news-story/good-posture-important-physical-and-mental-health

To assume the collapsed position, they were asked to slouch and look down while slightly rounding the back. For the erect position, they were asked to sit upright with a slight arch in their back, while looking upward. After experiencing both postures, half of the students sat in the collapsed position while the other half sat in the upright position. While in this position, they were asked to rapidly subtract the number 7 from 843 sequentially for 15 s. A counterbalancing scheme was used where they were then asked to switch positions. Those who were collapsed switched to sitting erect, and those who were erect switched to sitting collapsed. They were then to rapidly subtract the number 7 from 843 sequentially for 15 s. Next, participants rated the difficulty in performing the mental math in each position, and in which position it was easier to perform the math.

Results

Among the participants, 56.4% reported that it was easier to perform math in the upright position, 16.1% in the collapsed position, and 27.4% reported position had no effect as shown in Figure 2.

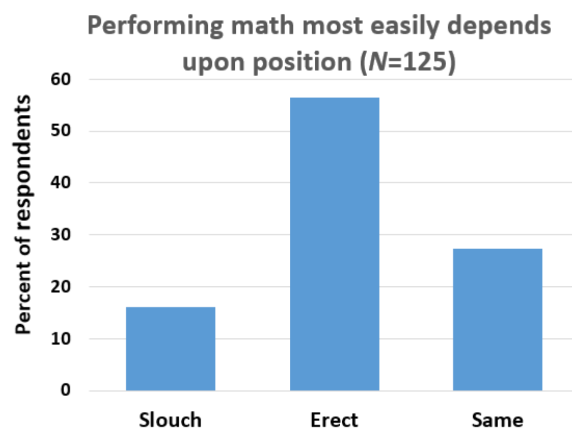

Figure 2. The percentage of participants who reported it was easier to perform the serial 7 math subtraction, by position.

It was significantly more difficult to perform the serial 7 subtractions in the collapsed position (*M* = 6.2; *SD* = 2.4) than in the erect position (*M* = 4.9; *SD* = 2.5) ANOVA [$F(1, 243) = 17.06$, p <.001] as shown in Figure 3.

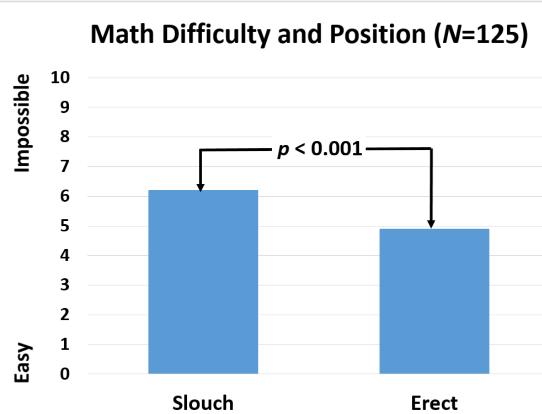

Figure 3. The relative subjective rating in the ease or difficulty of performing the serial 7 math subtraction in collapsed and upright positions.

Effect of posture on math performance for the highest and lowest 30% reporting test anxiety, math difficulty, and blanking out was statistically significant. They reported that the math task was significantly more difficult in the slouched position (M = 7.0) as compared to the erect position (M = 4.8) ANOVA [$F(1, 75) = 17.85$, $p < .001$]. There was no significant difference for the participants with the lowest 30% of reported test anxiety, math difficulty, and blanking out between slouched (M = 4.9) and erect positions (M = 4.0). Also observed was a statistically significant difference in breathing difficulty ($p < .05$), neck and shoulder tension ($p < .05$), headaches ($p < .01$), anxiety ($p < .01$), and sex (i.e., female) ($p < .01$) for the group of participants with the highest test anxiety, math difficulty, and blanking out as compared with the lowest text anxiety levels (Figure 4).

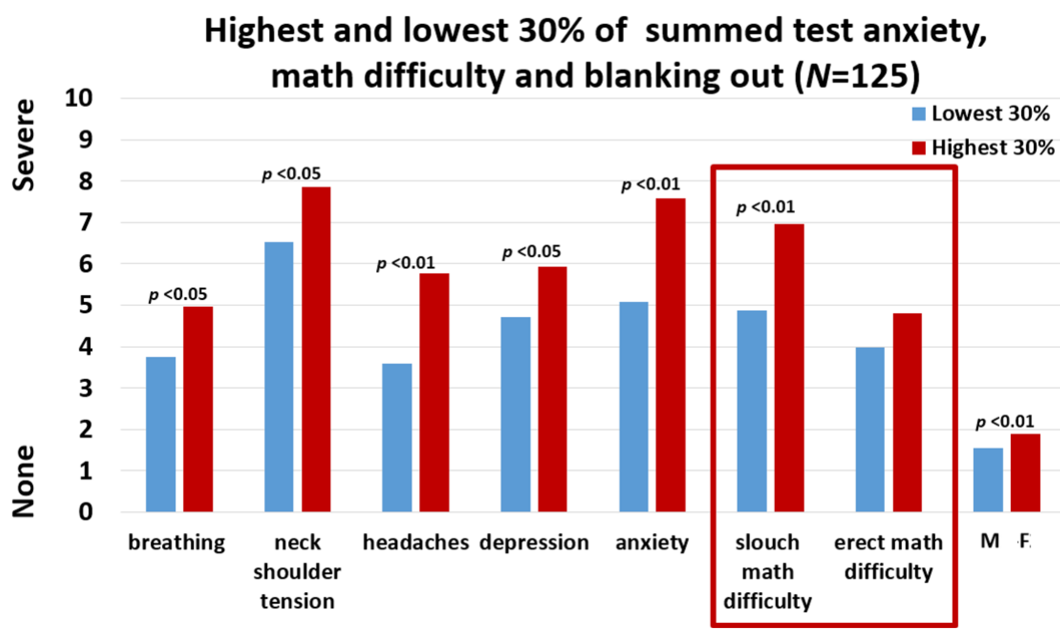

Figure 4. The highest and lowest 30% of summed test anxiety, math difficulty, and blanking out.

In comparing students with the highest versus lowest test anxiety, math difficulty, and blanking out, slouching positions significantly impacted math performance only for the high test anxiety, math difficulty, blanking out group; there was no significant difference when performing in the upright position (Figure 5).

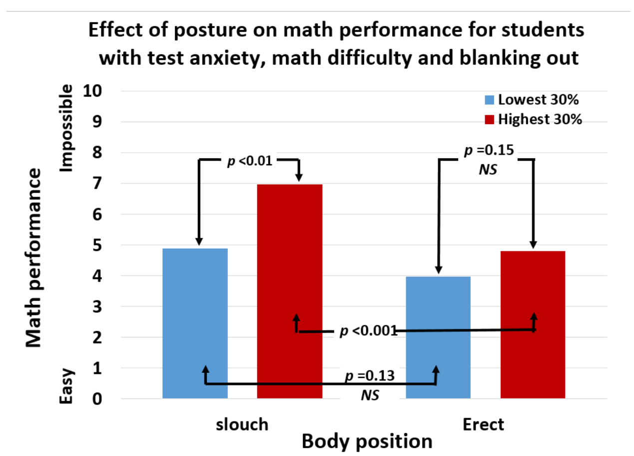

Figure 5. Effect of posture on math performance for students with test anxiety, math difficulty, and blanking out.

Discussion

The slouched position was associated with increased difficulty in performing a math subtraction task for 15 s, especially for students reporting higher test anxiety, math difficulty, and blanking out on exams. In contrast, slouched position had no significant effect on students who reported that they were not stressed about performance.

Self-reported anxiety levels have been correlated with a significant increase in breathing difficulty, neck and shoulder tension, headaches, depression, and anxiety, which confirmed the previous findings that students with higher math anxiety have increased physiological activation such as neural activation, heart rate, and increased cortisol (Faust, 1992; Lyons & Beilock, 2012; Pletzer, Kronbichler, Nuerk, & Kerschbaum, 2015). Most likely, the students attribute physiological reactions such as increased heart rate and breathing changes negatively, which amplifies their negative self-perception and exacerbates their anxiety symptoms; this may then inhibit their cognitive ability to perform on math tasks.

The activation of a "defense reaction," as well as curling into a slouching posture (flexor response), is probably a classically conditioned process since most people trigger the defense pattern under conditions of perceived physical threat. The activation of this defense pattern, and corresponding decrease in the performance of mental math, is associated with reduced levels of abstract thinking and frontal cortical deactivation. This biological defense response is triggered if the person expects the situation to be dangerous when there are conditions of SET among those who self-report that they have test anxiety, math difficulty, and blanking out on exams. Changing posture from a collapsed/slouched position to an erect/upright posture appears to inhibit the defense reaction; thus, the person may perform better on the math task (serial-7 subtraction under time pressure for 15 s).

Head-upright/erect postures may make it easier to access positive and empowering thoughts and memories, thereby helping students to perform better. This expanded upright position is an indicator of feeling safe and empowered. This upright posture inhibits the defense reaction and increases feelings of safety, which relate to the findings that the head-upright, erect posture or position make it easier to access positive and empowering thoughts and memories (Peper et al., 2017).

The significant effect of the upright posture may have occurred because the task was very neutral and the students did the task without anticipating the feeling of defeat or hopelessness. If a student already felt defeated and "knew" that they could not perform, the erect posture may have less benefit. In those cases, the student would also need to transform their cognition and change their underlying beliefs. Changing beliefs and self-talk may be slightly easier to perform when the person simultaneously changes their body postures to an erect position; since thoughts and feelings are connected, and in the erect position it is easier to access positive thoughts.

The research findings suggest that students, especially those who are anxious or fearful of math and blanking out during exams, could benefit from sitting upright instead of slouched while studying and taking exams to optimize performance and have greater access to positive thoughts and memories.

Implications for neurofeedback and therapy

Many therapists work with clients who have learning disabilities and use neurofeedback as the primary intervention. This research suggests that therapists need to be aware that posture impacts performance, especially with clients who feel judged, threatened, and/or have low self-esteem. Similarly, many students seek tutoring or counseling, and those who simultaneously report somatic symptoms associated with anxiety may especially benefit from incorporating posture awareness and retraining in addition to any learning strategies designed to improve study habits.

The findings of this study suggest that if participants have test anxiety, fear of math, report blanking out on exams, and appear in a slouched posture, the first interventions should include strategies not only to reduce anxiety and increase cognitive reframing but also to improve posture. By changing body posture, the classically conditioned response to have a defense reaction to perceived threats is interrupted. Classroom learning processes are optimized when learners feel safe.

For highly anxious participants who also slouch habitually, posture awareness and retraining can be learned with posture feedback devices such as an UpRight. We recommend that the participant uses posture feedback to become aware of the situations that are associated with slouching, such as ergonomic factors (looking down at the screen), being tired, and having depressive thoughts or feeling powerless and defeated. The moment participants experience posture feedback, they have the option to shift to an upright posture and perform interventions to counter the factors that caused the slouching. These include ergonomic changes of their computer or laptop, transforming self-critical thoughts to empowering thoughts, and taking a break or doing exercise when tired. When students practice these interventions for 4 weeks, they report an increase of confidence, decrease in stress levels, and an improvement in health and performance (Harvey et al., in press). Equally important is to teach the participants somatic self-regulation strategies to reduce somatic complaints. These may include slower breathing, heart rate variability training, and muscle relaxation. The training needs to be generalized and taught how to do this at home, school, or work.

We recommend that therapists observe and help clients to optimize their posture in the office and at home. By guiding clients through two different positions as described in the article, the client may subjectively experience that one type of posture appears to inhibit cognitive performance while the other posture increases performance. This approach often increases motivation because the participant can now make choices based upon self-experience.

The take home message echoes what your mother said, “Don’t slouch. Sit up straight!”

- If you feel secure and safe, posture has little to no effect on performance: you can be collapsed or slouched.
- If you are anxious and fearful, sitting erect may improve your performance.
- If you want to become aware when you slouch, posture feedback from a wearable posture feedback device such as an UpRight can provide tactile feedback each time you slouch; then you can implement strategies to sit erect.
- If you automatically slouch while working at the computer or sitting in chair, change your furniture so that you sit in an upright position while studying or watching digital devices.
- If you experience significant somatic symptoms such as headaches, breathing difficulty, neck and shoulder tension, or depression and anxiety, learn self-regulation skills, such as slower diaphragmatic breathing and heartrate variability training in conjunction with changing negative self-talk to positive self-talk to positively impact performance and personal experience.

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NeuroRegulation

LORETA Neurofeedback at Precuneus in 3-year-old Female with Intrauterine Drug Exposure

Rex L. Cannon, Whitney Strunk, Stephanie Carroll, and Spencer Carroll*

Knoxville Neurofeedback Group, Knoxville, Tennessee, USA

Abstract

This case study presents data for operant conditioning of alpha current source density (CSD) in a 3-year-old female that completed 20 sessions of EEG LORETA neurofeedback (LNFB) to address sequelae associated with intrauterine drug exposure (IUDE), including explosive reactions to unfavorable activities and siblings, deficits in self-care, self-direction, and social interaction. One of the more difficult processes is to assess children less than 6 years of age due to extreme variability in affect, interest, and focus. However, IUDE increases the range of potential problems and diagnostic confounds. This individual showed adaptive behavior improvements ratings by parents posttraining and was able to complete a measure of attention after training and at 30-day follow-up. Her data demonstrated a general increase in the trained CSD of the alpha frequency at precuneus across time. Additional changes were evident in the self-regulation network (SRN) posttraining with a significant decrease at follow-up suggesting a learning effect over time. This case study demonstrates that LNFB may produce positive effects in children under the age of 4.

Keywords: LORETA neurofeedback; intrauterine drug exposure; EEG; neuroimaging

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***Address correspondence to**: Rex L. Cannon, PhD, Knoxville Neurofeedback Group, 214 S. Peters Road, Suite 102, Knoxville, TN 37923, USA. Email: rexcannon@gmail.com

Edited by:
Nancy L. Wigton, PhD, Grand Canyon University, Phoenix, Arizona, USA

Reviewed by:
Wesley D. Center, PhD, Liberty University, Lynchburg, Virginia, USA
John Davis, PhD, McMaster University, Hamilton, Ontario, Canada

Introduction

This case study examines the effects of a standard procedure (Cannon, Congedo, Lubar, & Hutchens, 2009; Cannon et al., 2007; Cannon et al., 2014) of low-resolution electromagnetic brain tomographic neurofeedback (LNFB) in a 3-year-old female to aid in addressing sequelae associated with intrauterine drug exposure (IUDE). Differentiating IUDE and Neonatal Abstinence Syndrome (NAS) from other psychiatric symptoms is of growing concern due to the current opioid problem and its collateral damage. It is proposed that about 14–22% of pregnancies in the United States are complicated by exposure to opioid medications, and the trend is also shown in most European countries to a lesser degree (Huybrechts et al., 2017). However, establishing actual rates of illicit drug exposure during pregnancy are limited at best. NAS represents a cluster of problems and treatment for withdrawal symptoms when the infant is exposed to opiates and/or other drugs in utero. Currently, there are no diagnostic criteria to serve as a guide for treating problems that present in children suffering from IUDE. Intrauterine drug exposure and its potential long-term effects in the developing brain are of great concern for researchers and clinicians. The costs of treatment for NAS and IUDE are substantial for medical, social, educational, and support services to address this epidemic. It is also quite important that the foster care and adoption services for these children be informed of specific clusters of problems that occur to facilitate the proper care and adjustments for this growing population. Additionally, rates of diagnosis of Attention-Deficit/Hyperactivity Disorder (ADHD) in populations of children suffering from IUDE can be as high as approximately 36%, as contrasted to 2% in nonexposed children. In such cases there are currently no published data describing treatment efficacy with the use of stimulants or other medications to treat the clusters of symptoms that are present in these children.

There are relatively few data providing descriptive patterns of persistent cognitive, social, and executive function deficits in this population (Butz, Pulsifer, Leppert, Rimrodt, & Belcher, 2003; Franck, 1996; Freeman, 2000; Kelley, 1992; Kne, Shaw, Garfield, & Hicks, 1994; Mayes, Cicchetti, Acharyya, & Zhang, 2003; McNichol, 1999). The effects of IUDE can persist over the developmental continuum into adulthood, and the deficits seen across populations can vary (Bard, Coles, Platzman, & Lynch, 2000; Bhide & Kosofsky, 2009; Buckingham-Howes, Mazza, Wang, Granger, & Black, 2016; Derauf, Kekatpure, Neyzi, Lester, & Kosofsky, 2009; Jaeger, Suchan, Schölmerich, Schneider, & Gawehn, 2015; Nadebaum, Anderson, Vajda, Reutens, & Wood, 2012; Pulsifer, Radonovich, Belcher, & Butz, 2004; Robey, Buckingham-Howes, Salmeron, Black, & Riggins, 2014); however, executive functions, social and emotional delays, and integration of social cues and rules appear to be the most prevalent issues seen in the clinical experience of the current authors.

There are suggestions that network processes in the brain associated with these behaviors involve shifts in the default mode network (DMN) and its connectivity and overlap with other functional hubs and networks including task associated with social cognition (Mars et al., 2012; Sidlauskaite, Sonuga-Barke, Roeyers, & Wiersema, 2016). The EEG current source density (CSD) in ventromedial prefrontal cortex (PFC) and posterior cingulate were therefore targets for monitoring in this study with intent to understand behaviors as correlated with brain activity. In prior data with ADHD, a network associated with self-regulation (SRN) was put forth which demonstrated shifts in both amplitude and connectivity between these specific nodes relative to training one region and one frequency within it (Cannon, 2014). The client described in the present study completed a standard operant conditioning LNFB procedure with the aim of decreasing emotional reactivity to environmental cues (e.g., tantrums when not getting her way), and improving self-care, self-direction, social-executive and focused awareness (e.g., attention). Operant conditioning as defined in neurofeedback can be thought of in terms of pairing the alpha CSD at the region of training with a stimulus event (game or movie) in order to increase the likelihood of generating alpha CSD at certain levels across time. As this behavior is acquired and practiced then both regional and network changes should be evident with the added direction of psychometric data.

Methods

This case study is of a 3-year-old female presenting for LNFB to address issues associated with IUDE including difficulties with attention, focus, emotional regulation, and behavioral outbursts. The primary known intrauterine exposures were to cocaine and opioids; therefore, she would be better classified in the range of polydrug exposure. She lives in a supportive and nurturing environment with her adoptive parents and siblings, and because adoption occurred at an early age the problems of accompanying abuse and neglect often seen in these children were avoided. Upon her initial visit to the authors' clinic, a diagnostic interview was conducted, and the Adaptive Behavior Assessment System 3rd edition (ABAS-3) was provided to parents. The ABAS-3 is a rating scale useful for assessing skills of daily living in individuals with developmental delays, autism spectrum disorder, intellectual disability, learning disabilities, neuropsychological disorders, and sensory or physical impairments (Harrison & Oakland, 2015). We attempted to administer the Conners Kiddie Continuous Performance Test, Second Edition (K-CPT 2). The K-CPT 2 provides an objective measure of attention in children ages 4 to 7 years old. The 7.5-min performance-based assessment uses pictures of objects that are familiar to young children (Conners, 2015). It should be noted that the subject was under the minimum age for the K-CPT-2 test sample, but we sought a basal level on her ability to comply with task demands. However, at pretraining it was not possible to administer the K-CPT 2 due to the child's distractibility and random clicking behavior.

The client was prepared for EEG recording using a measure of the distance between the nasion and inion to determine the appropriate cap size for recording (Blom & Anneveldt, 1982). The head was measured and marked prior to each session to maintain consistency and for placement of frontal electrodes. The ears and forehead were cleaned for recording with a mild abrasive gel (NuPrep) to remove any oil and dirt from the skin. After fitting the caps, each electrode site was injected with electroconductive gel, and prepared so that impedances between individual electrodes and each ear were less than 10 KΩ. The LNFB training was conducted using the 19 leads of the standard international 10/20 system with linked ear reference. The center voxel for the region of training (i.e., left precuneus) was located at Talairach coordinates (x = -31, y = -81, z = 22). The data were collected and stored utilizing the Deymed TruScan Acquisition system with a band-pass set at 0.5–64 Hz at a rate of 256 samples per second. We used standard 6-mm tin cups ear electrodes. All recordings and sessions were carried out in a quiet, comfortably lit, clinical neurofeedback room at the authors' clinic. Lighting and temperature were held constant for the duration of the sessions.

LNFB training sessions were composed of six 5-min rounds and were conducted five times per week for 20 consecutive weekdays. Each session collected 3-min presession eyes-opened baselines (EOB). Each session required 48 minutes on average to complete. In the preliminary shaping session, the participant was introduced to the EEG on screen and educated on how to minimize artifact to get the optimal signal. She was instructed to control tongue and eye movements, blinks, and muscle activity in forehead, neck, and jaws. This helped to reduce the effects of extracranial artifacts from electromyographic (EMG) and electro-oculographic (EOG) signals during the sessions. During the preliminary session thresholds were set so that the participant met the reinforcement criteria (20%; e.g., generate the desired response at a minimal rate). The participant was informed of the inhibitory and reward aspects of the training. Thresholds were then set and maintained for the participant.

The participant was provided visual and auditory feedback with a game interface or children's videos, and points were achieved when able to simultaneously increase alpha current source density (CSD, 8–13 Hz) at the region of training (ROT), while minimizing EMG (35–55 Hz) and EOG (1–3 Hz) in linear combinations of channels (i.e., for EMG: T3, T4, T5, T6, O1, and O2; for EOG: FP1, FP2, F3, F4, F7, and F8). These criteria had to be maintained for .75 s to achieve 1 point. The auditory stimuli provided positive reinforcement with a pleasant tone when the criteria were met. Similarly, the visual stimuli were activated when the criteria were met (e.g., a car or a spaceship driving faster and straighter). Alternatively, slower speed of the car, driving in the wrong lane, or the spaceship flying slowly and crookedly were seen when the criteria were not met. The score for meeting the criteria was also seen by the participant in a small window of the game screen. Additionally, the visual stimuli contained a signal for reward and inhibits relative to a threshold level, and a bar graph illustrating reward, EOG, and EMG. When the children's video was used for feedback, the visual image remained clear and the sound remained on when criteria were met; otherwise the picture blurred, and sound was interrupted when criteria were not.

The regions within a theorized self-regulation network (SRN; Cannon, 2014) were identified as a focus of study based on their association with the precuneus and studies showing activation across attention, cognitive, and self-regulatory tasks. The center voxels for the regions of interest (ROIs) for this case study data are shown in Table 1. The mean CSD for the alpha 1 and alpha 2 frequencies were extrapolated from precuneus and network regions of interest for the EOB recordings at time 1, time 2 and time 3, in similar fashion the mean CSD for alpha for the LNFB training rounds were extrapolated and placed into SPSS 22 for analyses. We utilized paired comparisons to contrast pretraining and posttraining means for alpha CSD at left precuneus region of training (ROT), for associated network regions, as well as for psychometric data. We compared the mean score for the nine scales on the ABAS and K-CPT across all categories at each administration. We re-administered the ABAS-3 posttraining, and the K-CPT 2 posttraining and at 30-day follow-up.

Table 1
SRN Regions of interest for this study data.

Brodman Area (BA)	Hemisphere	x,y,z Coordinates	Neuro-anatomical	# Voxels
19	L	-31, -81, 22	Precuneus	3
13	R	39, -4, 8	Insula	6
23	R	4, -32, 29	Cingulate gyrus	5
25	L	-3, 10, -13	Subcallosal gyrus	6
29/30/31	L	-3, -46, 22	Posterior cingulate	6

From left to right are the Brodmann Area, Hemipshere, LORETA x,y,z coordinates, neuroanatomical label and number of voxels in the ROI.

Results

The results for the pre–post training paired comparisons for the ABAS-3 are shown in Table 3. In the figure from top to bottom are the domain measures and from left to right pre and post scaled scores for parents. Significant shifts did occur across time with the more interesting changes showing improvement in the social, self-direction, and leisure domains. Parents were provided summary of ABAS-3 recommendations and are continuing to address items as they arise. At a follow-up meeting 30 days after training, her mother reported continued reduction of problematic behaviors and more positive engagement in social and interpersonal domains. The client also recently started pre-Kindergarten and will continue to be monitored over time. In contrast to her inability to complete the K-CPT 2 during the pretraining assessment, she was able to complete this test posttraining and at the 30-day follow-up assessment. We contrasted the mean results for all scales of the K-CPT posttraining and at follow-up which showed statistically elevated errors relative to the 4-year-old normative group which had increased at follow-up with $t(9) = -3.12$, $p = .014$. These results must be interpreted cautiously due to her age being below that of the test's normative sample. Figure 1 and Table 2 show the results for alpha CSD contrasts for pre, post and follow-up EOB. The ROT (precuneus) did show significant increases at posttraining, and significant decrease at follow-up, which impacted the shifts in the remaining network nodes. In the figure are the CSD for 5 ROIs implicated in the SRN. The precuneus is shown in black to the left of each ROI. In general, there was a significant increase in mean alpha 1 CSD posttraining in all ROIs of the SRN, including the ROT, the precuneus. At 30-day follow-up there is a significant decrease in all network nodes. Alpha 2 shows a similar trend, although at posttraining the result was in the desired direction but did not reach significance. The same trend in alpha 2 CSD is present at follow-up with an interesting and significant decrease in CSD amplitude in 3 ROIS and relative higher amplitude in the right insula and orbital frontal cortex. Figure 4 shows the mean ROT alpha CSD levels for sessions 1, 5, 10, 15, and 20. The trend is in the desired direction $y = 14.112x + 59.199$; $R^2 = 0.8856$.

Table 2
Results for paired comparisons for combined ABAS-3 parent ratings were significant with t(18) = 2.86, p = .010.

Skill Area	Mother Pre	Mother Post	Father Pre	Father Post
Communication	10	9	7	8
Community Use	6	5	4	6
Pre-Academics	6	5	6	8
Home Living	6	6	6	7
Health and Safety	8	8	5	7
Leisure	1	9	6	7
Self-care	8	9	7	8
Self-direction	5	8	4	5
Social	6	9	3	5
Motor	11	9	9	11

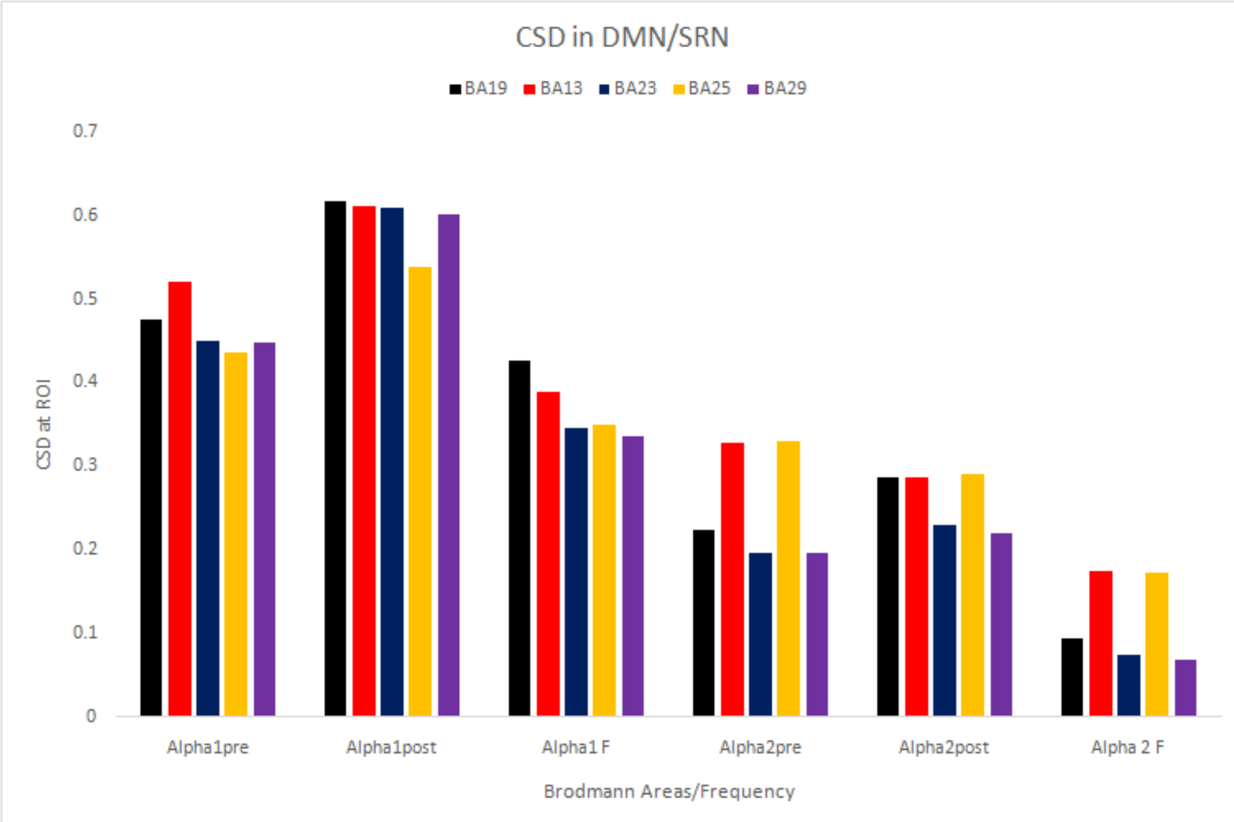

Figure 1. Results for paired *t*-test for pre/post pre/follow and post/follow alpha activity at specific SRN network ROIS corresponding to Table 2. In the figure from left to right are alpha 1 pre EOB, alpha 1 post EOB, alpha 1 follow EOB, alpha 2 pre EOB, alpha 2 post EOB and alpha 2 follow EOB.

Table 3
Paired sample results for region in SRN in alpha 1 and alpha 2 current source density.

Contrast	Mean	*SD*	*SE*	95% L	95% U	*t*	*df*	*p*
a1 pre – a1 post	-.1294	.03068	.01372	-.16757	-.09139	-9.438	4	.001
a1 pre – a1 follow	.09617	.03115	.01393	.05750	.13485	6.904	4	.002
a1 post – a1 follow	.2256	.03721	.01664	.17945	.27185	13.560	4	.000
a2 pre – a2 post	-.0083	.04589	.02052	-.06537	.04859	-.409	4	.704
a2 pre – a2 follow	.1377	.01592	.00712	.11796	.15749	19.347	4	.000
a2 post – a2 follow	.1461	.03224	.01442	.10608	.18615	10.133	4	.001

In the table from left to right are the mean, standard deviation, standard error, lower and upper 95%, *t*-value, degrees of freedom and *p*-value.

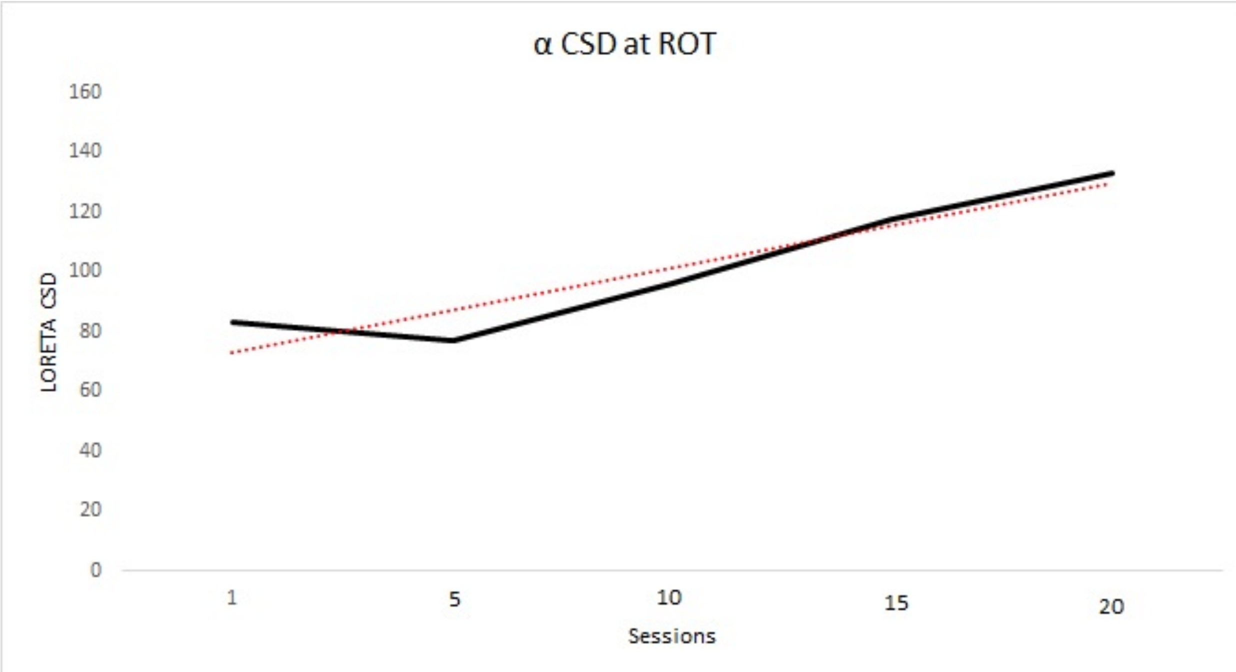

Figure 4. Learning trend for alpha CSD at region of training (ROT), $y = 14.112x + 59.199$; $R^2 = 0.8856$.

Discussion

The client was able to complete the 20 sessions of LNFB in the desired fashion. She improved across ABAS-3 ratings by parents and was able to complete an attention test posttraining and at follow-up. She generated a learning trend in the desired direction and shifted alpha CSD in a proposed self-regulation network. She was able to complete the K-CPT posttraining and, at 30-day follow-up with atypical scores in sustained attention and vigilance, there was a significant increase in atypical findings at follow-up. Prior research has noted the important relationship between this anterior insula region with DMN activity, in addition to attention, self-awareness, switching and socio-emotional functions (Menon & Uddin, 2010; Nomi et al., 2016; Odriozola et al., 2016; Uddin & Menon, 2009). Importantly the anterior insula is considered a core hub in the salience network (Goulden et al., 2014). In this respect children suffering from IUDE tend to have difficulties regulating emotionally charged reactions to the environment, including social and interpersonal aspects. In many cases they may be more aggressive and violent as contrasted with normative peers.

The medial parietal and posterior regions of the cortex play a significant role in self-regulation and learning; moreover, recent data suggest a high degree of overlap between DMN and regions activated in social cognitive tasks (Kuzmanovic et al., 2009; Schilbach, Eickhoff, Rotarska-Jagiela, Fink, & Vogeley, 2008). These overlapping regions include the ventromedial prefrontal, including orbital frontal cortex, posterior cingulate/retrosplenial cortices, and inferior parietal lobes. It is therefore relative that the proposed network and its functionality include regions associated with social cognition in addition to the affective and executive processes needed to perform in this domain. The default network has been investigated in 2-week-old to 2-year-old healthy subjects (Gao et al., 2009; Giovanello, Schnyer, & Verfaellie, 2009; Supekar et al., 2010), and is of particular interest concerning exposure to opioids and other drugs of abuse and their impact on the brain for all ages, but more importantly children.

Studies of the effects of opiates on the EEG typically show an increase in beta and higher alpha amplitude and also suggested a right hemisphere sensitivity to adverse opioid effects (Fingelkurts et al., 2008). The neural substrates impacted by IUDE remain unclear as does which neurometric and psychometric data best facilitate rigorous and accurate differential diagnosis. However, the risk of an ADHD diagnosis in these children is increased relative to the increase in DMN activity at rest (Sheinkopf et al., 2009), as well as the well described pronounced difficulties in sustained attention and impulse control across all prenatal substance exposure (Nygaard, Slinning, Moe, & Walhovd, 2016). The current data presents the effects of a standard operant conditioning model in which training produces effects in relative clusters of a network (SRN) that is shown to increase in CSD relative to training one node within it. Additionally, with specific practice of behavioral, social, and executive processes, the activity in this network decreased dramatically over time. This learning and neural efficiency result is important to understanding the effects of neurofeedback over time, in addition to the effects of practice.

The current case study does have limitations. Currently, there are few normative data to contrast children under the age of 4, especially concerning neurometric data. It is worthwhile to mention that younger children are excited and engaged by certain videos that attempt to engage them physically and verbally and patience on the part of the technician or provider is highly productive. Although there are limited data to evaluate normative DMN levels in children less than 6 years of age. She was able to generate a positive linear trend of alpha CSD in the ROT in the specific trained frequency. IUDE presents numerous challenges across all disciplines working with children and operant conditioning of the EEG and current sources within the brain may present the best first line approach to improving a multitude of symptoms and reducing the degree of medication in these children.

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