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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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Welcome to *NeuroRegulation* Volume 6, Issue 3; we are pleased you are joining us for the latest issue.

In this issue authors share reviews and utilize a variety of techniques demonstrating interesting findings. Erik Peper, Weston Pollock, Richard Harvey, Aiko Yoshino, Jennifer Daubenmier, and Madhu Anziani present data exploring the effects of mindfulness meditation and toning on awareness and intervention on mind wandering. Estate Sokhadze, Lonnie Sears, Allan Tasman, Emily Cassanova, and Manuel Cassanova present event-related potential data for a visual oddball task in children with autism spectrum disorder (ASD), attention-deficit/hyperactivity disorder (ADHD), and children with comorbid ASD+ADHD contrasted with neurotypical children. Erik Peper, Richard Harvey, and Daniel Hamiel present data on transforming thoughts with postural awareness and its relation to therapeutic and teaching efficacy. And finally, Giulia Fronda, Davide Crivelli, and Michela Balconi present a discussion of applications and ethical issues relating to neurocognitive enhancement.

NeuroRegulation thanks these authors for their valuable contributions to the scientific literature for neurofeedback, neuroscience, 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. It would be of interest to have case studies for postconcussive syndrome, traumatic brain injury, and posttraumatic stress disorder. We encourage researchers, clinicians and students practicing neurofeedback to submit case studies, or groups of case studies! We thank you for reading *NeuroRegulation*!

The journal continues to take great strides for increasing the scientific integrity of neurofeedback, biofeedback, and applied neuroscience. We extend an invitation to all researchers and clinicians interested in human performance, the human brain, and methods to improve its functionality to submit reviews, theoretical articles, and research data. We would like to thank our editorial board, reviewers, and contributors for this success. When writing this editorial, I decided to conduct my usual search of PubMed with the term "neurofeedback" for articles dated from 1994 to current. In addition to finding a substantial increase in the number of articles over the last few years, the growth in number of publications has been exponential in the last decade, since 2009. We are confident this trend will continue and believe our no-fee open-access journal is well positioned to be an active player in that growth. If we are clear to purpose, consistent with methods and publishing outcomes, then we are capable of much. I look forward to more discoveries and processes uncovered to aid in improving human performance across all functional domains.

It is time for the 27th Annual International Society for Neurofeedback and Research (ISNR) Conference in Denver, Colorado, September 19–22. We look forward to seeing you there!

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NeuroRegulation

Which Quiets the Mind More Quickly and Increases HRV: Toning or Mindfulness?

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Abstract

Disruptive thoughts interfere with concentration and performances. This report compares mindfulness practice (MP) with toning practice (TP) to reduce mind wandering and intrusive thoughts. Ninety-one undergraduate students (average age 22.4 years) began with either an MP or TP for 3 min. Respiration, blood volume pulse, and heart rate were monitored for 11 participants. The participants reported less mind wandering during TP ($M = 3.7$) than during MP ($M = 6.5$; $p < .001$), fewer intrusive thoughts during TP ($M = 3.2$) than during MP ($M = 4.7$; $p < .001$), and more body vibrations during TP ($M = 6.2$) than during MP ($M = 2.3$; $p < .001$) on a scale from 0 (*not at all*) to 10 (*all the time*). For participants with the highest self-reported rating of depression, TP was more effective in reducing mind wandering and intrusive thoughts than the MP ($p < .001$). There was no difference in self-reports in peacefulness, warmth, relaxation, anxiety, and depression between TP and MP. There was a decrease in respiration rate during TP (4.6 br/min) as compared to MP (11.6 br/min; $p < .001$) and an increase in heart rate variability during TP (SDNN = 103.7 ms; $SD = 11.6$) as compared to MP (SDNN = 61.9 ms; $SD = 6.4$). The findings suggest that TP is a powerful strategy to reduce mind wandering and intrusive thoughts.

Keywords: toning; mindfulness meditation; respiration; heart rate variability; intrusive thoughts; wandering thoughts; peacefulness; relaxation; depression

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Background

Intrusive thoughts and worries are common experiences that are often challenging to control, and sometimes interfere with learning self-regulation and mastering bio-neurofeedback skills. Mindfulness practice (MP) and heart rate variability (HRV) training have been combined by some practitioners with neurofeedback training as an integrated approach for enhancing emotional and physiological self-regulation, and for achieving sympathetic and parasympathetic balance (Thompson & Thompson, 2015). Numerous clinical strategies are taught to clients to reduce negative ruminations such as third-wave cognitive behavioral therapy (CBT) as described by Kopelman-Rubin, Omer, and Dar (2017). In this context, third-wave CBT considers how people relate to their thoughts and emotions rather than the exact content of those thoughts and emotions, such as using emotion regulation therapy (Renna, Quintero, Fresco, & Mennin, 2017) and more recently mindfulness meditation/training (Hofmann & Gomez, 2017; Ost, 2008). Although participants often become successful in learning to relate better to their thoughts and emotions using these third-wave techniques, many continue to struggle with distracting or wandering thought processes. Letting go of worrying thoughts and rumination is even more challenging when one is upset, angry, or captured by stressful life circumstances. It may be possible that other strategies can more rapidly reduce wandering and intrusive thoughts. For example, van der Zwan, de Vente, Huizink, Bogels, and de Bruin (2015) found that physical activity (PA), mindfulness meditation (MM; in contrast to mindfulness-based CBT), and heart rate variability biofeedback (HRV-BF) for 5 weeks' practice are equally effective in reducing stress and its related symptoms when compared to typical psychotherapies. In addition, meditators often report that mantra meditation, singing, chanting, and toning can quickly quiet the mind.

Recently, MM has been integrated and adapted as one major strategy for reducing wandering thoughts during bio- and neurofeedback training (Khazan, 2013, 2019). Within the context of the techniques described by Khazan (2013), mindfulness training consists of instructions for attending to present-moment experiences such as the experience of breathing, repeating a mantra, or imagining some visual object, as well as embracing an attitude of nonjudgmental acceptance and awareness of present-moment thoughts. As negative-emotion thoughts arise, the instruction is to recognize the thoughts without judging or becoming experientially "fused" with them in a process referred to as "meta-awareness" (Dahl, Lutz, & Davidson, 2015) before "disengaging" from those negative thoughts, and then turning attention back to the experiences of training and raising awareness of the intended goal of the training. Mindfulness training combined with bio- and neurofeedback training has been shown to improve a wide range of psychological and physical health conditions associated with symptoms of stress, such as anxiety, depression, chronic pain, and addiction (Creswell, 2015).

Biofeedback-assisted HRV training can be very effective to encourage sympathetic–parasympathetic balance (Lagos, Thompson, & Vaschillo, 2013; Lehrer & Gevirtz, 2014; McGrady & Moss, 2018; Shaffer & Ginsberg, 2017). It is a highly beneficial approach for the treatment of anxiety, gastrointestinal distress, posttraumatic stress, and concussions (Condor & Condor, 2014; Ginsberg, Berry, & Powell, 2010; Goessl, Curtiss, & Hofmann, 2017; Lagos et al., 2013; Lehrer & Gevirtz, 2014). The biofeedback-assisted training focuses on increasing HRV typically through breathing pacing at a rate of about 6 breaths per minute.

In a randomized control trial (RCT), van der Zwan et al. (2015) compared the efficacy of self-help PA, MM, and HRV-BF training over 5 weeks of practice to reduce stress and its related symptoms. They found that PA, MM, and HRV-BF training were equally effective in reducing their measurements of stress and its related symptoms. Even though people can learn to practice PA, MM, and HRV-BF techniques, many continue to struggle, although less often, with distracting or wandering thought processes. Letting go of worrying thoughts and rumination is even more challenging when one is upset, angry, or captured by stressful life circumstances.

During conversations with students about PA, MM, and HRV-BF, there were reports that other approaches—such as singing, chanting, or toning—were able to capture rapidly their attention and quiet the "busy-mind" more quickly. There has been some support for the hypothesis that vocalizations have a calming or soothing effect on strong negative emotional experiences. For example, preliminary research related to vagal nerve stimulation in patients with depression suggested that audible chanting of *OM* vs. *ssss* (e.g., repeating the sound produced by uttering *OM* or *ssss*, respectively) resulted in "significant deactivation observed bilaterally during 'OM' chanting in comparison to the resting brain state in orbito-frontal, anterior cingulate, parahippocampal gyri thalami and hippocampi" (Kalyani et al., 2011, p. 4). The authors speculated the sound vibrations stimulated the auricular branches of the vagal nerve with resultant effects on brain activation. Another study examining OM meditation using EEG spectral analysis found increases in theta waves across all brain regions, an indicator of enhanced relaxation (Harne & Hiwale, 2018). Porges (2017) suggests that "…prosodic vocalizations (e.g., chants) in the frequency band that would overlap with the vocal signals of safety…" (p. 10) and "…by expanding the duration of exhalation and reducing the duration of inspiration…" (Porges, 2017, p. 16) have a positive effect on reducing emotional reactivity.

Whereas other studies have directed participants to rhythmically chant the sounds of *OM* or repeatedly form the sound of *ssss*, this activity explored 1) the self-report of mindfulness and toning practice *UO* (pronounced as *you*) as well as 2) the psychophysiology effects of mindfulness and toning practice. Toning as a practice can be distinguished from chanting or singing, where, for example, Snow, Bernardi, Sabet-Kassouf, Moran, and Lehman (2018) write: "Toning is a form of vocalizing that utilizes the natural voice to express sounds ranging from cries, grunts, and groans to open vowel sounds and humming on the full exhalation of the breath. Music therapists are increasingly utilizing toning in their clinical practice for a variety of therapeutic aims" (p. 221).

Method

Observation 1

Self-report of mindfulness and toning practice.

Subjects: 91 undergraduate college students (35 males, 51 females, and 5 unspecified; average age, 22.4 years, *SD* = 3.5 years). 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: In the classroom, students sat comfortably in their chairs. Then the mindfulness and toning practices were explained, and the students were given an opportunity to ask questions. While sitting in class, students began either a 3-min mindfulness practice or a 3-min audible toning practice (vocalizing the sound of *UO*). They then filled out a subjective assessment form rating experiences of mind wandering, occurrence of intrusive thoughts, and sensations of vibration on a scale from 0 (*not at all*) to 10 (*all the time*) that occurred during the practice. They also rated experiences of peacefulness, relaxation, stress, warmth, anxiety, and depression from before to after the practice, as well as a description of prior experiences with depression and anxiety symptoms. The brief 3-min practices were counterbalanced with either mindfulness practice or audible toning, respectively, followed by completion of subjective rating forms.

Observation 2

Psychophysiology of mindfulness practice and toning practice.

Subjects: 11 undergraduate students (4 males, 7 females; average age 21.4 years).

Equipment: Physiological signals were recorded with an 8-channel polygraph (ProComp Infiniti system running Biograph Infiniti software version 6.1, Thought Technology, Ltd., Montreal, Canada). Respiration was monitored from the abdomen and upper thorax with strain gauges. Heart rate (HR) was monitored with a blood volume pulse sensor placed on the thumb.

Procedure: After the sensors were attached, the subjects faced away from the screen, so they did not receive feedback. They then followed the same procedure as described above, with 3 min of mindfulness, or toning practice, counterbalanced. After each condition, they completed a subjective assessment form rating experiences as described above.

Physiological Data Analysis

The respiration signal was analyzed for breathing rate per minute. The blood volume pulse (BVP) signal, from which the HR was derived as the index of HRV, is used to compute the standard deviation of HR in beats per minute and then expressed as the standard deviation of the normalized beat-to-beat interval (SDNN) measured in milliseconds (ms).

Results

Subjective Results of Observation 1

The participants reported less mind wandering during the toning condition (*M* = 3.7) than during meditation condition (*M* = 5.6) as determined by a single factor ANOVA, *F*(1, 179) = 29.17, *p* < .001; less intrusive thoughts during toning (*M* = 3.2) than during meditation (*M* = 4.7) as determined by a single factor ANOVA, *F*(1, 178) = 14.56, *p* < .001; and more awareness of body vibration during toning (*M* = 6.2) compared to the meditation condition (*M*= 2.3) as determined by a single factor ANOVA, *F*(1, 178) = 104.03, *p* < .001, as shown in Figure 1.

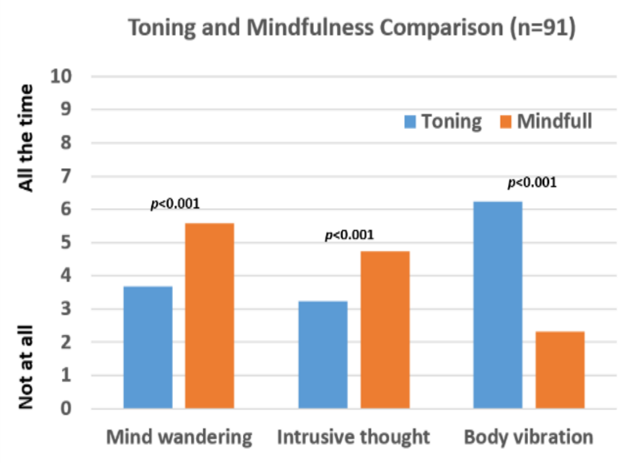

Figure 1. Differences between mindfulness and toning practice.

There was no statistically significant difference between the two practices in the increased self-report of peacefulness, warmth, relaxation, and decreased self-report of anxiety and depression as shown in Figure 2.

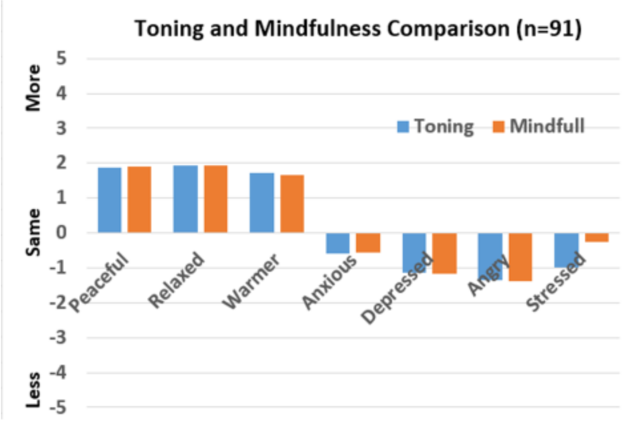

Figure 2. No significant difference between toning and mindfulness practice in relaxation or stress reports.

For the 30% of participants with the highest self-reported rating of depression, toning was more beneficial than mindfulness practice in reducing mind wandering as determined by a single factor ANOVA, *F*(1, 58) = 6.30, *p* = .015; as well as reducing intrusive thoughts as determined by a single factor ANOVA, *F*(1, 58) = 6.20, *p* = .016, as shown in Figures 3 and 4.

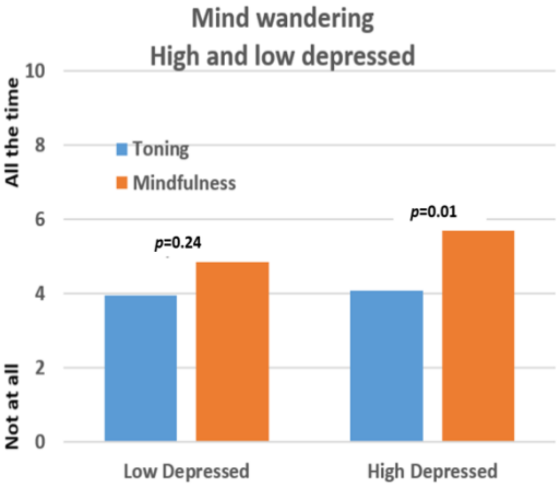

Figure 3. Effect of mindfulness and toning practice for high versus low reports of depression.

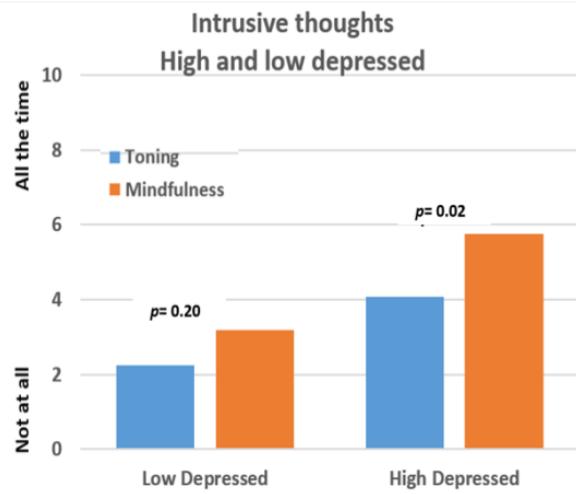

Figure 4. Effect of mindfulness and toning practice for high versus low reports of depression.

Physiological Results of Observation 2

There was a decrease in respiration rate during toning practice (TP, 4.6 br/min) as compared to MP (11.6 br/min) as determined by a single factor ANOVA, *F*(1, 18) = 30.84, *p* < .001); as well as an increase in HR standard deviation (SDNN) during the toning condition (11.6; SDNN 103.7 ms) as compared to the mindfulness condition (6.4; SDNN 61.9 ms) as determined by a single factor ANOVA, *F*(1, 20) = 11.86, *p* = .002). Two representative, counter-balanced recordings are shown in Figure 5. For both sample recordings, during toning the respiration rate (abdomen and chest) decreases. Furthermore, in these samples the HR increases much more during inhalation and decreases much more during exhalation, as compared to mindfulness portions of the recordings, and with the pre and post baselines.

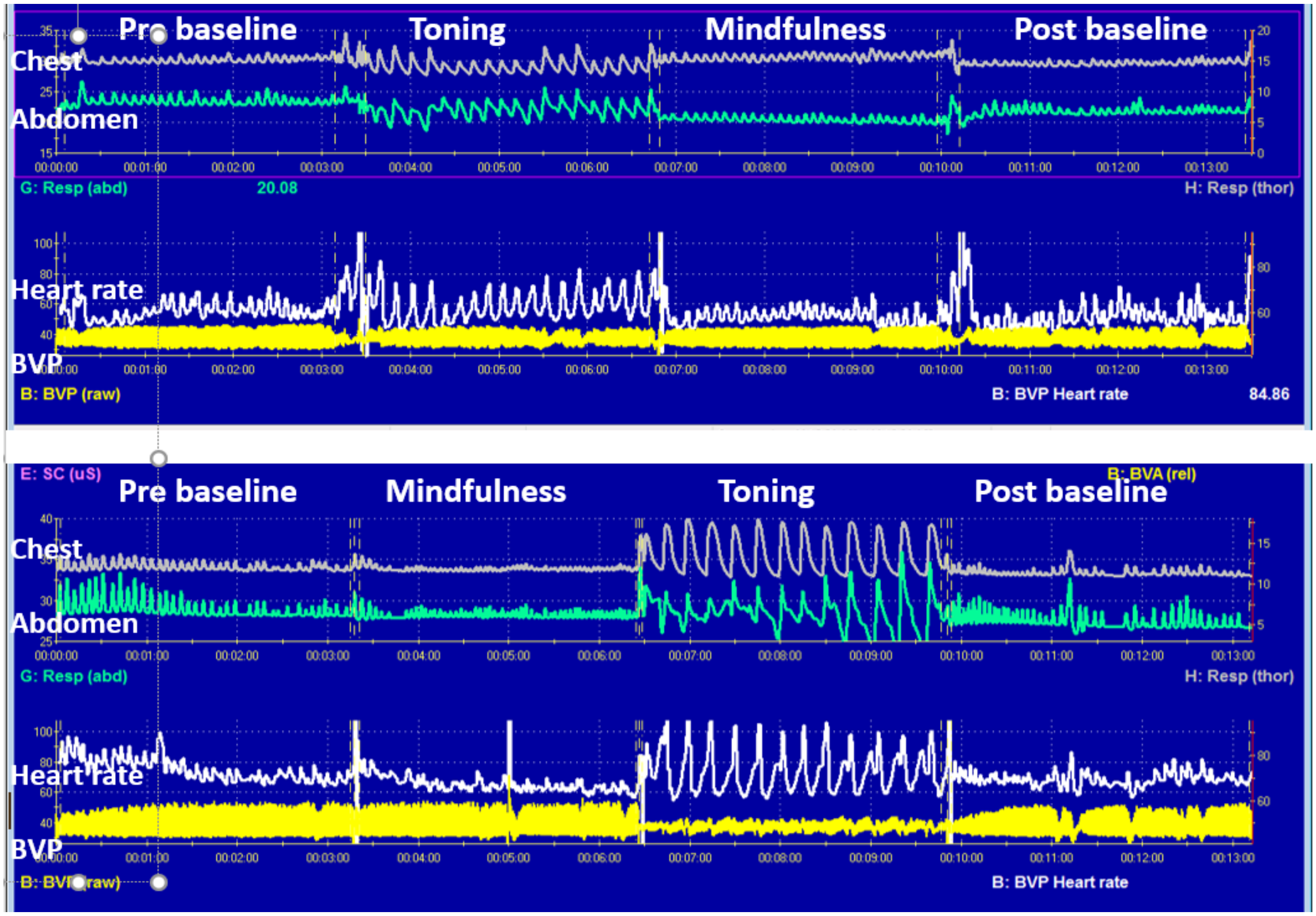

Figure 5. Two participants' representative recordings of breathing and heart rate during mindfulness and toning practice.

Discussion

The observations suggest that a brief 3-min TP is a useful strategy to reduce mind wandering as well as inhibit intrusive thoughts and increase HRV. We recommend that when patients report feeling worried and anxious that they first practice toning before beginning bio-neurofeedback training.

TP very rapidly reduced respiration rate and increased HRV. The increase in HRV and slow respiration during TP occurred along with self-reported reductions in mind wandering and intrusive thoughts, as well as increases in awareness of somatic sensations such as body vibrations. It will be a useful strategy to practice toning as a complement to other bio-neurofeedback protocols, including biofeedback-assisted HRV training, especially because focusing on the toning appears to facilitate HRV increases without striving.

It is recommended that when clients report excessive mind wandering and intrusive thoughts, that they practice toning as the first intervention before beginning the MP, relaxation or bio-neurofeedback training. By combining toning as a rapid thought-reducing strategy and mindfulness-based stress reduction as a long-term skill acquisition practice, clinical outcomes may improve. Toning is a portable skill that clients can implement immediately to inhibit intrusive thoughts and to enhance parasympathetic tone.

There are some limitations of these observations. The data represents a student sample that may not generalize to other populations. The audible toning also took place in a group setting; thus, effects may vary if done alone or with a facilitator. There are enough encouraging observations to suggest that more research is needed to explore the value of TPs as a brief intervention for practitioners to use during biofeedback/neurofeedback sessions.

Future research directions include exploring conditions that are similar to ruminative thoughts. For example, as described by Smith and Alloy (2009), other disruptive thought processes may be at work with labels such as negative automatic thoughts, private self-consciousness, self-focused attention, repetitive thoughts, intrusive thoughts, obsessions, worry, emotion regulation and coping, and neuroticism. Furthermore, future research may explore conditions that distinguish frequency, intensity, and duration of toning, chanting, singing, and other vocal productions that affect affective states. Regardless of what future discoveries await, TPs appear to be a simple and easy strategy for reducing intrusive thoughts and improving cardiorespiratory balance.

Author Disclosure

Authors have no grants, financial interests, or conflicts to disclose.

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Comparative Event-related Potential Study of Performance in Visual Oddball Task in Children with Autism Spectrum Disorder, ADHD, Comorbid Autism and ADHD, and Neurotypical Children

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Abstract

Autism spectrum disorder (ASD) and attention-deficit/hyperactivity disorder (ADHD) are the most commonly diagnosed neurodevelopmental disorders. Although the comorbidity was excluded in DSM-IV (APA, 2000), DSM-5 (APA, 2013) does not preclude the concurrent diagnosis of ASD and ADHD (ASD+ADHD). This study aimed to understand distinctions in executive deficits among these conditions. We used analysis of reaction time (RT) and event-related potentials (ERP) during performance on oddball task with illusory figures. Participants were children (*N* = 18 per group) with ASD, ADHD, ASD+ADHD, and neurotypical controls (CNT). Analysis revealed that ASD and ASD+ADHD groups committed more errors and had higher omission error rates. Post-error RT in ASD and ASD+ADHD manifested as a post-error response speeding rather than normative RT slowing. The ASD and ASD+ADHD demonstrated an attenuated error-related negativity (ERN) as compared to ADHD and controls. The frontal N100 was enhanced to both target and nontarget figures in ASD and ASD+ADHD groups. Frontal ERPs had prolonged latencies in the ADHD as compared to other groups. The study confirmed the utility of using ERP to elucidate differences between ASD and ADHD and their impact in dual diagnosis. This information helps define the extent of overlap among these conditions both in terms of symptom expression and underlying neuropathology.

Keywords: autism spectrum disorder (ASD); ADHD; event-related potential; attention; oddball task; comorbid ASD+ADHD; executive functions

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Introduction

In DSM-5 (APA, 2013), the autism spectrum disorder (ASD) and attention-deficit/hyperactivity disorder (ADHD) diagnoses have almost no core clinical symptom overlap; nevertheless, their similarities in associated features are significant. In DSM-5 and ICD-10 (WHO, 2008) manuals, ASD is defined by significant impairments in reciprocal social interaction and communicative function and restricted, repetitive behaviors and interests, while ADHD is defined by developmentally inappropriate and functionally impaired levels of hyperactivity, impulsivity, and inattention. However, before the DSM-5 release in 2013, according to diagnostic criteria enunciated in the DSM-IV-TR (APA, 2000), both pervasive disorders of development (PDD; i.e., autistic disorder, Asperger syndrome, PPD-Not Otherwise Specified [PDD-NOS]) and ADHD were classified as mutually exclusionary diagnoses. There was a growing consensus from clinicians and researchers that behavioral characteristics of ADHD are observed in 14–78% of ASD patients (Holtman, Bolte, & Poustka, 2007; Keen & Ward, 2004; Lee & Ousley, 2006; Leyfer et al., 2006; Reiersen, Constantino, Volk, & Todd, 2007; Ruggieri, 2006; Sinzig, Walter, & Doepfner, 2009; Yoshida & Uchiyama, 2004). Furthermore, among patients diagnosed with ADHD, up to two-thirds of individuals exhibited autism-like symptoms, especially in the social communication domain (Cooper, Martin, Langley, Hamshere, & Thapar, 2014; Davis & Kollins, 2012; Leitner, 2014). These studies questioned the validity of comorbidity as an exclusionary criterion within DSM-IV-TR guidelines, and argued in favor of changes (Ruggieri, 2006) that eventually resulted in the revision of this clause in the DSM-5. Although behavioral characteristics of autism and ADHD may coexist, the more relevant question remains whether these neurodevelopmental conditions share the same underlying neuropathology. Some of the shared symptoms between ASD and ADHD suggest that these conditions may well share some aspects of neurodevelopmental pathologies affecting their behavior and performance during neurocognitive tests. However, it should be noted that these neurodevelopmental disorders have been investigated in divergent fields in the past. Rommelse, Geurts, Franke, Buitelaar, and Hartman (2011) reviewed ASD and ADHD phenotypes related literature and emphasized that on most occasions in the past decades ASD and ADHD have been studied in isolation from each other, without networks of collaborating experts and common theoretical frameworks. He strongly argued for the concomitant, rather than individual, investigation of ASD and ADHD.

There is a need to investigate specifics of the overlap and distinction in behavioral and neurophysiological impairments typical for ASD and ADHD and to determine how symptoms combine in ASD+ADHD cases (Lau-Zhu, Fritz, & McLoughlin, 2019). Reports have shown that children with ASD+ADHD present more behavioral difficulties of adaptation to daily life hassles as compared to those with ASD or ADHD alone. Furthermore, compared with ASD alone, ASD+ADHD are associated with generally poorer quality of life. It was reported (Frazier et al., 2011) that children diagnosed with ASD+ADHD are more likely to be taking psychiatric medication (58%) than those with ADHD (49%) or ASD (34%) alone. It is therefore unsurprising that children with ASD+ADHD could be less responsive to treatments specific to ADHD or ASD alone and therefore require more attention in order to achieve desired outcomes. In addition, it is still not clear whether comorbid ASD+ADHD presents as an additive condition with a similar contribution by both disorders or whether one of these diagnoses contributes more to symptom expression (Tye et al., 2014). Although there are important differences in core symptom definition in the DSM-5, the co-occurrence between ASD and ADHD is supported by numerous clinical, behavioral, neurophysiological, and neuroimaging studies (Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009; Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2004; Hovik et al., 2014; Johnston, Madden, Bramham, & Russell, 2011; Sinzig, Bruning, Morsch, & Lehmkuhl, 2008; Tye et al., 2014). In previous years most clinical and research studies have reported executive function impairments in ADHD and ASD (see Rommelse et al., 2011) separately; however, in recent years, a considerable amount of studies focused specifically on investigation of the executive deficits directly comparing ASD and ADHD (Lawson et al., 2015; Ray et al., 2014; Salcedo-Marin, Moreno-Granados, Ruiz-Veguilla, & Ferrin, 2013; Sinzig, Vinzelberg, Evers, & Lehmkuhl, 2014). Several studies directly addressed comparative analysis of symptoms in ASD, ADHD, and ASD+ADHD comorbidity (Hovik et al., 2014; Lawson et al., 2015; Salcedo-Marin et al., 2013; Samyn, Wiersema, Bijttebier, & Roeyers, 2014; Semrud-Clikeman, Walkowiak, Wilkinson, & Butcher, 2010; Sinzig et al., 2008; Sinzig et al., 2014; Tye et al., 2014). However, findings of the neuropsychological tests that rely solely on behavioral assessments can hardly be considered decisive in resolving the nature of the underlying neurobiological distinctions between autism and ADHD. That is to say, the coincidence and overlap of behavioral symptoms does not necessarily imply a similarity in underlying neurobiological pathology. Indeed, lines of research, in particular those based on pharmacological tests, have shown that behavioral symptoms for both ASD and ADHD might be mediated by different pathophysiological mechanisms. For instance, pharmacological interventions using stimulant medication that target hyperactivity and inattention in children with autism, even when proved to be effective for these particular behavioral clinical symptoms, still did not reduce the core symptoms of autism (Hazell, 2007).

There were expectations that neuroimaging data comparing ASD and ADHD might have provided insight related to their differences. Eventually, certain neuroimaging data did show some differences in neuroanatomy. For example, brain size in ASD appears to be increased (Stanfield et al., 2008), while ADHD exhibits an opposite trend towards smaller volumes (Batty et al., 2010). Other neuroimaging studies found group differences in gyral complexity, gray white matter parcellation, and size of the corpora callosa (Casanova et al., 2009; Casanova, El-Baz, Giedd, et al., 2010; El-Baz et al., 2011; Wolosin, Richardson, Hennessey, Denckla, & Mostofsky, 2009). Patients with ASD, as compared to neurotypical individuals, have larger brains but, at the same time, a smaller corpora callosa. Contrariwise, patients with ADHD have smaller brains but a larger corpora callosa. These morphometric differences in corticocortical connectivity may suggest a bias in short (i.e., arcuate) versus long projections (e.g., commissural fibers) that may help explain some of the behavioral manifestations observed in these conditions (Casanova, El-Baz, Vanbogaert, Narahari, & Switala, 2010). Review of 26 studies that examined executive function in children with ASD and ADHD by Craig et al. (2015) concluded that the ASD+ADHD group appears to share impairments in flexibility and planning with the ASD group, while it shares the response inhibition deficit of the ADHD group. Conversely, deficit in attention, working memory, preparatory processes, and concept formation does not appear to be distinctive in discriminating between the ASD, ADHD, or the ASD+ADHD group. Although ADHD and ASD seem very distinct in terms of core clinical symptoms, they have been shown to share some similarities in their executive functions deficit. Executive functioning skills fall under the purview of those prefrontal functions that facilitate problem-solving, flexible set-shifting and forward planning in the implementation of goal-directed behavior (Hughes, Russell, & Robbins, 1994). The executive deficits in autism have been related to specific frontal mechanisms, principally to the prefrontal and midfrontal cortices and associated neural circuitries (reviewed in Bishop, 1993; Hill, 2004). Executive deficits in ADHD are also associated with hypofunctional frontal networks (Hovik et al., 2014; Salcedo-Marin et al., 2013; Samyn et al., 2014; Semrud-Clikeman et al., 2010; Sinzig et al., 2014). Craig et al. (2015) reviewed studies comparing ASD and ADHD performance and reported that overlapping and specific profiles for ASD and ADHD were found mainly for such neurocognitive domains as attention processing, performance monitoring, and face processing. The domain of executive functions has significant implications for developmental psychopathologies, and more rigorous studies are warranted to understand specifics of executive deficit profiles of ASD and ADHD and comorbid ASD+ADHD.

The present study focused on the possibility of differing underlying pathophysiological mechanisms in both ASD and ADHD, as well as their comorbid condition by comparing behavioral responses and patterns of event-related potentials (ERP) during performance on three-stimuli visual oddball task with illusory Kanizsa figures. It should be noted that the majority of studies examining electrocortical biomarkers of executive functions in neurodevelopmental disorders focused on ERP measures (Hoeksma, Kemner, Kenemans, & van Engeland, 2006; Jeste & Nelson, 2009; Johnston et al., 2011; Johnstone & Barry, 1996; Jonkman, Kenemans, Kemner, Verbaten, & van Engeland, 2004; Kemner, van der Gaag, Verbaten, & van Engeland, 1999; Smith, Johnstone, & Barry, 2004; Verbaten, Roelofs, van Engeland, Kenemans, & Slangen, 1991). Analysis of ERP is a very informative method of monitoring information processing stages in the brain. Different amplitude and latency characteristics of ERP components at specified topographies reflect both early sensory perception processes and higher-level processing including attention, cortical inhibition, memory update, and other cognitive activity (Duncan et al., 2009; Polich, 2007).

Studies using oddball tasks and other attention paradigms (e.g., continuous performance, go/no-go, response choice tasks, and variety of similar tests) in ADHD have provided evidence for smaller visually evoked P300 amplitudes and prolonged latencies of P300 (Barry, Johnstone, & Clarke, 2003; Hoeksma et al., 2006; Kemner, van der Gaag, Verbaten, & van Engeland, 1999; Polich, 2007; Townsend et al., 2001; Verbaten et al., 1991). In sum, several studies found reduced frontal amplitudes and longer latencies in ADHD, which can be taken as suggesting a deficit in selective attention. In autism, on the other hand, only few studies reported a reduced ERP response to attended visual stimuli. Therefore, the majority of ERP studies have demonstrated altered visual P300 amplitudes in both ADHD and autism; however, it should be emphasized that these stimulus-locked ERP alterations do not seem to be specific markers. One of the important executive functions that may differentiate ASD and ADHD inputs to deficits observed in comorbid ASD+ADHD condition is response monitoring and error correction function. This function has well recognized ERP correlates in oddball tasks with motor responses. Most well validated among those is response-locked error-related negativity (ERN). This ERP component is a negative-going waveform peaking 40–140 ms after an error response or a negative feedback stimulus (Falkenstein, Hohnsbein, Hoormann, & Blanke, 1991; Gehring & Knight, 2000; Miltner, Braun, & Coles, 1997). It occurs in response to response errors, response conflict, and decision uncertainty (Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004). Conscious error processing is thought to be reflected by the error positivity (Pe), which is a positive-going potential following the ERN. It was reported that autistic children, especially those with impairments in social interaction, were more likely to fail correcting errors than controls (Henderson et al., 2006; Russell & Jarrold, 1998). Moreover, Bogte, Flamma, van der Meere, and van Engeland (2007) found that a group of autistic subjects, as compared to controls, showed no post-error normative slowing. These studies suggest decreased error awareness in autism, predicting decreased ERN and Pe amplitudes along with delayed latencies.

Several studies have found reduced ERN amplitudes in children with ADHD compared to typically developing children, suggesting that children with ADHD also present a deficit in monitoring ongoing behavior (Liotti, Pliszka, Perez, Kothmann, & Woldorff, 2005; van Meel, Heslenfeld, Oosterlaan, & Sergeant, 2007). Reduced Pe amplitudes in ADHD are in accordance with the findings of reduced post-error compensatory behavior; that is, the strategic RT slowing after the commission of errors (Schachar et al., 2004; Sergeant & van der Meere, 1988; Wiersema, van der Meere, & Roeyers, 2005). Reduced error awareness may thus hamper children with ADHD in adequately adapting their behavior and consequently in learning from their mistakes. Considering that both ASD and ADHD present ERN and Pe reactivity deficits and impaired post-error normative slowing of RT, it is possible to propose that the error monitoring and correction will be even more pronounced in dual diagnosis when children with ASD have ADHD as a comorbid condition. We proposed that error detection, monitoring, and correction function—as indexed by ERN, RT accuracy, and post-error RT adjustment—will be more significantly compromised in children with ASD+ADHD as compared to ASD-alone or ADHD-alone and will clearly differentiate these conditions from neurotypical peers.

The goal of this study was to investigate stimulus- and response-locked ERPs during performance on a visual three-category oddball task with illusory figure stimuli in children with ASD, children with ADHD, children with dual diagnosis (ASD+ADHD), and age-matched typically developing children (CNT group). We proposed that behavioral (RT, accuracy) and electrocortical (ERP, ERN, Pe) measures would provide differentiating features between the groups. We also expected to see more pronounced between group differences at the frontal topography as both ADHD and ASD typically present executive function deficits.

Methods

Participants

Participants with ASD (age range 7 to 19 years) were recruited through the University of Louisville Weisskopf Child Evaluation Center (WCEC). Diagnosis was made according to the DSM-IV-TR (APA, 2000), after 2013 according to DSM-5 (APA, 2013), and further ascertained with the Autism Diagnostic Interview – Revised (ADI-R; LeCouteur, Lord, & Rutter, 2003). They also had a medical evaluation by a developmental pediatrician. All subjects had normal hearing based on past hearing screens. Participants either had normal vision or wore corrective lenses. Participants with a history of seizure disorder, significant hearing or visual impairment, a brain abnormality from imaging studies, or an identified genetic disorder were excluded. All participants were high-functioning persons with ASD with full scale IQ > 80 assessed using the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV; Wechsler, 2003) or the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 2004).

In the ADHD diagnosis group, male and female patients aged 8 to 18 years old meeting inclusion and no exclusion criteria were eligible for the study. Diagnosis of ADHD was based on DSM-IV and/or DSM-5 criteria (ADHD, Inattentive, Hyperactive–Impulsive, and Combined type) using a structured parent interview (DICA; Reich, 2000) and was made by a clinical psychologist and child and adolescent psychiatrist. The DSM requires that symptoms be present in at least two settings; therefore, prior to the interview, two rating scales were administered to each child's parent as well as to the teacher (parents: Achenbach Parent Form and The Conner's Parent Rating Scale-R; while teacher: Achenbach Teacher Rating Form and Conner's Teacher Rating Scale-R). Subjects met criteria for ADHD on at least one of the two parent rating scales and on one of the two teacher rating scales. Only following these evaluations was the child considered as meeting criteria on the DICA-IV (Reich, 2000). Children with ADHD on stimulant medication were included in this study only if they were taken off medication on the day of the lab visit for tests. In addition, according to inclusion/exclusion criteria, eligible participants with ADHD had to be judged to be in generally good health and be willing and able to participate in lab tests. Exclusion criteria for this group were (a) current diagnosis of any Axis I psychiatric disorder, such as psychosis, bipolar disorder, and schizophrenia; (b) current psychiatric symptoms requiring medication other than those for ADHD; (c) severe medical, cognitive, or psychiatric impairments that preclude from the cooperation with the study protocol; and (d) inability to read, write, or speak English. The ERP procedures required the following additional exclusion criteria: (1) impaired, noncorrectable vision or hearing; (2) significant neurological disorder (epilepsy, encephalitis) or head injury.

Typically developing children (i.e., control subjects) were recruited through advertisements in the local media. All control participants were free of neurological or significant medical disorders, had normal hearing and vision, and were free of psychiatric, learning, or developmental disorders based on self- and parent reports. Subjects were screened for history of psychiatric or neurological diagnosis using the Structured Clinical Interview for DSM-IV Non-Patient Edition (SCID-NP; First, Spitzer, Gibbon, & Williams, 2001). Participants within the control, ADHD, autism, and ASD+ADHD groups were attempted to be matched by age, full scale IQ, and socioeconomic status of their family. Socioeconomic status of ASD, ADHD, ASD+ADHD, and control groups was compared based on parent education and annual household income. Participants in four groups had similar parent education levels. Participating subjects and their parents (or legal guardians) were provided with full information about the study including the purpose, requirements, responsibilities, reimbursement, risks, benefits, alternatives, and role of the local Institutional Review Board (IRB). The consent and assent forms approved by the University of Louisville IRB were reviewed and explained to all subjects who expressed interest to participate. All questions were answered before consent signature was requested. If the individual agreed to participate, she or he signed and dated the consent form and received a copy countersigned by the investigator who obtained consent.

Subject Demographics

The mean age of 18 participants enrolled in the ASD group was 13.2 ± 3.5 years (range 8–18 years, 14 males, 4 females); the mean age of the 18 participants in the ADHD group was 13.4 ± 2.9 years (range 8–18 years, 14 males, 4 females); the mean age of the 18 participants in the ASD+ADHD group was 12.5 ± 3.1 (range 7–17, 15 males, 3 females); and the mean age of the 18 participants in the CNT group was 14.2 ± 3.9 years (range 9–19 years, 13 males, 5 females). The age difference between groups was not significant (*p* = .323). Nine subjects from the ADHD group, 8 subjects from the ASD group and 10 subjects from the comorbid ASD+ADHD group were on medication. Children with ADHD and ASD+ADHD were taking stimulants (such as Ritalin–Methylphenidate or Adderall–Dextroamphetamine). Only 3 children with ASD were taking stimulants (Ritalin, Concerta, Adderall, etc.), and 10 in ASD and 7 in ASD+ADHD were taking antidepressants (Prozac–Fluoxetine, Zoloft–Sertraline) and mood stabilizers (Depakote–Divalproex, Abilify–Ariprazole). Four children in the ASD group and three in ASD+ADHD had comorbid mild mood disorders, and five in both of these groups had anxiety disorders. Two subjects from the ADHD group had comorbid mild mood disorders, and another three had anxiety disorders. All subjects with ADHD diagnosis (in ADHD only and in ASD+ADHD groups) were included regardless of their ADHD subtype (Inattentive, Hyperactive–Impulsive, or Combined).

Three-Stimuli Visual Oddball Task with Illusory Kanizsa Figures

In this task subjects responded with a button-press to rare (25% probability) Kanizsa squares (targets) among Kanizsa triangles (rare nontarget distracters, 25% probability) and non-Kanizsa figures (standards, 50% probability). The stimuli were presented for 250 ms with intertrial intervals (ITI) varying in the range of 1100–1300 ms. A fixation point (cross) was presented during ITI. White figures were displayed on a black background on a flat monitor. Subjects were instructed to press the first button on a five-button keypad with their right index finger when a target appears and ignore nontarget Kanizsa or standard stimuli. The stimuli consisted of either three or four inducer disks which are considered the shape feature, and they either constitute an illusory figure (square, triangle) or nonillusory figure (collinearity feature). The nontarget Kanizsa triangle was introduced to differentiate processing of task-relevant (Kanizsa square) and task-irrelevant Kanizsa figures.

ERP Data Acquisition and Signal Processing

Electroencephalographic (EEG) data was acquired with a 128-channel Electrical Geodesics Inc. (EGI) system (v. 200) consisting of Geodesic Sensor Net electrodes, Net Amps, and Net Station software (Electrical Geodesics Inc., Eugene, OR). EEG data were sampled at 500 Hz and 0.1–200 Hz analog filtered. Impedances were kept under 40 KΩ. According to the *Technical Manual of EGI* (2003), this Net Sensor electrode impedance level is sufficient for quality recording of EEG with this system. The Geodesic Sensor Net is a lightweight elastic thread structure containing Ag/AgCl electrodes housed in a synthetic sponge on a pedestal. The sponges are soaked in a KCl solution to render them conductive. EEG data were recorded continuously. EEG channels with high impedance or visually detectable artifacts (e.g., channel drift, gross movement, etc.) were identified using Net Station event marker tools in “on-line” mode and removed in the “off-line” mode using Net Station Waveform Tools (NSWT). Stimulus-locked EEG data were segmented offline into 1000-ms epochs spanning 200-ms prestimulus to 800-ms poststimulus around the critical stimulus events; for example, in an oddball task: (1) rare target (Kanizsa square), (2) rare nontarget distracter (Kanizsa triangle), and (3) frequent nontarget (non-Kanizsa standards). Response-locked EEG data (for ERN and Pe analysis) were segmented off-line into 1000-ms epochs spanning 500-ms prestimulus to 500-ms poststimulus around the critical stimulus events–committed error. Data were digitally screened for artifacts (eye blinks, movements), and contaminated trials were removed using artifact rejection tools. The NSWT Artifact Detection module in off-line mode marked EEG channels “bad” if fast average amplitude exceeded 200 μV, differential average amplitude exceeded 100 μV, or if the channel had zero variance. Segments were marked bad if they contained more than 10 bad channels or if eye blinks or eye movements were detected (> 70 μV). The remaining data set was digitally filtered using 60 Hz Notch and 0.3–20 Hz bandpass filters and then segmented by condition and averaged to create ERPs. Averaged ERP data were baseline corrected and re-referenced into an average reference frame. All stimulus presentation and behavioral response collection was controlled by a PC computer running E-prime software (Psychology Software Tools Inc., PA). Visual stimuli were presented on a 15-inch display. Manual responses were collected with a five-button keypad (Serial Box, Psychology Software Tools, Inc., PA).

Behavioral Measures

Behavioral response measures were mean reaction time (RT in ms) and response accuracy (percent of correct hits). Both commission and omission error rates were calculated. Post-error slowing was calculated as a difference between the first post-error RT and mean RT.

Event-Related Potentials (ERP)

Response-locked ERPs. Response-locked ERP dependent measures were adaptive mean amplitude and latency of two ERP peaks (i.e., ERN, Pe) within a temporal window across two region-of-interest (ROI) channel groups at the midline fronto-central area. Each ROI contained at least four electrodes. A list of dependent variables included response-averaged amplitude and latency of the fronto-central ERP components: ERN (40–150 ms poststimulus) and Pe (100–200 ms).

The frontal and fronto-central ROIs for both ERN and Pe components included the following EGI channels: midline frontal and fronto-central ROI contained Fz and FCz, and the extended fronto-central ROI contained five EEG sites—FCz, two left EGI channels 7 and 13 (between FCz and FC3 and C1), and two right EGI channels 113 and 107 (between FCz and FC2 and C2).

Stimulus-locked ERPs. Stimulus-locked ERP dependent measures were adaptive mean amplitude and latency of ERP peak (e.g., N100) within a selected temporal window across a region-of-interest (ROI) channel group. Each ROI contained at least four electrodes. A list of ERP dependent variables included stimulus-averaged amplitude and latency of the frontal ERP components: N100 (90–180 ms), P200 (180–300 ms), N200 (200–320 ms), and P300 (P3a, 300–500 ms), and the posterior (centro-parietal and parieto-occipital ROIs) ERP components N100 (80–180 ms), N200 (180–300 ms), and P300 (300–500 ms). The frontal (i.e., frontal and fronto-central) ROIs for N100, P200, N200, and P300 components included the following EGI channels: left ROI contained EGI channel 29, F3, FC1, FC3; midline ROI contained Fz, FCz, EGI channels 5, 12; and the right ROI contained EGI channel 118, F4, FC2, FC4. The parietal (i.e., centro-parietal and parieto-occipital) ROIs for N100 and P200 components included following EGI channels: left ROI contained EGI channel 67, PO3, PO7, O1; and right ROI contained EGI channel 78, PO4, PO8, O2. Midline parietal (Pz) and parieto-occipital (POz) channels were used in combination with the left and right parieto-occipital ROIs to form a comprehensive parieto-occipital ROI containing 10 EEG channels. For parietal and parieto-occipital N200 and P300 (P3b) were used channels P1, P3, PO3, EGI channel 54 and 67 (left) and P2, P4, PO4, EGI channels 78 and 80 (right). Midline parietal channels included Pz and POz.

Social and Behavioral Questionnaires

Social and behavioral functioning of participants were evaluated using caregiver reports and clinician ratings of improvement. Selected tests that have been shown to be sensitive to behavioral and social changes expected to occur with treatment and included following the Aberrant Behavior Checklist (ABC; Aman & Singh, 1994). The ABC is a caregiver-completed rating scale assessing five problem areas: Irritability, Lethargy/Social Withdrawal, Stereotypy, Hyperactivity, and Inappropriate Speech based on caregiver report. In addition, we used the Achenbach System of Empirically Based Assessment (ASEBA) questionnaire (parent version) for assessing adaptive and maladaptive functioning (Achenbach & Rescorla, 2012).

Statistical Data Analysis

Statistical analyses were performed on the subject-averaged behavioral and ERP data with the subject averages being the observations. The primary analysis model is the repeated measures ANOVA, with dependent variables being reaction time (RT), accuracy, error rate, post-error RT change for behavioral responses, and ERN, Pe, and all the specific stimulus-averaged ERP components' amplitudes and latencies at selected ROIs. The data of stimulus-locked ERP dependent variable for each relevant ROI was analyzed using ANOVA with the following factors (all within-participants): *Stimulus* (Target Kanizsa, Standard, nontarget Kanizsa), *Hemisphere* (Left, Right), etc. The between subject factor was *Group* (ADHD, ASD, ASD+ADHD, CNT). The data of each response-locked ERP dependent variable for relevant midline frontal ROI was analyzed using one-way ANOVA. Post hoc analysis using Tukey test was conducted where appropriate. A priori hypotheses were tested with Student's *t*-tests for two groups with unequal variance. In all ANOVAs, Greenhouse-Geisser corrected *p*-values were employed where appropriate.

Results

Attention symptoms on ASEBA. Main group differences using Achenbach's ASEBA (Achenbach & Rescorla, 2012) were found in *Attention Deficit Hyperactivity Problem* (DSM-oriented scale) *T-scores* (57.4 ± 6.1 in ASD vs. 69.9 ± 8.3 in ASD+ADHD, *F*(1, 34) = 23.24, *p* < .001) and in general *Attention Problems T-scores* (76.3 ± 9.1 in ASD+ADHD vs. 59.1 ± 6.5 in ASD, *F*(1, 34) = 31.04, *p* < .001). Differences in *Oppositional Behavior* or *Conduct Behavior* subscale ratings between these two groups did not reach statistical significance.

ABC scores. Children in ASD, ASD+ADHD, and ADHD groups were evaluated using parental rating of symptoms of the ABC. Statistically significant group differences were present only in the *Stereotypic Behavior* subscale rating scores, *F*(2, 53) = 6.74, *p* = .001. In particular, the ASD+ADHD group showed higher scores (7.67 ± 5.39) as compared to the ASD (3.55 ± 2.39, *p* = .002) and ADHD (2.69 ± 4.64, *p* = .005) groups. Other ABC subscales (*Irritability, Lethargy/Social Withdrawal, Hyperactivity, Inappropriate Speech*) did not show any between group differences.

Reaction time (RT) and accuracy. There were no significant group differences in RT (492 ± 111 ms in ASD vs. 523 ± 107 ms in ASD+ADD vs. 470 ± 89 ms in ADHD vs. 450 ± 97 ms in CNT, *F*(3, 71) = 1.45, *p* = .236, n.s.). Accuracy of response was different between groups, in particular total error percentage showed significant differences, *F*(3, 71) = 3.78, *p* = .015. A post hoc Tukey test yielded significant difference between ASD and CNT groups (17.9 ± 14.3 % in ASD vs. 2.4 ± 4.6 % in CNT, *p* = .009). Omission error contributed significantly to group differences, *F*(3, 71) = 5.87, *p* = .001. Post hoc analysis showed both ASD and ASD+ADHD vs. CNT difference (5.5 ± 4.9 % in ASD, 4.3 ± 5.3 % in ASD+ADHD vs. 0.4 ± 0.9 % in typical children with *p* < .01 in both comparisons). Furthermore, the ASD group had more omission errors even as compared to the ADHD group (difference was 3.80%, *p* = .038). In general children with ASD diagnosis (both ASD-only and ASD+ADHD) had more omission errors as compared to both typical controls (difference 4.36%, *p* = .001) and ADHD group (by 3.13%, *p* = 0.01). The ADHD factor (ADHD and ADHD comorbid with ASD) negatively affected total percentage of errors (12.2 ± 15.4% in combined ADHD and ASD+ADHD vs. 2.4 ± 4.6% in CNT, *p* = .043). The most pronounced group differences were found in the normative post-error RT slowing measure, *F*(3, 71) = 16.45, *p* < .001. Differences in mean post-error reaction time changes clearly separated groups with ASD from the typical children and ADHD groups, as both ASD and ASD+ADD groups showed post-error speeding (−46.1 ± 47.4 ms in ASD, −52.1 ± 51.7 ms in ASD+ADHD), while CNT and ADHD groups showed normative slowing of RT following committed errors (49.1 ± 45.9 ms in CNT, 11.9 ± 14.2 ms in ADHD). Post hoc test confirmed that differences between ASD and ASD+ADHD group post-error RT changes vs. CNT and ADHD groups were significant (all $p < .01$). The CNT and ADHD post-error measures were not statistically different. The ASD diagnosis (combined ASD and ASD+ADHD) factored most significantly in affecting post-error RT change (−49.1 ± 48.3 ms in combined ASD vs. 49.2 ± 45.9 ms in CNT, $p < .001$). At the same time, combined ADHD (ADHD and ASD+ADHD) also showed difference in this post-error RT measure resulting in significant difference from the control group (9.7 ms, $p = .043$). Distribution of individual post-error RT values in four groups are depicted in Figure 1.

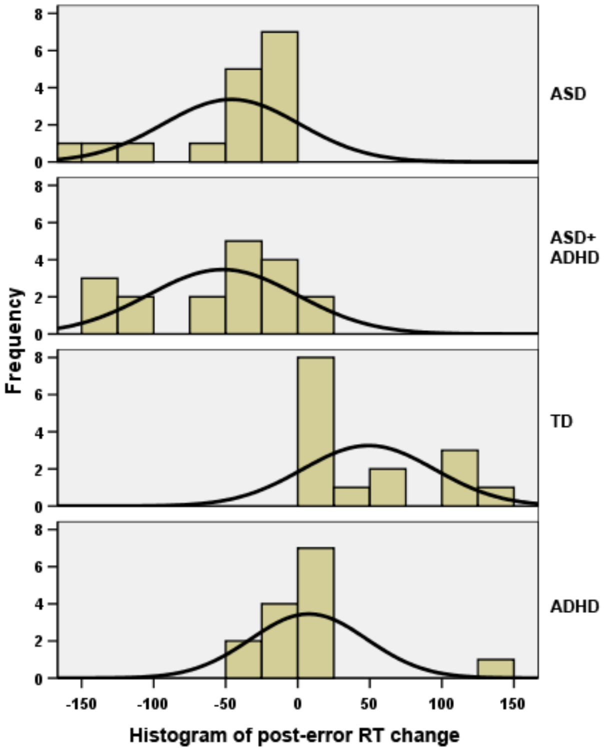

Figure 1. Histogram of distribution of individual post-error reaction time (RT) in children with autism, children with ASD+ADHD, typically developing (TD) controls, and children with ADHD. Both ADHD and control groups demonstrate slower (positive) post-error RTs compared to correct response RTs. The ASD and ASD+ADHD groups show speeding of post-error RTs with a negative peak of distribution curve. The ADHD shows positive peak of the curve though still less expressed post-error RT slowing as compared to controls.

Response-averaged Event-related Potentials (ERP): ERN and Pe

Five subjects (4 in CNT and 1 in ADHD group) did not have enough errors to calculate reliable ERN, and their response-locket ERPs were omitted from analysis. Amplitude of the ERN measured at the midline fronto-central ROI (Fz-FCz) showed significant between group differences, $F(3, 65) = 3.15$, $p = .031$. The group differences of the ERN amplitude were better pronounced across more expanded ROIs that included five frontal and fronto-central sites, $F(3, 65) = 3.51$, $p = .02$. At these regions the differences were mostly expressed as less negative amplitudes of ERN in ASD and ASD+ADHD groups as compared to typically developing children (difference respectively −5.32 μV and −5.15 μV, both $p < .05$). The ASD-diagnosed combined group (ASD and ASD+ADHD) was statistically significantly different from the CNT group by ERN amplitude at fronto-central ROI (by 5.43 μV, $p = .005$), while combined ADHD group (ADHD and ASD+ADHD) was not different from the group of control peers ($p = .487$, n.s.), thus pointing at the more important contribution of ASD factor on attenuated ERN amplitude. Amplitude of response-locked positivity was not different between groups (e.g., for midline ROI, $p = .118$, n.s.). We could not find any statistically significant group differences either in ERN or Pe latencies.

Stimulus-averaged ERPs

Anterior event-related potentials: Frontal and fronto-central N100 and P300 (P3a). Group differences of the midline frontal and fronto-central N100 component amplitudes were statistically significant for frequent standards, $F(3, 71) = 4.95$, $p = .003$); rare nontarget Kanizsa, $F(3, 71) = 4.26$, $p = .007$); as well as target Kanizsa stimuli, $F(3, 71) = 5.73$, $p = .001$). Post hoc test showed more negative N100 in ASD group as compared to the control group in response to all the type of stimuli (standards, −2.65 ± 2.31 μV in ASD vs. −0.91± 0.90 μV in CNT, $p = .001$; nontarget distracters, −2.56 ± 2.19 μV in ASD vs. −1.20 ± 1.26 μV in CNT, $p = .036$; targets, −3.49 ± 3.15 μV in CNT vs. −1.01 ± 1.11 μV in CNT, $p = .001$). Group differences in N100 component latencies were significant only in response to task-irrelevant frequent standards, $F(3, 71) = 3.14$, $p = .028$. These differences were significant when comparing post hoc ADHD and CNT groups (145 ± 25 ms in ADHD vs. 129 ± 15 ms in CNT). We did not find any group differences in either amplitude or latency of the anterior P200 component. Amplitude of the midline frontal and fronto-central P300 (i.e., P3a) ERP component yielded group differences only in response to target Kanizsa figures, *F*(3, 71) = 2.96, *p* = .038). Post hoc test revealed statistically significant higher amplitude of the P3a in ASD group as compared to ADHD group (6.23 ± 4.67 μV in ASD vs. 4.27 ± 2.21 μV in ADHD, *p* = .041). Analysis of P3a latencies at the midline ROI revealed significant group differences for all three conditions—frequent standards, *F*(3, 71) = 8.80, *p* < .001; rare nontargets, *F*(3, 71) = 7.31, *p* < .001; targets, *F*(3, 71) = 8.60, *p* < .001. Post hoc analysis demonstrated that differences were significant when ASD and ASD+ADHD groups were compared with the ADHD group. For instance, in ADHD group latency to nontarget Kanizsa stimuli was 52 ms longer than in ASD, 73 ms longer than in ASD+ADHD, and 79 ms longer than in the CNT group (all *p*s < .01). However, in response to target stimuli only ASD and ADHD groups P3a latencies were statistically distinct (66 ms longer in ADHD, *p* = .002). Similar trends of P3a latency differences were found not only for midline but also for all other frontal and fronto-central ROIs. Grand averages of frontal ERP in four groups are shown in a Figure 2.

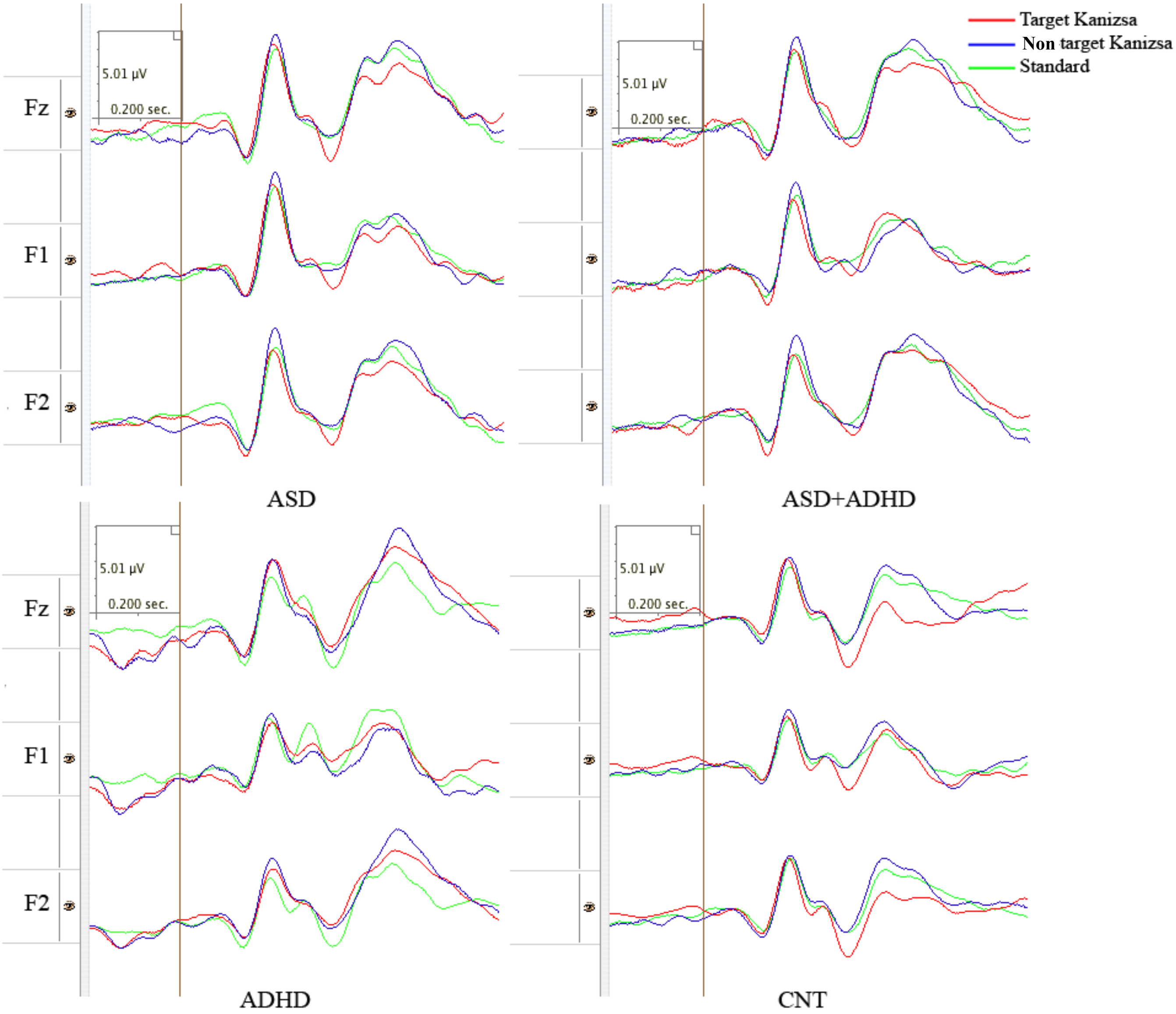

Figure 2. Frontal (Fz, F1, F2) ERPs to target Kanizsa, nontarget Kanizsa and standard stimuli in ASD, ASD+ADHD, ADHD, and CNT groups (*N* = 18/per group).

Posterior ERPs: Parietal and parieto-occipital N100, N200, and P300 (P3b). There were no significant between group differences found for amplitude and latency of the parietal and parieto-occipital N100 and N200 components. The parietal P3b ERP component did not show any statistically significant between group differences in amplitude. Between group differences in the latency of P3b were found only for frequent standards, *F*(3, 71) = 2.67, *p* = .046 across both left and right hemisphere; while at the right parietal and parieto-occipital ROI *F*(3, 71) = 3.64, *p* = .015. Post hoc analysis yielded statistically significant difference in latency (31 ms, *p* = .011 at the right ROI; 26 ms, *p* = .047 across both ROIs) between ADHD and typical controls, with more prolonged latency being noted in the ADHD group. Stimulus type (standard, nontarget Kanizsa, target Kanizsa) had main effect, *F*(2, 67) = 5.75, *p* = .004, partial sigma squared = 0.107, observed power = 0.85. Stimulus x Group interaction was significant, *F*(3, 66) = 2.39, *p* = .029, partial sigma squared = 0.069, observed power = 0.81. This effect can be described as a delayed latency to target and nontarget Kanizsa stimuli in ADHD, and similar latency to all stimuli in the ASD and at a lesser extent in the ASD+ADHD group, whereas typical controls showed longer latency to targets, shorter to both task-irrelevant stimuli (Figure 3). Grand averages of posterior (parietal and parieto-occipital) ERPs for four groups are presented in Figure 4.

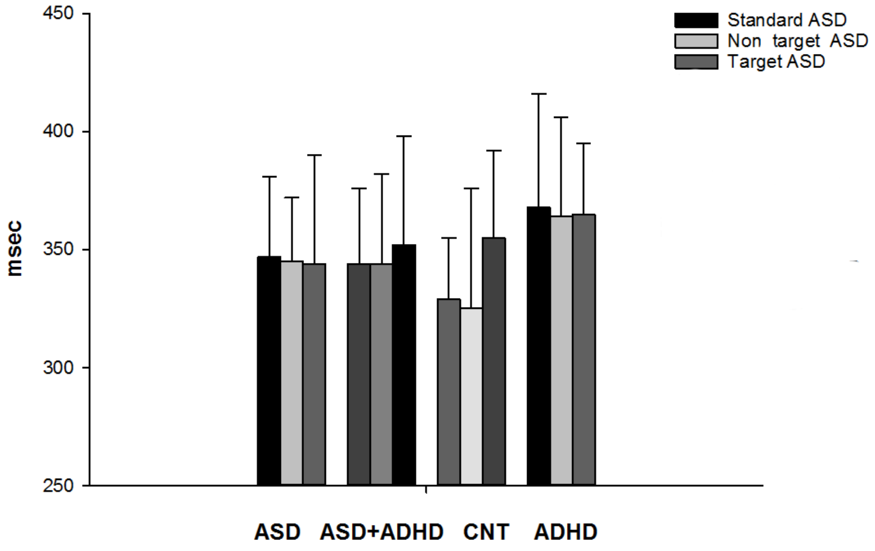

Figure 3. Latency of parietal P3b ERP component (mean with standard deviations) in response to standard, nontarget Kanizsa and target Kanizsa figures in visual oddball task in four groups of children (ASD, ASD+ADHD, CNT, ADHD, *N* = 18/per group). Stimulus x Group interaction was significant (*F* = 2.39, *p* = .029). Children with ADHD have delayed latencies to all type of stimuli, while ASD-only group is featured by similar latency to both task relevant and task-irrelevant stimuli. Note that control children (CNT group) showed shorter latency to both task-irrelevant items (standard and nontarget Kanizsa).

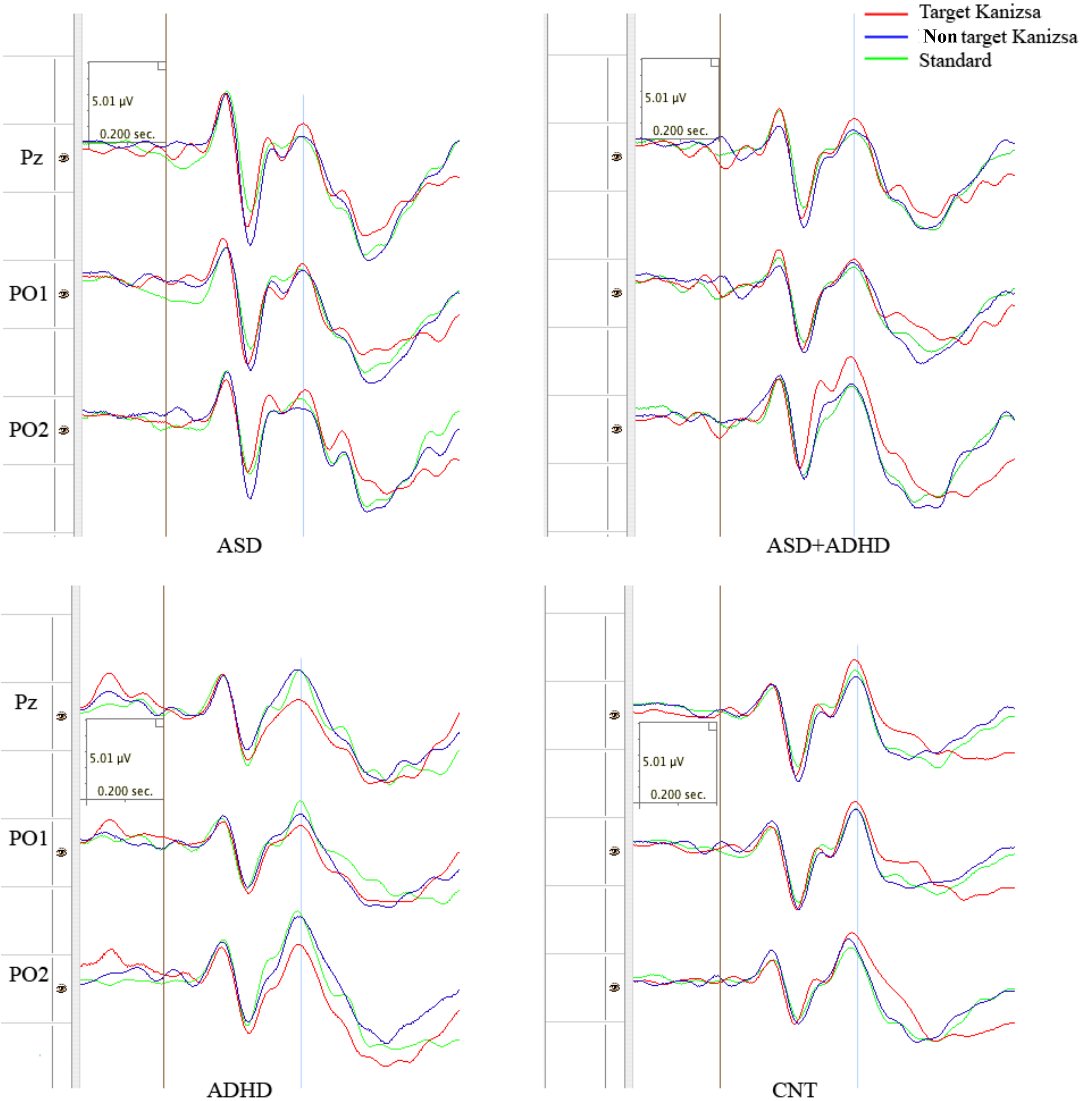

Figure 4. Parietal and parieto-occipital (Pz, P01, P02) ERP to target and nontarget Kanizsa and standard stimuli in ASD, ASD+ADHD, ADHD, and CNT groups. P3b component is marked by a blue line.

Discussion

The present study investigated differences in the behavioral (RT, accuracy, error rate, post-error slowing) and neurophysiological (ERP, including response-locked ERN and Pe) correlates of executive functions during task performance in children with ASD, ADHD, ASD+ADHD, and neurotypical controls (CNT). Our study also explored whether these prospective biomarkers were shared or distinct in comorbid ASD+ADHD by using a behavioral screening (RT, error rate, post-error RT adjustment) and ERP paradigm (ERP at frontal and parietal sites, response-averaged error-related negativity, and error-related positivity) that we implemented in previous studies (Sokhadze, Baruth, et al., 2009; Sokhadze, El-Baz, et al., 2009; Sokhadze, El-Baz, Sears, Opris, & Casanova, 2014; Sokhadze, Tasman, Sokhadze, El-Baz, & Casanova, 2016). Our findings indicate a dissociation between disorders on the basis of distinct stages of illusory figures processing during performance on Kanizsa task. In particular, children with ASD diagnosis (both ASD-only and ASD+ADHD) showed alterations at the early stages signal processing along with impairments in habituation to task-irrelevant stimuli, committed more errors and presented deficits in error monitoring and post-error response adjustment and correction; while children with ADHD displayed abnormalities at a later processing stage, mostly by displaying delayed ERP latencies of cognitive potentials. The comorbid ASD+ADHD group presented only partially as an additive condition with the ASD diagnosis factoring more in response monitoring and correction functions. The role of ADHD factor was better pronounced in latencies of the late ERP components. This supports the use of objective neural measurement of complex signal processing to delineate pathophysiological mechanisms in complex overlapping neurodevelopmental disorders such as ASD and ADHD. Our results show that children with ASD, ADHD, and ASD+ADHD do not differ on mean reaction time, but they commit more errors than neurotypical children. Furthermore, children with ASD and ASD+ADHD do not present normative post-error slowing of RT indicative of impaired error correction capacity. As evidenced by a higher rate of response errors (total errors and omission errors) and impaired post-error normative RT slowing and lower amplitude of ERN, the ASD+ADHD group appears to share impairment in performance monitoring and error detection and correction with the ASD group. This combined group, as compared to ASD-only group, had higher attention deficits scores and higher general ASEBA attention *T*-score and higher stereotype behavior rating scores on the ABC subscale emphasizing that ADHD diagnosis factors in severity of attention-related symptoms and stereotype behaviors. In addition, ADHD comorbidity affects latency of cognitive potentials (P3a, P3b) at the frontal and parietal topographies, especially in response to nontarget distracter stimuli. Latencies of both P3a and P3b in ADHD and ASD+ADHD groups were significantly delayed. Conversely, other stimulus-locked ERP measures (e.g., amplitude to targets) do not appear to be distinctive in discriminating between the ASD, ADHD, or ASD+ADHD groups. On the basis of performance monitoring and correction phenotype, the common co-occurrence of this particular executive function deficit seems to reflect a comorbidity of two separate conditions with distinct impairments. Our study showed certain similarities and differences in executive functioning between ASD, ADHD, and ASD+ADHD groups. Identification of group differences among children with ASD-only, ADHD-only, ASD+ADHD, and neurotypical (CNT) children during performance on attention task may lead to better understanding of clinical phenotypes (Gadow, DeVincent, & Schneider, 2009).

One of the most significant findings of this study was that response-locked ERN is less negative both in ASD and ASD+ADHD groups as compared to both ADHD and control groups, thus supporting our prior findings of differences in error monitoring impairment extent in ASD and ADHD. In this regard it is very important to emphasize the importance of such frontal response-locked potentials as ERN, as it may provide a viable biomarker for differentiation of the impact of ASD and ADHD in the comorbid ASD+ADHD condition. Combination of such behavioral response measures as RT, accuracy, post-error slowing, and frontal ERN/Pe indices of error-processing in children with ASD, ADHD, ASD+ADHD, and in typical children allows us to assess the ability to monitor ongoing behavior and exercise adaptive control. It is therefore of interest that our prior studies reported on several deficits in error monitoring function in autism (Sokhadze, Baruth, El-Baz, et al., 2010; Sokhadze, Baruth, Tasman, et al., 2010; Sokhadze et al., 2014). There are somewhat less reports about performance monitoring abnormalities in ADHD using ERN/Pe measures. Several studies addressed neural correlates of error processing and behavioral monitoring measures in children and adults with ADHD (Burgio-Murphy et al., 2007; Groom et al., 2010; Hermann et al., 2010; Liotti et al., 2005). For instance, the Groen et al. (2008) study used ERN/Pe using ERP technique considering error processing specifics as a useful method for dissociating ADHD from ASD and elucidating pharmacotherapy effects on performance monitoring in ADHD. Our prior study (Sokhadze, Baruth, El-Baz, et al., 2010) also discussed error processing measures as useful biomarkers of executive dysfunctions in children with ASD. The current study contributes to these investigations by adding an ADHD group as well as comorbid ASD+ADHD and a group of typically developing children as contrast groups.

Our prior study (Sokhadze, Baruth, El-Baz, et al., 2010) found substantial differences in error monitoring measures (e.g., in ERN and post-error adjustment) between the ASD and ADHD groups; though both groups showed more deficits compared to the typical individuals. However, we could not find group differences in amplitude and latency of Pe measure. Our current study suggests that impaired conflict monitoring is more pronounced in ASD than in ADHD and neurotypical children and that ASD probably contributes more significantly to error detection and correction deficit in the comorbid ASD+ADHD group. Our study specifically found that children with ASD and those with ASD+ADHD have more performance monitoring deficit (lower ERN, impaired post-error slowing of RT) compared to ADHD alone and CNT children. The neuronal source of ERN has been recognized as frontal and localized in the anterior cingulate cortex (ACC) (Taylor, Stern, & Gehring, 2007). The ERN is hypothesized to reflect phasic ACC activity in response to reinforcement signals from the mesencephalic dopamine system that serves as a trigger for further processing of the event and further deliberate compensatory behavior (Holroyd & Coles, 2002). In our prior studies (Sokhadze, Baruth, El-Baz, et al., 2010; Sokhadze et al., 2012ab, 2018), we already examined the possibility that children with ASD exhibit a deficiency in the processing of error, reflected by a reduction and delays in the ERN and Pe response-locked brain potentials. Our results showed that ASD patients had high rate of errors in the visual oddball task. In addition, in neurodevelopmentally normal subjects, it has been observed that after an error has been committed, subjects show slower RT and decreased error rates. These changes have been interpreted as revealing alterations in the speed–accuracy strategy of the subjects possibly due to error-induced control processes and concomitant corrective adjustments. The patients with ASD showed opposite response: faster post-error RT instead of slowing down. We found as well lower ERN amplitude and prolonged Pe in ASD as compared to typical controls. The reduced ERN along with a lack of post-error RT slowing in autism was interpreted as an insensitivity to detect and monitor response errors and reduced ability of execute corrective actions (Sokhadze, Baruth, El-Baz, et al., 2010). Results were indicative of reduced error awareness and a failure in stimulus-response mapping adjustment in ASD when dealing with situations where erroneous responses may occur.

At the frontal topography, the ASD group and combined ASD+ADHD show higher stimulus-locked early ERP component (N100) amplitude to all stimuli (i.e., standards, nontarget and target Kanizsa figures) and delayed latency to nontargets as compared to controls. These groups showed higher P3a amplitude as compared to the ADHD group. Children with ADHD showed delayed latency of the frontal P3a to nontargets as compared to the ASD, ASD+ADHD and typical controls. At the posterior topographies, the ADHD group had longer latencies to each type of stimuli, while the ASD group along with ASD+ADHD had similar latency to all stimuli. It should be noted that we found group differences predominantly in frontal ERP components indicating that these neurodevelopmental groups exhibit frontal function deficits. Most behavioral and ERP measures in this study show that the ASD group is significantly different from controls on many measures, but to a lesser extent different from the ADHD group. The most pronounced was the difference in reactivity to nontarget items. Autistic children showed excessive response to frequent standards and rare nontarget distracters. Differences between ADHD groups (ADHD and ASD+ADHD) and typical controls were minimal and were mostly manifested in prolonged latencies of ERP. Shorter latency and higher amplitude of the early frontal negativity (N100) in the autism group with minimal differentiation of response magnitude to either target or nontarget stimuli is an interesting finding that replicates our earlier report (Sokhadze, Baruth, et al., 2009; Sokhadze, Baruth, Tasman, et al., 2010) where different visual oddball task was used. Visual processing is based on a core system consisting of occipito-temporal regions in extrastriate visual cortex (Haxby, Hoffman, & Gobbini, 2002) although parietal (Posner & Petersen, 1990) and frontal (Clark, Fan, & Hillyard, 1994) regions also play a role in directing visual attention. The visual N100 is considered an index of stimulus discrimination (Hopf, Vogel, Woodman, Heinze, & Luck, 2002; Vogel & Luck, 2000); Visual N100 over frontal electrode sites most likely is reflective of frontal generators (Clark et al., 1994). The visual N100 generally is augmented during attentional stimulus processing, which is also known as the N1-effect (Hillyard, Hink, Schwent, & Picton, 1973), and is larger towards task-relevant target stimuli (Hillyard, Mangun, Woldorff, & Luck, 1995; Luck, Heinze, Mangun, & Hillyard, 1990). Therefore, augmented and undifferentiated N100 in response to all stimuli regardless of their task relevance in the ASD group probably reflects deficient discrimination capacity.

Most investigations into visual processing in ASD have focused predominantly on P300 (Courchesne,

Courchesne, Hicks, & Lincoln, 1985; Courchesne, Lincoln, Kilman, & Galambos, 1985; Courchesne, Lincoln, Yeung-Courchesne, Elmasian, & Grillon, 1989; Hoeksma et al., 2006; Kemner et al., 1999; Polich, 2007; Townsend et al., 2001; Verbaten et al., 1991). As compared to cognitive P300 component, there have been significantly fewer studies focused on the early stage of visual perceptual processing in ASD (Jeste & Nelson, 2009). In our prior ERP studies (Sokhadze, Baruth, El-Baz, et al., 2010; Sokhadze, Baruth, Tasman, et al., 2010; Sokhadze et al., 2017) on novel distracters processing in children with ASD and neurotypical children, we reported that ASD group showed higher amplitudes and longer latencies of early ERP components such as parieto-occipital P100 and frontal and fronto-central N100 to novel distracter stimuli in both hemispheres. Studies of P300 in ADHD have suggested that children with this diagnosis have attenuated P300 to both auditory and visual stimuli (Barry et al., 2003). In children with ADHD, especially with those with the combined type of ADHD as compared to inattentive type, a decreased P300 at centro-parietal sites has been reported in conjunction with an augmentation at frontal sites (Banaschewski et al., 2003; Banaschewski, Roessner, Dittman, & Santosh, 2004; Dimoska, Johnstone, Barry, & Clarke, 2003; Duncan et al., 2009; Johnston et al., 2011; Johnstone & Barry, 1996; Klorman et al., 1983; Smith et al., 2004). In ADHD population, some selective attention studies found a smaller early frontal negativity in ADHD as compared to controls, suggesting deficiencies as well in early attention processes (Jonkman et al., 2004; Satterfield, Schell, & Nicholas, 1994; van der Stelt, van der Molen, Gunning, & Kok, 2001). For the P300, the findings were inconsistent, demonstrating no differences in amplitude, a smaller amplitude or a deviation in scalp distribution but majority reported delayed latencies of most ERP components in response to target stimuli (Dimoska et al., 2003; Jonkman et al., 1997, 2004; Smith et al., 2004). Interesting results in our study were found for the P3a (sometimes referred to as the novelty P300 or attention-orienting P300). This is a fronto-central wave occurring within a time window of 300 to 520 ms that reflects an aspect of the orienting response and has been related to evaluative attentional processes (Hruby & Marsalek, 2003; Polich, 2003). The ASD group shows clearly augmented and delayed frontal P3a that might have resulted from an impaired early differentiation of target and nontarget items (e.g., on N100 stage) and more effortful compensatory strategies involved for successful target identification and correct motor response selection. In general, the autistic group showed prolonged latencies to standard and rare nontarget illusory figures, and relatively unaffected response to targets. These results suggest that individuals with autism probably over-process information needed for the successful differentiation of task-relevant and task-irrelevant stimuli. The P3b is a centro-parietal wave occurring between 320 and 560 ms that has been linked to task-relevance and the decision-related character of the eliciting stimulus; it reflects memory-updating processes and/or processing closure (Picton, 1992). Most studies agree that the P3b has multiple dipole sources (Halgren, Marinkovic, & Chauvel, 1998; Knight, 1997; Townsend et al., 2001). Considering that most studies on P3b in ADHD report attenuated amplitude and prolonged latency of this cognitive component (Banaschewski et al., 2003, 2004; Barry et al., 2003; Dimoska et al., 2003; Duncan et al., 2009; Jonkman et al., 2004; Satterfield et al., 1994; Smith et al., 2004; van der Stelt et al., 2001), our finding of delayed latencies in the ADHD group is in good concordance with prior reports, even though amplitude differences did not reach significance levels. In general, our study found only minimal group differences in posterior stimulus-locked ERP components, as most ERP differences were at the anterior (frontal and fronto-central) topographies.

Our results show significant differences both in behavioral and electrocortical responses between ASD, ADHD, ASD+ADHD, and typical controls during performance on illusory figure test. In autism, a model of local hyperconnectivity and long-range hypoconnectivity explains many of the behavioral and cognitive deficits present in the condition, while the inverse arrangement of local hypoconnectivity and long-range hyperconnectivity in ADHD explains some deficits typical for this disorder (Williams & Casanova, 2010). Casanova, Buxhoeveden, and Brown (2002) proposed that information processing exists within a connectivity spectrum that affects the excitation/inhibition ratio of the cerebral cortex. A similar theory was later elaborated by Rubenstein and Merzenich (2003). Because local- and long-range cortical coordination is a finely tuned relationship of the signal-to-noise ratios, extremes of either edges of the spectrum can disrupt functionality and result in similar behavioral manifestations (e.g., attention deficits) despite opposing underlying etiologies in autism and ADHD. Following the hypothesis suggested in Williams and Casanova (2010) while considering dyslexia and autism conditions, it is possible to propose that ASD and ADHD are two conditions that share aspects which are also “cortical opposites.” This idea may help explain why some children with ASD may present with attention disorders similar to those seen typically in ADHD. Indeed, the present study identified distinct patterns of behavioral and ERP measures in ASD versus ADHD, and in co-occurring ASD+ADHD diagnosis suggesting that there may be distinct neural mechanisms underlying the expression of each these conditions (Ray et al., 2014).

Several limitations of this study should be noted. There was no differentiation of ADHD patients according to their subtypes (Inattentive, Hyperactive, or Combined) providing for clinical heterogeneity within our study groups. Our efforts were also very selective for our stated goals and did not include analysis of several ERP components (e.g., frontal P2a, parietal N2b, etc.) that could have provided additional markers of cognitive processes specifics in ASD and ADHD. Finally, the majority of the patients in this study were high-functioning individuals with ASD, ADHD, and ASD+ADHD, and generalization of results to more severe cases should be pursued with caution.

Conclusion

The current ERP study supports the proposed suggestion that some between group differences (e.g., ASD vs. ADHD vs. ASD+ADHD vs. CNT) could be manifested in the frontal ERP indices of executive functions during performance on illusory figure categorization task. Our study suggests that investigation of quantitative EEG and ERP biomarkers of executive function abnormalities and other behavioral performance deficits present in ASD and ADHD is a feasible research strategy that may contribute to the better understanding of nosology of these two disorders and their co-occurrence. Efforts to define the common or distinct phenotype of these two disorders are important as they may help to improve classification systems and enhance the assessment of these dual diagnosis (ASD+ADHD) cases for better targeted and more specific treatment strategies. The study supports the use of objective neurophysiological biomarkers such as ERP and behavioral (e.g., reaction time and accuracy) measures to delineate pathophysiological mechanisms in such complex and often overlapping disorders. These findings have significant implications for both shared and discrete symptom presentations for the two conditions. Moreover, they can help delineate the boundaries and overlap between ADHD and ASD, especially if children with ADHD-alone and ASD-alone are compared with those with dual ASD+ADHD diagnosis, and further compared to neurotypical children used as a normative contrast group.

Author Disclosure

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Authors have no financial interests or conflicts of interest to disclose.

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NeuroRegulation

Transforming Thoughts with Postural Awareness to Increase Therapeutic and Teaching Efficacy

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Abstract

This article suggests that clinicians as well as educators should employ simple and quick posture comparison techniques to shift awareness, elevate mood, and support cognitive function. The report examines the impact of a short somatic involvement technique that involved changing one's body posture to reduce the effect of self-evoked memory of stress. Group observations of 90 men and 55 women, mean age 22.5 years, suggest that people were able to reframe stressful memories much more easily when in an upright posture compared to a slouched posture. They reported a significant reduction in negative thoughts as determined by a single factor ANOVA, $F(1, 285) = 42.92$, $p = .001$; and anxiety and tension as determined by a single factor ANOVA, $F(1, 287) = 62.38$, $p = .001$. We suggest that therapists and clients get up out of their chairs and incorporate body movements when either the therapist or the client feels stuck, in order to reduce rigidity and increase openness of thoughts and emotions facilitated, which may increase educational and therapeutic goals with sustained benefits outside of the classroom or clinic.

Keywords: posture; psychotherapy; cognitive behavioral therapy; stress reduction; internal language; breathing

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Purpose and Background

As patients or students experience psycho–emotional anxiety, whether related to a chief complaint or negatively projecting about the outcome of an exam, there is a tendency to reflect their negative emotions in their body, sometimes slouching in a chair, or almost curling up into a protective position. In a variety of settings, people's posture reveals something about their positive and negative affective state of mind. For example, Riskind (1984) found that people recall more positive (vs. negative) autobiographical memories when seated in an upright posture during therapy sessions. Michalak, Mischnat, and Teismann (2014) as well as Michalak, Rohde, and Troje (2015) found that a slouched versus erect sitting position, or slouched versus erect walking posture, respectively, leads to more negative processing of emotions surrounding a topic. The observations described in this report relate to the value of asking clients, patients and students to "pay attention and shift intention" about their posture while engaging in learning or therapy processes. For example, this report describes a simple posture-adjustment activity designed to raise awareness about slouched, slumped, or stooped standing or sitting posture in the therapy office—facilitating intentional shifts into a posture that permits better breathing as well as better mood.

There are physiological models that explain the neuroceptive and visceral feedback benefits from posture shifts. For example, Berntson, Gianaros, and Tsakiris (2018) outline the interceptive and proprioceptive mechanisms by which humans increase or decrease awareness of their body. In particular, Bernston et al. (2018) describe classes of sensory systems such as proprioceptors involved in joint movements and vestibuloceptors involved in body balance given various contexts of gravity. Bernston et al. (2018, p. 23) also describe how people experience emotion change concomitant with body change by citing others:

> Critchley, Mathias, and Dolan (2001, p. 207) asserted that "body state changes, particularly those mediated by the autonomic nervous system, are crucial to the ongoing emotional experience of emotion," and Goldstein (2012) reported that partial cardiac denervation was associated with fatigue, altered mood, blunted emotion, and decreased ability to concentrate.

Whereas the purpose of this article is to raise awareness about simple posture change techniques that are effective in assisting clients, patients, and students to pay attention to shift their intention, the goal of this report is also to serve as a methodological note rather than an in-depth exposition on posture and emotion mechanisms. For example, there may be some questions raised in the text, such as "What can you do under pressure?" or "How can you keep your cool?" which are intended to stimulate thought about exposures to various types of stresses and strains along with preferred reactions. Asking these kinds of questions is not intended to start a discussion about the wide range of physical and emotional pressures people can encounter, nor to contrast "cool" reactions from "hot and bothered" reactions, nor to address the value of a cool reaction with a 6-s "quick and warm" quieting reflex (Stroebel, 1982).

What can you do under pressure? How can you keep your cool?

Most brief therapies, typically numbering less than 10 sessions, are often designed to address, manage, or ameliorate various cognitive, affective, and somatic symptoms and complaints and may include teaching quick interventions that are very effective in reducing psychophysiological reactivity. Examples of quick interventions for reducing psychophysiological reactivity include adapted autogenic training or mindfulness techniques; however, even these quick interventions require 20 min of practice (Cruess et al., 2015). Additional quick interventions such as adapted versions of progressive muscle relaxation (Gao, Curtiss, Liu, & Hofmann, 2018); eye movement desensitization and retraining, or EMDR (Navarro et al., 2018) or yoga, breathing, and other meditation, imagery, or visualization techniques require times greater than a minute (e.g., 5–30 min) to achieve stress reduction outcomes (Brown, Gerbarg, & Muench, 2013). Although these brief therapies can be very helpful in the controlled context of an office visit, in various daily activities, negative thoughts and stress often occur unexpectedly. What is needed are quick strategies, typically that begin to take effect in seconds, to interrupt and change negative self-talk, anxiety, and other stress reactions—especially during high pressure social interactions, during high pressure classroom situations (e.g., test taking) and during high pressure or panic-inducing topics with client and patient sessions involving psychiatry or psychotherapy. Examples of quick interventions include not only the quieting reflex (Stroebel, 1982), but also manipulating particular pressure points (Wang & Kain, 2001), such as the superior lateral wall of the triangular fossa of the ear. This paper reports on observations of a quick intervention related to posture change directed towards increasing awareness about and intentional control over psychophysiological reactions to stress.

Talking, reflecting, problem solving, consulting, counseling, and psychotherapy usually take place while the person is sitting in a fixed position, sometimes related to a person bracing or freezing their posture in a relatively constrained or immobilized position. For example, psychotherapy and counseling sessions usually take place in a private, one-to-one setting in which participants sit in comfortable chairs that may facilitate slouching in the chair with their lower backs slightly rounded. Unfortunately, sustaining posture in this position is associated with experiences of feeling powerless, helpless, and defeated—a position of submission (Cuddy, 2012; Weisfeld & Beresford, 1982). In a slouched, slumped, or stooped position, it is easier to evoke hopeless, helpless, powerless, and defeated thoughts and memories than when sitting upright (Peper, Lin, Harvey, & Perez, 2017). The brain has to work significantly harder, where "working harder" is considered a difficulty for the individual to evoke positive and empowering thoughts and memories compared to when the individual is in an upright erect position (Michalak et al., 2014; Tsai, Peper, & Lin, 2016). Not surprisingly, a slumped posture can be found among the diagnostic feature of depression as described in the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM-5; APA, 2013).

There are a variety of techniques which facilitate quick posture change that in turn elevates mood, increased awareness, and perspective building. For example, either through internal direction, such as directing oneself towards looking up and reaching up, or through external direction of a professional, such as taping their shoulders so the individual positions themselves upright, or through mechanical direction by a wearable device that alerts them to change posture (e.g., signals with vibration, sounds, or visual displays), the person may quickly, in a matter of seconds, decrease experiences of depression and anxiety as well as increase energy (Peper & Lin, 2012; Wilkes, Kydd, Sagar, & Broadbent, 2017). Although there may be questions about what energy, depression, and anxiety levels are in various settings, the purpose of this report is to increase curiosity and awareness about a simple and, most importantly, quick strategy to shift mood using a simple and quick posture change technique.

Benefits of posture change strategies

The benefits of posture change strategies have also been shown among individuals who suffer from a mild to moderate level of depression (Wilkes et al., 2017). In addition, when subjects sit collapsed rather than upright, they experience more helplessness (Riskind & Gotay, 1982). Even solving math problems during a classroom activity is easier when the individual is sitting upright and erect rather than in a slouched and collapsed position (Peper, Harvey, Mason, & Lin, 2018). Currently, the psychotherapy and psychiatry literature does not really focus on body posture as a potential therapeutic tool for adjusting mood or reducing feelings of powerlessness. Other studies have also addressed the impact of a sitting posture on parameters that are important in various settings from the classroom to a psychotherapy session. For example, Nair, Sagar, Sollers, Consedine, and Broadbent (2015) demonstrated how adopting an upright and seated posture in the face of stressful circumstances can help an individual maintain their self-esteem, reduce negative mood, increase positive mood, and use fewer sadness words compared to when the individual adopts a slumped and seated posture.

Building on the notion of “embodied attitudes,” Briñol, Petty, and Wagner (2009) examined how body postures can influence self-evaluations and metacognitive processes. Briñol et al. (2009) found that the effect of the direction of thoughts (positive or negative) on self-related attitudes was significantly greater when participants wrote down their thoughts while maintaining a confident (upright) posture compared to when they maintained a doubtful posture (slouched). Positive self-evaluation or self-image is one of the main targets or outcomes where learning is occurring, whether in a classroom or during a psychotherapy session.

The studies mentioned in this report are all consistent with general theories of “embodied cognition” (Niedenthal, 2007; Oosterwijk, Rotteveel, Fischer, & Hess, 2009) which contend that muscular and autonomic states influence emotional and stress regulation. Sitting upright may offer a simple behavioral strategy to help build up resilience to stress and therefore can be integrated into psychotherapy sessions related to stress topics. The effects of a postural intervention on stress responses are particularly relevant to psychotherapy because stress has been implicated in the etiology of depression (Quinn, Grant, & Adam, 2018) as well as other major psychological disorders.

Positive posture perspective

One more implication of this “positive posture perspective” is to suggest that psychotherapy might be more effective when an upright body posture is infused into therapeutic sessions. Of course, some sessions are done when someone is lying down, and some sessions occur while walking; however, a seated and slouched posture during an office session is contraindicated from the viewpoint of this paper. The effects of changing body posture from slouched, slumped, or stooped offers the potential to benefit psychotherapy interactions related to different disorders, mainly depression and anxiety, or approaches that focus on problem solving. The approach of maintaining an upright position has already been suggested in many settings. This study reported here has three goals: 1) to provide examples of simple techniques for demonstrating and explaining a posture change effect in settings such as a therapy session; 2) to suggest using a positive posture perspective as part of therapeutic work (cognitive or other); and 3) to apply the effects of posture awareness to intentional actions (e.g., more positive posture) outside the clinic.

Method

Participants

As part of a curricular classroom practice in four different classes, 145 college students (90 women and 55 men), average age 25.0 (7.6), participated. 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.

Procedures

Students in a university class completed an anonymous informational questionnaire (history of depression, anxiety, blanking out on exams, worrying, slouching). The class was then divided into two groups. All were then asked to evoke and think of a stressful conflict or problem and make it as real as possible for 1 min. Then one group was asked to let go of the stressful memory and experience and reframe it positively (reframing practice; RP), while the other group was asked to sit up erect, look up, take a breath, let go of the stressful memory, and reframe it positively (posture, breath, and reframing practice; PBRP) for 20 s. They then rated the extent to which their negative thoughts and anxiety or tension were reduced, from 0 (*not at all*) to 10 (*totally*). The groups then repeated the study except the RP group now did PBRP and the PBRP group now did RP.

Results

As shown in Figure 1, 88.2% of the students rated the PBRP more effective than the RP, while 9.6% rated RP more effective than the PBRP, and approximately 2.2% rated them the same.

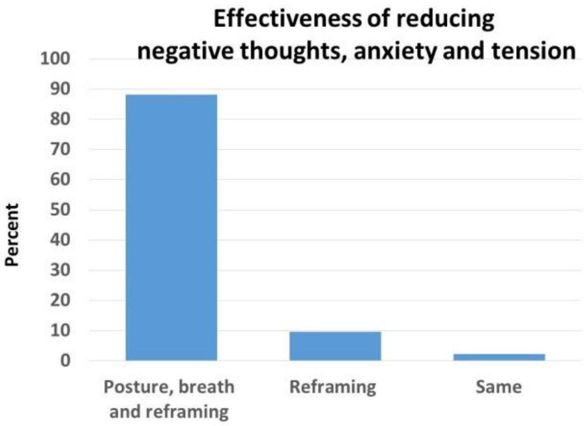

Figure 1. Percentage of students rating PBRP as more effective than RP in reducing negative thoughts, anxiety, and stress.

The responses suggested a reduction in negative thoughts when they practiced PBRP (*M* = 6.6) compared to when they practiced RP (*M* = 5.0), as determined by a single factor ANOVA, *F*(1, 285) = 42.92, *p* = .001. They reported a reduction in anxiety and tension when they practiced PBRP (*M* = 6.7) compared to when they practiced RP (*M* = 4.7), as determined by a single factor ANOVA, *F*(1, 287) = 62.38, *p* = .001. These results are graphically displayed in Figure 2.

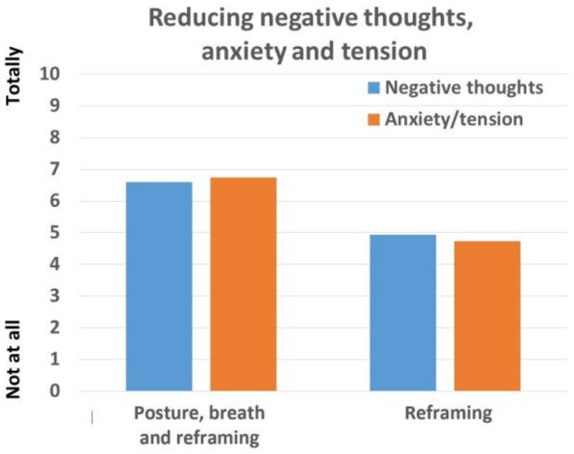

Figure 2. Self-rating changes in reduction of negative thoughts and anxiety or tension.

There were no significant correlations between the two techniques (RP vs. PBRP) and the self-rating of depression, anxiety, energy level, sitting or standing slouched, worrying, blanking out on exams, gender, and age. There was one noteworthy difference between men and women, where RP appeared to reduce negative thoughts more for men (*M* = 5.42) than women (*M* = 4.64) as determined by a single factor ANOVA, *F*(1, 142) = 4.09, *p* = .045. There were no significant differences between men and women for reduction of anxiety or stress by PBRP.

There was another noteworthy difference due to the order effect of PBRP and RP in reducing negative language. RP was rated more effective in reducing negative thoughts if it was carried out first, rather than second. If RP was second, after PBRP, then RP was rated as less effective, as determined by a single factor ANOVA, *F*(1, 63) = 8.50, *p* = .005. There were no other significant differences due to order effect. There were no other significant differences between the highest and lowest quartile.

Comparing the top quartile to the lowest quartile of experiencing reduction in negative thoughts and anxiety or stress, there was a noteworthy difference in the self-rating of "depression at this moment" for the top quartile (*M* = 2.57) as compared to the lowest quartile (M = 4.51), as determined by a single factor ANOVA, *F*(1, 142) = 4.09, *p* = .045. There were no differences between the 13 participants who reported that RP was more effective than the 124 participants who reported that PBRP was more effective on any of the self-reported measures (history of depression, anxiety, blanking out on exams, worrying, or slouching).

Discussion

Changing posture, especially in conjunction with reframing language, is effective in reducing negative language as well as self-reported anxiety or stress compared to reframing language by itself. The classroom observations have implications for counseling and psychotherapy because clients usually sit in a slouched position during the therapeutic session and a "positive posture perspective" can be utilized, especially while clients or patients are exploring new options or interpretations of their experiences.

The findings reported here suggest that it is more challenging to let go of the evoked negative feeling and memories by RP than by PBRP. By shifting the body position to an erect upright position, taking a breath, and then reframing, participants are much more successful in reducing their negative thoughts and anxiety or stress. They report feeling much more optimistic and better able to cope with felt stress (see Table 1 for some sample comments).

The results observed in the classroom setting are not surprising and are part of common knowledge, such as the instructions to take three breaths before answering questions, pausing and reflecting before responding, or taking time to cool down before replying in anger. What makes these observations valuable is practicing a technique where participants could compare the effects of the two different posture awareness strategies. Instead of being told what to do, they could experience and discover which positive posture strategy was more effective for them, since no strategy is effective for everyone.

To assign the appropriate home practice when clients are stressed, it is recommended that practitioners guide their clients through the simple and quick procedures described in this study. Then, if their clients experience PBRP to be more beneficial than RP, or vice versa, they will know which strategy is more effective in interrupting the cycle of negative thinking, anxiety, and stress.

It was not clear why approximately 9.6% of the participants rated RP as more beneficial than PBRP in reducing negative thoughts, anxiety, and stress. Future research is needed to explore the individual differences in response to posture change techniques under various conditions of classroom and therapy session settings.

For most participants, PBRP was more beneficial than RP and was not affected by the order. Whether PBRP was first or second, there was no change in its mean benefit rating. On the other hand, RP was reported to be significantly less beneficial when it followed PBRP. A hypothesis is that participants found they had a more significant and/or long-lasting decrease in negative language, anxiety, and stress after PBRP and thus, in comparison, found RP less beneficial.

Application of this upright sitting posture or experiencing a general positive posture intervention effect (whether sitting, standing, or lying) can be demonstrated simply and quickly in psychotherapy sessions as part of psychoeducation as well as in classroom or other settings. The demonstration should be even more useful and attractive if done in groups because almost all will report that PBRP is more effective to reduce negative internal language, anxiety, and stress.

The simple and quick technique described here can be used throughout therapy for dealing with negative language and stress. In classical cognitive behavioral therapy (CBT), sitting upright can help the individual replace a thought with a more reasonable one. In third-wave CBT, it can help bypass the negative content of the original language and create a metacognitive change, such as "I will not let this thought control me." It can also help in acceptance and commitment therapy (ACT) that changing one's body posture may facilitate the process of acceptance (Hayes, Pistorello, & Levin, 2012). Adopting an upright sitting position and taking a breath is like saying, "I am here. I am present. I am not escaping or avoiding." This change in body position represents movement from inside to outside, movement from accepting the unpleasant emotion related to the negative thoughts toward a commitment to moving ahead, contrary to the automatic tendency to follow the negative thought. The positive reframing during body position or posture change is not an attempt to color reality in pretty colors, but rather a change of awareness, perspective, and focus that helps the individual identify and see some new options for moving ahead toward commitment according to one's values. This intentional change in direction is central in ACT and also in positive psychology (Stichter & Saunders, 2018).

Table 1
Some Representative Comments of the Experience Practicing RP or PBRP

RP	PBRP
After changing my internal language, I still strongly felt the same thoughts.	I instantly felt better about my situation after adjusting my posture.
I felt a slight boost in positivity and optimism. The negative feelings (anxiety) from the negative thoughts also diminished slightly.	The effects were much stronger and not isolated mentally. I felt more relief in my body as well.
Even after changing my language, I still felt more anxious.	Before changing my posture and breathing, I felt tense and worried. After, I felt more relaxed.
I began to lift my mood up; however, it didn't really improve my mood. I still felt a bit bad afterwards and the thoughts still stayed.	I began to look from the floor and up towards the board. I felt more open, understanding, and loving. I did not allow myself to get let down.
During the practice, it helped calm me down a bit, but it wasn't enough to make me feel satisfied or content; it felt temporary.	My body felt relaxed overall, which then made me feel a lot better about the situation.
Difficult time changing language.	My posture and breathing helped, making it easier to change my language.
I felt anger and stayed in my position. My body stayed tensed and I kept thinking about the situation.	I felt anger but once I sat up straight and thought about breathing, my body felt relaxed.
Felt like a tug of war with my thoughts. I was able to think more positively but it took a lot more brain power to do so.	Relaxed, extended spine, clarity, blank state of mind.

If we consider the studies cited in this report that indicate that changing to an upright posture has a positive impact on energy (Peper & Lin, 2012), mathematical skills (Peper et al., 2018), memory recall (Peper et al., 2017), self-evaluation (Briñol et al., 2009), thoughts and memories (Tsai et al., 2016), and self-focus (Nair et al., 2015) in both normal and depressed individuals (Wilkes et al., 2017), together with the physiological and perhaps even rapid hormonal changes that occur (Carney, Cuddy, & Yap, 2010; Cuddy, 2012), we recommend that this approach should be included in psychotherapy. Indeed, the observations reported here indicate that a "posture awareness" tool is suitable for affecting all kinds of psychotherapeutic languages, including dynamic psychotherapy. This somatic intervention that leads to a positive posture perspective appears to have the potential to connect clients to their strengths, or even perhaps to their authentic self, therefore improving their ability to work courageously in therapy.

As this study indicates, the benefits of simple and quick posture awareness techniques can be accomplished by systematically exploring the effect of the somatic manipulation on thinking and emotion and primarily on the ability to move and create behavioral change. While the elaborated experiments related to manipulating various postures by psychotherapy conditions is beyond the scope of this article, as was already mentioned, sitting posture should not be the only body posture option in therapy. For example, Smith, Davoli, Knapp, and Abrams (2019) showed that standing enhances cognitive control and alters visual search, compared to sitting positions.

Finally, and perhaps most importantly, since the main goal of therapy, and especially CBT, is to provide tools for life, the therapist should guide clients to use this upright sitting and breathing effect in their life outside of the clinic. For that purpose, clients need a very simple and quick procedure for achieving a positive posture perspective like the one offered here.

Nevertheless, we must be careful in discussing the ultimate positive role of the upright sitting posture. It would be preferable to think about flexibility in the sitting posture rather than indicating a preference for one way of sitting over another. The limitations of this study are found mainly in its research procedure. The procedure involves the risk that a meaningful placebo effect will intervene, since the participants can imagine the predicted or desired results of the experiment. Nevertheless, the main goal of this study was not to prove the effect of a specific or particular somatic manipulation, but rather to suggest to educators and clinicians alike that simple and quick posture awareness techniques can positively benefit their psychoeducational goals. Again, the goal is to describe a simple tool for demonstrating this positive posture perspective effect with the potential for use as a psychoeducation tool, later as a therapeutic tool, and finally as an effective tool that clients can use outside the clinic. By offering here this simple tool or intervention, hopefully these goals will be more achievable.

Future studies in this field of postural psychophysiology should try to find out how good the tool is for a clinical population as part of therapy and how helpful it is in real-life implementations. These future studies will need to be more precise in order to use more correctly and flexibly changing the body posture according to mood and the therapeutic goal at the moment. Future research is also needed to explore the importance of individual differences so that appropriate techniques can be matched to the appropriate participant.

In conclusion, we suggest that therapists and clients get up out of their chairs and incorporate body movements when either the therapist or the client feels stuck in order to reduce rigidity and increase openness of thoughts and emotions. To that end, continue exploring some of following strategies:

- Take a walk with your client for an hour while doing therapy. This has many benefits. Clients can share intimate feelings and thoughts while experiencing the support of the therapist by their side. This also may increase access to felt emotions with less shame because the therapist is not looking at the client and has more freedom.
- Shift position, look up, breathe, and change the internal focus or dialogue whenever you feel stuck, frustrated, rushed to reach a conclusion, or overwhelmed by emotions.
- Pay attention and teach your client to pay attention to his or her emotions and thoughts in order to work flexibly on body change.
- Mark on a tally sheet each time you practice a body change and observe the effect by the end of the day.

Finally, to invoke the views stated many times before that the mind and body are not separate and the mind and body affect one another and are affected by each other, posture providing another example of the psychophysiological principle enunciated by Elmer Green (1999, p. 368):

> Every change in the physiological state is accompanied by an appropriate change in the mental–emotional state, conscious or unconscious; and conversely, every change in the mental–emotional state, conscious or unconscious, is accompanied by an appropriate change in the physiological state.

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NeuroRegulation

Neurocognitive Enhancement: Applications and Ethical Issues

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Abstract

In recent years, the interest in neurocognitive empowerment has increased, thus making it a hot topic, especially because of possible ethical implications. Specifically, the term *neurocognitive empowerment* refers to the use of different neuroscientific techniques and tools that increase the cognitive functioning of the individual beyond the normal threshold—on the one hand, improving functions such as attention, perception, and memory—and, on the other hand, physical and motor functions. Neuroethics is peculiarly interested in monitoring and discussing ethical implications and possible consequences or undesirable effects of neurocognitive strengthening techniques. In particular, the use of different tools for neurocognitive enhancement requires an in-depth analysis of the ethical and legal principles in terms of security and social justice that allow the improvement of mental and physical functions of an individual. The present work aims at introducing the use of specific techniques—such as neurofeedback devices for the enhancement of attention regulation skill—in specific application contexts; that is, sports in which athletes are continuously subjected to external pressures for performance and constant improvement. Furthermore, this document explores possible ethical critical issues raised by such use of neurocognitive enhancement techniques.

Keywords: neuroethics; neurocognitive enhancement; peak performance; wearable devices; sports

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Preliminary Definitions: Why Neurocognitive Enhancement

Neurocognitive enhancement is a theme of the latest definition. Whilst the term *neuroenhancement* was, at first, frequently paired with those of *doping* and *brain drugs* and with the idea of boosting neural activity to improve cognitive and motor skills (Bell, Partridge, Lucke, & Hall, 2013; Dodge, Williams, Marzell, & Turrisi, 2012; Svetlov, Kobeissy, & Gold, 2007), in recent years the interest into its implications and potential for performance improvement and promotion of optimal functioning in many professional contexts has progressively grown (Bell, Bryson, Greig, Corcoran, & Wexler, 2001; Fronda, Balconi, & Crivelli, 2018; Shook & Giordano, 2016).

Neurocognitive enhancement refers, in particular, to qualitative and/or quantitative improvement of specific cognitive–affective skills or sets of cognitive functions (Farah, 2005; Fronda et al., 2018; Lucke & Partridge, 2013; Nagel, 2010, 2014), which can be modulated by means of various neuroscientific techniques. Such techniques (e.g., noninvasive brain stimulation and neurofeedback), by acting on brain structures and on neural networks within the central nervous system, allow modulating brain activity during a given task with the final aim of improving information-processing; optimizing the functionality of perceptual, attention, and cognitive systems; and making them operate in a more adaptive, flexible, and efficient way (Bostrom & Sandberg, 2009; Harvey, 2008). Indeed, neuroenhancement interventions usually aim to increase mental functioning beyond what is necessary to sustain or restore a condition of individual well-being (Juengst, 1998). The alteration of brain functions occurs because the brain can change in response to stimulating experiences, practice, or specific training (Engvig et al., 2012; Lövdén, Bäckman, Lindenberger, Schaefer, & Schmiedek, 2010; Schooler, 1984; Schooler, Mulatu, & Oates, 1999). Specifically, cognitive enhancement through given training can be aimed at improving a specific function or enhancing the effectiveness of certain activities (Anguera et al., 2013; Chapman et al., 2013; Dahlin, Nyberg, Bäckman, & Neely, 2008; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Nyberg et al., 2003; Valenzuela-Fernández, Cabrero, Serrador, & Sánchez-Madrid, 2008; Zelinski & Reyes, 2010). Therefore, through neurocognitive enhancement, it is possible to optimize the functioning of specific cognitive functions to achieve optimal performance (Agar, 2013).

Neuroscientific Techniques for Sports Performance Enhancement

The interest in neuroscience focuses specifically on the implementation of different interventions aimed at enhancing performance in various contexts, such as sports. In the sports context, there is a continuous demand for improvement in performance across all levels of expertise, from amateurs to semiprofessional and professional athletes. Advances in neuroscience suggest that sports performance can be enhanced by using methods and techniques that modify brain activity, thus leading to the improvement of athletes' mental state and focus, as well as encouraging motor learning (Vargo et al., 2014). Recently, the potential and effectiveness of noninvasive brain stimulation techniques (i.e., neuroscientific intervention techniques, able to safely induce neuromodulation or neurostimulation effects on cortical structures and networks)—and of combined neurofeedback and mental training programs for pursuing such goals and for optimizing athletes' cognitive and behavioral performances—have been more and more explicitly explored (Balconi, Fronda, Venturella, & Crivelli, 2017; Balconi, Pala, Crivelli, & Milone, 2019; Borducchi et al., 2016; Colzato, Nitsche, & Kibele, 2017; Crivelli, Fronda, Venturella, & Balconi, 2019; Davis, 2013; Lewthwaite & Wulf, 2017). While the attention given to potential applications of noninvasive stimulation and neuromodulation techniques likely followed the need for novel models and methods for intervention and the will to try and overcome limitations and ethical issues raised by first tentative neuroenhancement approaches based on chemicals and psychoactive drugs, it has to be acknowledged that such potential and its practical–ethical implications in the field of sports practice is still a matter of debate. The growing development of those techniques devised to foster the improvement in sports performance has been, for example, defined as a form of "neurodoping" (Davis, 2013). Several studies (Colzato et al., 2017; Flöel et al., 2011) have demonstrated the effectiveness of brain stimulation and neuromodulation techniques for the enhancement of various cognitive functions even outside the laboratory. In the sports context, in particular, brain stimulation and neural entrainment techniques such as transcranial direct current stimulation (tDCS) and transcranial alternate current stimulation (tACS), which are able to modify cerebral excitability and cortical oscillations by working on specific physiological mechanisms of action (Vernon, 2005), have been used to try and foster optimal neurocognitive efficacy and to improve individual performance (Grosprêtre, Ruffino, & Lebon, 2016). Some studies have shown the effectiveness of these techniques with regard to athletes' physical skills, namely motor learning and muscular strength, and with regard to their cognitive skills, namely learning ability and attention (Vargo et al., 2014). Moreover, recent studies have shown that the use of tDCS to enhance sports performance is useful in modulating and controlling the autonomic nervous system, allowing the increase in the exercise capacity under challenging conditions (Okano et al., 2013; Williams, Hoffman, & Clark, 2013). Another study (Vitor-Costa et al., 2015) demonstrated the tDCS effectiveness in improving muscle fatigue, exercise tolerance, and visuomotor coordination, as well as long-term implicit learning processes (Antal et al., 2004; Reis et al., 2009; Zhu et al., 2015).

In addition to neuromodulation techniques, several studies have demonstrated the effectiveness for enhancing sports individual's cognitive and behavioral performance of practices and training programs aimed at fostering self-awareness and self-regulation skills via mental training and neuroscientific techniques (Crews & Landers, 1993; Haufler, Spalding, Santa Maria, & Hatfield, 2000; Landers et al., 1991; Salazar et al., 1990). Those neurofeedback techniques seem to be able to improve specific aspects of physical or cognitive individuals performance (Alexeeva, Balios, Muravlyova, Sapina, & Bazanova, 2012; Zoefel, Huster, & Herrmann, 2011), such as attention regulation or stress management, by helping practicers to become increasingly aware of their automatic physiological reactions to different conditions or, for example, of physiological correlates of specific mindsets and by helping them to strengthen individual strategies to adaptively control such reactions and correlates, thus containing or modulating their occurrence.

Similarly, another tool that proved to be useful as a cognitive enhancement technique with relevant effects in terms of performance improvement is biofeedback, which turned out to be valuable for strengthening control over the bodily arousal levels and for empowering emotional regulation and stress management skills, thus helping, for example, practicers to learn how to contain precompetition anxiety and how to redirect mental resources on their present goals fostering the achievement of optimal performance (Wood, 2006).

Ethical Implications of Performance Enhancement

Despite the positive evidence in favor of the effectiveness of these neurocognitive enhancement techniques in different contexts, cognitive and behavioral performance improvement appears to be a particularly debated topic for possible implications in terms of safety, morals (understood as the result of a system of collective cultural values), and ethics (understood as a set of personally and socially defined behavior rules that guide individuals' actions; Farah et al., 2004; Nagel, 2015; Ray, 2016; Sandel, 2004; Schelle, Faulmüller, Caviola, & Hewstone, 2014; Singh & Kelleher, 2010). Up to now, bioethical debate on neuroenhancement mainly focused on pharmacological, technological, nutritional, and behavioral methods used to enhance individual performance. Specifically, the discipline that investigates the ethical implications of cognitive enhancement techniques and performance is neuroethics. The latter has opened an enduring debate on possible implications and on positive and negative consequences of cognitive enhancement techniques and performance optimization (Farah et al., 2004).

The possible adverse effects of neurocognitive enhancement have been accurately recognized in the loss of interindividual equity and in authenticity of an individual's performance (Butcher, 2003), as well as on possible side effects and unwanted consequences of enhancement techniques and methods (Bostrom & Sandberg, 2009; Farah, 2005; Farah et al., 2004; Wolpe, 2002). Moreover, the possible negative consequences of neurocognitive enhancement techniques have been evaluated in both individual and social terms (Bostrom & Sandberg, 2009; Butcher, 2003; Farah, 2005; Wolpe, 2002). Farah and colleagues (2004), for example, have highlighted possible problems associated with neurocognitive enhancement techniques in terms of safety, coercion, distributive justice, personality, and tangible values. Regarding safety, the main concerns are related to the uncertainty of possible future side effects derived by the use of various neurocognitive techniques. Concerning coercion and distributive justice, the authors stressed potential ethical issues associated to the presence of and comparison with empowered individuals within different social contexts, such as the workplace, which might lead to situations in which people could be pressured to undergo neurocognitive enhancement protocols and improve their cognitive abilities. Again, another main concern in this regard resides in the fact that the alteration of the overall cognitive functioning, implemented through the use of enhancement drugs or techniques, could modify some personality aspects that would lead to individuals' homologation and to the occurrence of a significant discrepancy between enhanced and unenhanced individuals (Wolpe, 2002). Additionally, altered cognitive functioning in enhanced subjects could also modify individual aspects of the self, thus creating an alteration of the individuals' identity (Butcher, 2003). Furthermore, at the social level, widespread and uncritical use of neurotechnologies and other neurocognitive enhancement techniques could entail high costs for society and lead to the strengthening or creation of social barriers due to the differential use of these techniques and to different opportunities to access them.

These aspects were also emphasized by Fuchs (2006) who noticed some critical aspects of neurocognitive enhancement techniques—such as safety, change of the human condition, and competition—above all within working and sports contexts. Specifically, in the field of sports science and practice, the ethical and moral implications of performance–enhancement interventions are often not properly taken into consideration because athletes are frequently subjected to competitive pressures (Kayser & Broers, 2013; Petróczi, 2013) that lead them to disregard the harmful effects and the possible health consequences of using performance enhancers (Curry & Wagman, 2011; Kayser & Broers, 2013; Morente-Sánchez & Zabala, 2013). On the other hand, other recent studies and research have stressed the possible beneficial effects of neurocognitive enhancement techniques and methods by emphasizing the effectiveness of neuroscientific techniques in improving and increasing individuals' latent abilities without changing their peculiar and distinctively human characteristics (Cohen Kadosh, Johnson, Dick, Cohen Kadosh, & Blakemore, 2013). Furthermore, other research (Bostrom & Roache, 2011; Bostrom & Sandberg, 2009) has demonstrated the safety and efficacy of external devices for the enhancement of cognitive and behavioral performance compared to the use of psychotropic drugs and brain–computer interface technologies.

The Effects of Using Neuroscientific Techniques to Improve Performance in Sports

As noted above, several studies have highlighted the effectiveness of neurostimulation and neuromodulation techniques in improving and enhancing sports performance. Likewise, different studies have shown the effectiveness of using techniques based on self-awareness and self-regulation to improve athletes' performance and achieve optimal results (Crews & Landers, 1993; Hammond, 2007; Haufler et al., 2000; Landers et al., 1991; Salazar et al., 1990). As an example, the mechanisms of action of the neurofeedback technique—which is configured as a technique that allows individuals to learn to self-regulate their cortical activity based on the principle of operating conditioning—ground on the delivery of real-time feedbacks (typically acoustic and/or visual feedback) relative to ongoing modulations of brain functioning. Following, processing, and integrating those feedbacks, the practice can learn to modulate the amplitude, frequency, and coherence of distinct electrophysiological components of his or her brain, by voluntarily activating specific states of cortical excitation (Vernon, 2005). See Figures 1 and 2 for visual depictions of the main apparati of neuroregulation and neuroenhancement.

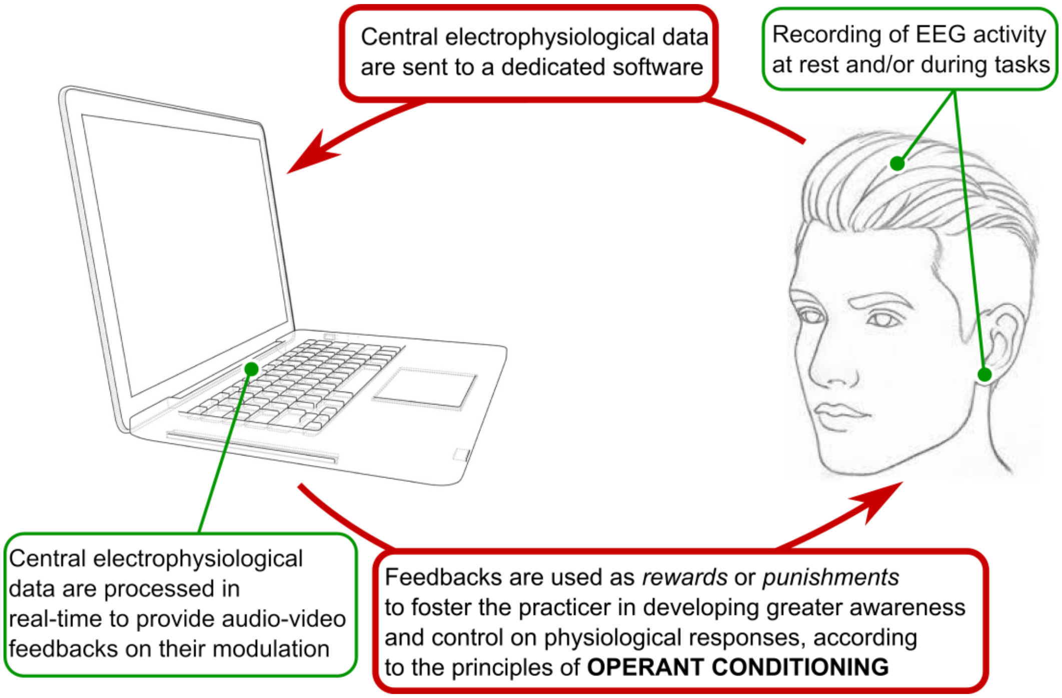
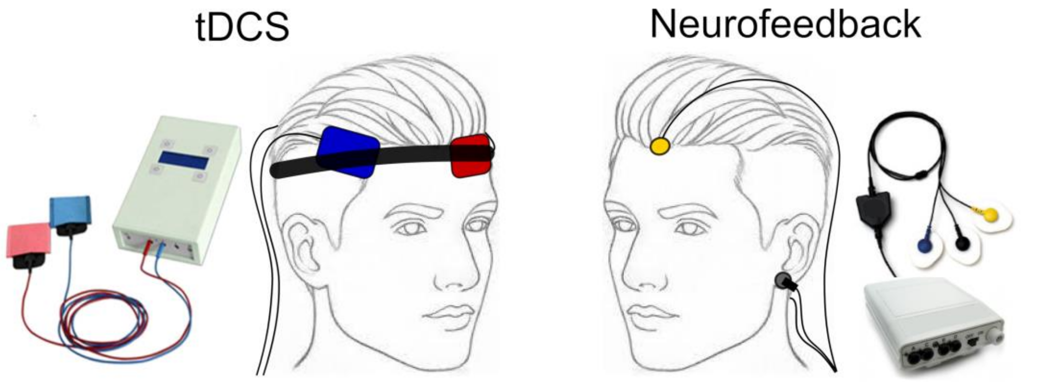


Figure 1. Main steps of the implicit learning cycle promoted by neurofeedback practice.



Sensors: active electrodes
Practicer: passive stance
Modulation of neural activity: induced by exogenous stimulation
Long-lasting effects due to neuroplastic changes fostered by *external facilitation/inhibition of neural activity that induces cognitive/physical effects*

Sensors: passive electrodes
Practicer: active stance
Modulation of neural activity: induced by endogenous strategies
Long-lasting effects due to neuroplastic changes fostered by *implicit learning processes and consolidation of individual self-regulation strategies*

Figure 2. Transcranial electrical stimulation and neurofeedback practice: schematic representations of illustrative montages and devices with reference to selected key aspects of the two intervention methods.

It has been shown that the use of neurofeedback in sports allows enhancing athletes' performance through the association between particular patterns of brain activity and behavioral states classified as optimal, improving some principal functions such as the level of concentration, attentive abilities, motivational status, and will (Balconi, Fronda, & Crivelli, 2018; Hung & Cheng, 2018).

For example, Balconi et al. (2017) observed the effectiveness of undergoing a mindfulness-based training supported by a wearable neurofeedback device in terms of enhanced cognitive performance, increased concentration, optimized attention regulation, and decreased stress levels in a sample of semiprofessional athletes. Specifically, the efficacy of an intensive 14-day treatment supported by the use of a highly usable and portable neurofeedback device was measured during two assessment phases (T0, T1), during which cognitive, electrophysiological (EEG), autonomic (biofeedback), and neuropsychological outcome measures were collected. Empirical observations added to the limited pieces of evidence suggesting that neurofeedback, through the modulation of electrophysiological central activity (Balconi et al., 2017; Mirifar, Beckmann, & Ehrlenspiel, 2017), could be an effective method for strengthening attention and emotional regulation, coping with stress, adaptive orientation of mental resources, focusing, and sensorimotor efficiency (Balconi et al., 2018; Crivelli et al., 2019). Again, those observations are also in line with other studies that, in different applied contexts, have observed the effectiveness of different neurofeedback-based training programs as valid enhancement tools able to provide a real-time performance feedback that leads to improved behavioral and physiological markers of neurocognitive efficiency (Balconi et al., 2018; Crivelli et al., 2019; Enriquez-Geppert, Huster, & Herrmann, 2013; Koberda, Moses, Koberda, & Koberda, 2012).

Conclusion

This article provides an overview of the debated topic of neurocognitive enhancement, emphasizing the possible effectiveness and benefits of using neuromodulation and awareness techniques in enhancing sports performance. In this article, a specific focus is also placed on the importance of neuroethics as a discipline that deals with considering the ethical and moral implications of the methods used to achieve optimal performance. The neuroethical debate has mainly focused on the importance of assessing the consequences and possible damage of the use of drugs (Repantis, Schlattmann, Laisney, & Heuser, 2010; Verhaeghen, Marcoen, & Goossens, 1992), neurostimulation, and neural entrainment techniques for the enhancement of sports performance (Davis, 2013). Despite the ethical controversies, these latter neuroscientific techniques have shown themselves to be promising in the enhancement of particular essential functions for the achievement of optimal results such as the facilitation of different cognitive abilities (Chatterjee, 2004; Sahakian & Morein-Zamir, 2011), motor learning, muscle strength, and learning skills (Antal et al., 2004; Reis et al., 2009; Vernon, 2005; Zhu et al., 2015).

Further, those benefits are demonstrated by several studies, which have reported no relevant side effects and evidence for better regulation of attention and cognitive control mechanisms following the completion of a combined mindfulness–neurofeedback program within different laboratory and applied contexts (Balconi et al., 2017, 2018, 2019; Crivelli et al., 2019). These results confirm that training self-awareness and self-regulation skills through the use of a wearable neurofeedback device might help athletes, through implicit learning, to improve their ability to focus, to intentionally redirect their attention resources, and to optimize body performance. The effectiveness of these techniques prefigures them as a possible future way to safely improve the mental and physical performance of athletes in different sports contexts.

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